Designing Tools to Support the Social Learning of Music Mixing Skills

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Abstract

Formal music education has been criticised for failing to meaningfully connect with the lives of the young people it serves. This research explores an alternative, technology-mediated approach to music education based around music remixing, where the activity is used to connect young people with established local musicians. However, the tools used to create impactful music remixes are often complex, which may present a barrier to participation. Accordingly, this research follows a design-based research methodology to develop an online, learning-focused music remixing and sharing platform – Remix Portal. Five field deployments of Remix Portal involving 20 sessions and 127 participants within education settings are reported, which resulted in three significant design revisions. Each field deployment produced insights for the design of learning-oriented music (re)mixing interfaces, as well as insights for the configuration of the social contexts within which such interfaces are used.

Remix Portal's initial, basic music mixing interface was refined to add text feedback facilities. The show-and-tell iteration that followed, enabled feedback givers to add control change suggestions so recipients can see, hear, and read a justification for proposed mix revisions. The multi-layered interface iteration encompasses five interfaces of increasing complexity, to enable users to select a layer that matches their abilities and desires, thereby avoiding the issues associated with using an interface that is either too basic or too complex.

The contributions of this research are four-fold: First, this research makes an artefact contribution in Remix Portal whose code is made available as an open-source system. Second, an empirical contribution is made through the data that resulted from the field deployments, which revealed insights into participants' experience with both the artefact and with the surrounding social configuration. Third, conceptual contributions consist of the development of a framework for understanding music mixing skills development; the expanding of the concept of 'local learning ecologies' to include young peoples' transitions into a community's cultural activities; a show-and-tell feedback approach which couples descriptive and depictive information representations within learning feedback; and the integration of flow theory and cognitive load theory and their relationship to multi-layered interface design. The research also makes a fourth, methodological contribution, as two novel data collection techniques were developed to capture user data which served to inform the design of a multi-layered interface. This research contributes most directly to human-computer interaction literature in the domains of music education, learning feedback, and multi-layered interface design.

For my daughter, who gave me the motivation to rise early and get this thesis completed. I am very much looking forward to meeting you.

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Chapter 1. Introduction

1.1. Music education in context

Music and arts education in the UK has been under increasing pressure from politicians seeking to prioritise resources to Maths and English, leaving behind a 'hollowed out' curriculum, as even Ofsted's Chief Inspector has recognised (Spielman, 2018). There is therefore a real danger that artistic subjects including music, will become second class 'citizens' (Bath et al., 2020; See and Kokotsaki, 2015). For example, the UK's main opposition party accused the government of underinvesting in school arts subjects over the past decade, resulting in the number of students participating in music and drama in English schools at GCSE level falling by one fifth; the number of drama teachers decreasing by one fifth; music teachers by one seventh; and art teachers by one eighth (Weale, 2021a).

The governments' deprioritization of the arts is perhaps most visible within the higher education sector, with the Education Secretary announcing in 2021 that a key funding stream for HE arts provision would be cut by 50 percent, which amounts to a subsidy reduction from £243 to £121.50 for each full-time student on an arts course (including art, design, music, drama, dance, media studies and journalism) (Harris, 2021). Critics have called this "*one of the biggest attacks on arts and entertainment in English universities in living memory*" (Weale, 2021b). The Education Secretary's announcement included the plan to use the money saved via these cuts to subsidise students on medicine and stem (science, technology engineering and mathematics) courses, due to their closer alignment with the governments' strategic aims (Harris, 2021). Furthermore, the cuts to arts subjects appear to be disproportionately impacting students from less well-off backgrounds, as the government chose to mitigate the impact of these cuts upon some elite arts institutions, leaving universities like Wolverhampton where 70% percent of students are first-generation university attendees, with no new support, forcing them to lay off staff and close arts courses (Musicians Union, 2022).

The relative neglect of music and the arts is short-sighted because these subjects are the bedrock of our creative and cultural industries; industries which make a significant contribution to the UK economy and are acknowledged as an area of growth (Department for Media Culture and Sport, 2016). This contribution is in the order of 6% of our GDP (Waitzman, 2021), or, as of 2018, £111 billion annually (Department for Digital, Culture, Media & Sport, 2020). In addition to the economic benefits, a good arts education, and a good music education in particular, can have a hugely positive impact upon individuals and society. For individuals, the opportunity to participate in musical education and activities can lead to the following benefits: an increase in self-esteem and educational engagement across all subjects (Ofsted, 2009); an increase to their intellectual, personal, social and physical development (Broh, 2002; North et al., 2000; Schellenberg, 2004); a boost to their creativity (Koutsoupidou and Hargreaves, 2009); enhancement of literacy and numeracy skills (Gardiner et al., 1996; Ho et al., 2003; Overy, 2003; Register, 2001); and a range of additional health and wellbeing benefits (The Royal Conservatory of Music, 2014). Furthermore, at a societal level, it is important that we encourage young people to participate in music making activities in order to foster the next generation of musicians who will go on to make an important contribution to our social fabric, culture and economy (Behr et al., 2016; Henley, 2011).

Whilst no arts subjects have escaped government cuts, it is argued that music has been particularly hard hit (Weale, 2021a), with a recent Ofsted report charting music's decline in England at A-Level, GCSE, and earlier. The report also acknowledged a decline in the specific training in music teaching offered to prospective primary school teachers, as well as a reduction in the lesson time afforded to music across all school years (Ofsted, 2021).

Critics have pointed out that music education tends to skew towards western classical music in the UK (Rogers, 2002; Spruce, 1999) and in other countries (Hess, 2014; Jaffurs, 2004). It is argued that this does not meaningfully connect with the interests of many young people, which disenfranchises them and impacts their motivation to participate in music education (Hess, 2014). However, Woody (2007) argues that when attempts are made to bring the music that young people feel an affinity with into the music classroom, it is often done disingenuously, as part of a 'bait-and-switch' tactic to try and excite the learners enough that they will engage with the traditional component of the lesson. An example of this would be trying to capture interest via orchestral arrangements of popular songs. An alternative to the traditional, classical-oriented educational approach, would be to accommodate the learners contemporary musical tastes by placing this at the heart of the music curriculum and to encourage them to learn about music by making it.

A government commissioned review by Darren Henley found that many children in England receive a substandard music education, and this disproportionately affects those from poorer areas (Henley, 2011). In considering how music education could be improved, Henley sites the need for schools to draw upon local resources by forming partnerships with groups, organisations, and individuals in the local area. A similar call was made by See and Kokotsaki who asserted that arts activities are more successful when they involve professional artists including musicians (See and Kokotsaki, 2015).

1.2. Music remixing as a learning opportunity

The picture of formal music education, and arts education more broadly, stands in contrast to descriptions of how young people participate in the arts beyond the school gates. Jenkins (2009) reported a set of vibrant online communities comprised of young people creating, sharing, reshaping and critiquing digital media, and developing their artistic skills as a byproduct. Music production and music remixing was a central activity. Väkevä (2010) studied music-oriented participation within online communities and described a blossoming *digital music culture* involving young people participating in, and learning through activities including: DJing/turntablism; music remixing; the creation of song mash-ups; collective songwriting online; producing music videos and sharing them on YouTube; creating, exchanging and comparing videos of Guitar Hero and Rock Band game performances. Similarly, Hugill (2018) noted the adoption of digital technology by musicians to assist their creation, production, expression, dissemination, promotion, and consumption of music, at a rate that has outpaced adoption within the music classroom. Academic and commentator Tim Cain considered the lag between music technology's use within the classroom and its use within real-world settings, and made the following comment – a comment which this thesis argues is sadly just as relevant today:

> "Curriculum change is necessary if the world of the classroom is to keep pace with the world outside... There needs to be more, and better, professional development, so that teachers can learn from each other, as well as from experts, how best to use music technology." (Cain, 2004)

1.2.1. Defining music remixing

M̀usic remixing', at its most basic level, is usually understood to involve some reworking of the sonic properties of a piece of music, with the output of the process being an artefact usually referred to as a 'remix'. However, when one looks more closely at how the term is interpreted and applied, subtle distinctions abound. For example, Casey and Slaney (2007) define a music remix as the output of a remixing process whereby: *"a vocal sample is taken from a source recording and summed into a completely new musical work created by a producer or DJ."* Woodruff et al. (2006), on the other hand, takes a broader view, and whilst they would agree that music remixing could lead to the creation of a completely new musical work, they also point out that an equally valid remix could be created by *"simply raising the level of a single instrument in a poorly balanced mixture"*. A popular and comprehensive definition of the music remix was offered by Navas (2014) who claimed that: *"A music remix, in general, is a reinterpretation of a pre-existing song, meaning that the 'spectacular aura' of the original will be dominant in the remixed version"*. They went onto identify three types of music remix: (i) the extended remix, which is an elongated version of the original music and is intended to be played in clubs, (ii) the selective remix, where the essence of the original music is preserved, but some material is selectively added or removed to change the sound, and (iii) the reflexive remix, where the original music is still audible yet the remix is claimed as an original and equal version rather than a derivative work.

Within this thesis, music remixing will be defined in relation to 'music mixing', and whilst there are distinctions in how this latter term is interpreted, it can be considered more homogeneous than 'music remixing'. Tankel (1990) defines music mixing as *"setting sound parameters and relationships during and after recording"*, and most other definitions found within the literature align closely with this. Remixing can therefore be considered the *resetting* of these sound parameters and relationships. Mixing can be thought of as a two-part process with sounds manipulated during the recording session to create a 'rough' mix, and again during post-production. Remixing can be achieved by replicating this second part of the process, using the raw material of the rough mix and reconfiguring it into a new artefact. This broad definition could accommodate all three types of remix described by Navas (2014): extended, selective and reflexive.

Remixing as a practice was born out of the realisation that mixes that work well on the radio do not work well in dance halls and vice versa, therefore separate mixes were created for each, typically with a remix created for the dance halls following a radio-friendly mix. Today it is common for a piece of popular music to be released in multiple forms, identified by the type of mix, or remix, such as: radio mix, dance mix, dub mix, or blaster mix. It should be noted that the terms 'mix' and 'remix' are frequently used interchangeably within the literature. Furthermore, a 'remix' should be considered both a process (the remixing of audio tracks) and an artefact (the remix record) (Tankel, 1990).

It is worth noting that whilst the above deals with defining music remixing, the term 'remix' is now used to reflect similar practices of manipulation and re-presentation of material within other domains including fashion, design, art, web applications, user created media, and food (Manovich, 2007). The remix has become culturally pervasive, leading Manovich (2007) to claim that: *"If postmodernism defined 1980s, remix definitely dominates 2000s, and it will probably continue to rule the next decade as well."*

1.2.2. Music remixing as an opportunity for collaboration

Väkevä (2010) argues that the democratisation of digital technology has brought music mixing and remixing activities within the reach of many people, and the author goes on to assert that this could lead to: *"a new participatory aesthetics of popular music which supports audience input e.g. in the form of fan-based remixing for which the artists willingly distribute raw material...In these processes what was originally 'a mix' becomes material for new creative ways of projecting oneself in artistic-technological space. This shifts the aesthetic focus from products to processes, from individual expression to communication."* Tankel (1990) is of a similar opinion arguing that the remixing of previously recorded music to create a new recording is itself a form of artistic expression, and remixing creates unending possibilities for artistic collaboration, stating. It is the potential for collaboration and communication brought about by participating in remixing practices, that the *social* aspect of this thesis title refers.

The work presented in this thesis was inspired by the idea of bringing collaborative and engaging music remixing activities into formal music education settings. Initial scoping discussions with teachers revealed that bringing young people together, face-to-face, with expert musicians or outside organisations can be very challenging as musicians often have limited availability during the working day; school budgetary constraints mean it is difficult to pay for their time; and safeguarding concerns and policies create often difficult logistical challenges. This research project therefore wanted to explore whether the types of music-making activities that engage young participants within online, participatory communities might work within formal music education settings. Specifically, this would mean exploring musical activities that involved working with outside experts remotely and asynchronously with interactions facilitated by technology. Given that this work would be conducted within a Human-Computer Interaction (HCI) department where projects are focused around the design, development, deployment and evaluation of technologies, it was deemed appropriate to take a design-based research approach (Barab and Squire, 2004) to the topic, and explore how we might produce tools to optimise the connections between learners with outside expert musicians.

This thesis takes as its starting point, that the purpose of education is to: *"ensure that all students benefit from learning in ways that allow them to participate fully in public, community, and economic life."* (Futures, 1996). I argue that a reformed, digitally-equipped music education could better support this goal by learning from and adopting the beneficial practices observed within informal, online music making communities. Were this to be widely adopted in formal education, it is hoped that significant benefits for young people may be realised, which would contribute to enabling music and arts education to be better valued. The following sections describe my own motivation for undertaking this research, the thesis aim and research questions, and an outline of the thesis structure.

1.3. Research motivation

This thesis seeks to make the case that a change in the formal music education landscape is desirable, and so my personal views and opinions are implicitly embedded within this presentation. There is a deeper motivation behind this work, so giving detail on my background in music education is relevant to explain the base of lived experience which informed the decision making throughout this research project.

I consider myself very lucky to have received a good music education whilst at school. Aged seven, I was one of five students within my class to be offered violin lessons. This opportunity led to me playing in youth orchestras and ceilidh ensembles, as well as helping me understand the importance of a daily practice routine in order to make progress on a fairly challenging instrument. A turning point came aged around eleven when we visited family friends who had a music rehearsal room in an outbuilding of their home. The father was in a band and I got to sit in during one of their rehearsals. They were playing rock and roll music which connected with me to the extent I decided I wanted to learn to play the electric guitar and focus my energies on trying to make music that more closely resembled the recorded music I enjoyed listening to. My enthusiasm had not gone unnoticed by my parents who gave me a shiny red electric guitar the following Christmas. Equipped with this guitar and knowledge of how to practice acquired from my formal violin tuition, I learned to play guitar sufficiently well that within a year I was able to start 'jamming' with fellow school pupils during lunch breaks. This then progressed to forming bands, initially playing renditions of other people's songs and then eventually writing my own songs and co-writing with members of my bands. I also progressed from playing school shows to, by my final year of school, playing regularly in the local pubs and clubs and getting to know my local music community.

I gained a lot from these formative experiences, in terms of the confidence and self-belief I acquired, and also in terms of the network of musicians I was exposed to. I consider each part of the journey described above an important stepping stone, without which I may not have gone on to derive great satisfaction playing the music I was passionate about with talented local musicians, and participating in my city's cultural output. These formative experiences are likely responsible for my belief that a good formal music education should help support and nurture young people to find their own path stylistically, and equip them with the confidence and ability to participate in the wider music-making community beyond the school gates, and better still, guide them towards this community.

I went on to work for the University of the Highlands and Islands for over a decade, where I was a lecturer in music and audio engineering. I spent a significant amount of time teaching young people the art of music production including music mixing. This (typically) involved teaching them to use specialist music production software, and I developed a pedagogy of encouraging students to draw upon the software's built-in library of audio samples and loops in order to help them find source material quickly, so they could then focus on learning how to use the software to arrange and manipulate this source material. The vast majority of novice students favoured this pedagogy based around using samples and loops in comparison to trying to record their own instruments into the computer, because they found it a quick, easy and low-frustration way of generating musical ideas and, ultimately, expressing themselves musically and creatively. During this time I began to think that this type of activity might be an ideal route into music making for many young people, as it required so much less effort than a traditional instrument necessitates before the person can create music they are happy with. Whilst I was teaching these skills at a post-compulsory education level, I was aware that this type of music-making activity did not match the experiences of many young people within formal school education environments.

The work presented in this thesis was motivated by these formative experiences. Firstly, there was a desire to explore how music education could be reconfigured to help young people express themselves musically and begin to see opportunities for themselves to participate in the music making world beyond the school walls. Secondly, there was a desire to explore whether music making involving samples and loops could provide an easy path to meaningful musical expression for young people, and whether this could fit within formal music education.

1.4. Research questions

The four research questions presented here are intended to address the project aim which was **to perform a design-based exploration of social music mixing; its tools and its impact upon learners**. The thesis aim was supported by four research questions, which were informed by the literature review and early case study deployment data.

Research Question 1: Can music remixing activities support the formation of a local learning ecology involving young people and established local musicians, and if so, what factors are important in the design of the tools and social configuration?

This question encompasses Hodgson and Spours's conception of a local learning ecology (Hodgson and Spours, 2013) which is unpacked in Chapter 2.5. Answering this question also involved drawing upon literature related to authentic learning (Shaffer and Resnick, 1999) and connected learning (Ito et al., 2013). It involved setting up a field study that enacted a music remixing-oriented local learning ecology, and then employing suitable data collection and analysis methods – including activity theory (Engeström, 2015; Engeström et al., 1999) – to probe the experience and motivation of all the participants.

This work adds to the literature on local learning ecologies, which has thus far focused on young people's transitions into further education or employment. The work presented here, in contrast, explores the potential for local learning ecologies to help young people transition into communities engaged in cultural activities, with music being the case study.

Answering this research question in the affirmative – i.e. music remixing activities *can* support the formation of local learning ecologies involving young people and established local musicians – is to raise the possibility for a new model of formal music education delivery. This new model may prove more beneficial to young people as a whole, by increasing the number of young people who go on to engage in meaningful music activities with others, and in doing so access the advantages that music participation has to offer. This should have the knock-on effect of enriching the cultural life of their locality, and should also increase the number of young people who are able to make successful transitions beyond school, into further education, training or employment.

Research Question 2: How can we design technology to support tacit knowledge transfer through feedback within the context of music mixing skill acquisition?

This research question was developed in response to findings following exploration of the first research question. The configuration of the local learning ecology that was enacted during exploration of that initial research question involved local musicians providing text-based feedback to the student participants, and an issue was identified around participants finding it difficult to make sense of, and acting upon this text-based feedback. Whilst this issue is explained in detail within Chapter 5, it is important to note here that this second research question was intended to explore solutions to this issue.

The question references tacit knowledge (Polanyi, 2009), which was identified as an important topic when researching the shortcomings of text-based feedback within the literature. Tacit knowledge is explained in Chapter 2.3.1, along with the related topic of apprenticeship learning (Collins, 1991; Collins et al., 1991, 1988). The literature review also surveys HCI research around systems designed to support tacit knowledge transfer, typically in the form of skill acquisition within craft domains.

The other side of this question relates to feedback, and accordingly literature around feedback for learning is reviewed in Chapter 2.3.6, with particular influences being the work of Hattie and Timperley 2007 and Shute (2008). The review then focuses on the way information is represented within feedback, with work exploring the advantages of multiple representation feedback presented (Ainsworth, 2006; Ice et al., 2010; Wiese and Koedinger, 2017), i.e. feedback that does not rely solely on descriptive text-based information. Finally, this part of the review moves on to survey HCI work around feedback for learning, including systems designed to support group critique including the work of Tinapple et al. (2013).

The potential reward for successfully addressing this research question would be to overcome a key obstacle to providing effective support for music mixing skills development when learners and feedback givers are not co-located or need to work asynchronously, as was the case in our enacted local learning ecology. This therefore informs our understanding of what may constitute viable configurations of social music mixing, and therefore addresses the aim of this thesis.

Beyond serving the aims of this thesis, the work resulting from addressing this question has the potential to contribute to the literature around tacit knowledge transfer by addressing Polanyi's assertion that we can "*know more than we can tell*" (Polanyi, 2009), by exploring a novel feedback mechanism that allows people to communicate information beyond 'telling'. This work also contributes to the literature on learning feedback, and particularly the literature around group critique, by demonstrating a technology that provides a novel mechanism for providing demonstration-based feedback that can function within remote or asynchronous learning contexts. Addressing this research question also allows us to offer a contribution to the music education literature, by proposing a framework for understanding key components of music mixing skill acquisition.

Research Question 3: How can we capture and use expert knowledge in the form of music mixing-oriented worked examples to support music mixing skills acquisition?

This research question addresses the thesis' aim by exploring an alternative configuration of social music mixing, with the *social* element comprising the relationship established between novices and experts within the local community. Whilst the previous research question focused on a configuration of experts as feedback givers and novices as recipients, the response to this research question explored a configuration where experts provide *worked examples* (Atkinson et al., 2000) of their music mixes upfront for novices to study prior to commencing their own music mixing activities. Participants' views of the relative merits of the worked examples as a pedagogical device were probed, and it is this qualitative data that serves to answer the question.

This work makes a contribution to the worked example literature by being one of the first studies to take worked examples outside of the STEM-based subject areas where they were used to support learning tasks around well defined problems featuring clear goals, solution paths and expected solutions (Rourke and Sweller, 2009). In contrast, the challenge of mixing music can be considered an ill-defined problem with an unclear goal, solution paths, or expected solutions, as explained in Chapter 2.3.4. The work presented here, therefore, broadens our understanding of where worked examples can be successfully applied.

Such a reconfiguration of *'the social'* has the potential to expose another avenue via which local musicians could contribute their expertise and participate in a local learning ecology, beyond providing feedback. If it was to become widely adopted, it could, ultimately, enhance the music education young people receive.

Research Question 4: How can we design multi-layered interfaces to support novice to expert transitions within the context of music mixing skills acquisition?

The literature survey revealed multi-layered interfaces (Shneiderman, 2002) as a design approach to helping people learn to use complex pieces of software. This approach was therefore explored as a potential solution to this research question. However, there were important differences between the prior literature and the context in which this thesis work was conducted. Multi-layered interfaces had previously been explored in relation to domain experts transitioning to an unfamiliar piece of software, however this contrasts with the work presented in this thesis where the intention was to help complete novices gain domain expertise as well as learn to use a piece of software. The work within this thesis is therefore able to contribute to the multi-layered interface literature by exploring their use in a new context. Flow theory (Csikszentmihalyi, 1990) also played an important role in the analysis of the data collected during the course of this work.

Answering this research question successfully is to both lower the bar to participation in computer-based music technology activities, and perhaps more importantly, it will help lower the likelihood of participants experiencing frustration or anxiety along their learning journey, and thus lower the likelihood of drop-out. Therefore, a greater number of people should, potentially at least, be able to enjoy participating in music technology activities including music mixing, and by supporting their skill development we should improve the quality of the musical contributions they are able to make to their social networks or communities.

1.5. Research approach

As Chapter 3 details, this thesis was conducted *in the wild*, in a mixture of formal and informal naturalistic learning settings. There were five field deployments totalling 20 sessions and involving one primary school, one secondary school, one secondary school after school club, and two further education colleges. Learners ranged in age from 10 years to mature students, with 127 people participating in total.

A design-based method (Anderson and Shattuck, 2012; Barab and Squire, 2004) was employed to explore the research questions and project aim. Central to this was Remix Portal, a music remixing, sharing and communication platform created and iteratively refined over the course of the project in response to research findings and with input from relevant literature. The broad concept was for participants to engage in music (re)mixing activities using Remix Portal, and for data to be captured on how its use impacted attitudes towards participation in music and education activities, or how participants' viewed its potential to support learning. However, this description is very 'broad brush' as each field deployment was linked to a specific research question and was thus uniquely configured to answer this question. The subsequently presented data chapters detail each study configuration and objectives.

The design-based research was supported by mainly qualitative data collection methods encompassing interviews (individual, paired and group) and surveys. The qualitative data was thematically analysed in line with the principles outlined by Braun and Clarke (2006). The exploration of research question 1 was supported by the analytical lens of Activity Theory

(Bødker, 1991; Kaptelinin and Nardi, 2006; Nardi, 1996) which helped make sense of the social setting surrounding the music remixing activities. For the deployments linked to research question 2, Likert items were added to the survey, giving access to additional quantitative data for analysis, however the majority of the data collected was qualitative.

1.6. Contributions

This thesis makes four types of contribution: artefact, empirical, methodological, and conceptual.

The artefact contribution comprises Remix Portal, the music (re)mixing, sharing and communication platform. This is offered as a free-to-use web application, and as open source code which others can build upon. Furthermore, this thesis presents the design criteria which describe key attributes of the application, and thus others could implement this design criteria to integrate aspects of Remix Portal's design into their own applications.

The empirical contribution consists of the data produced from the field studies which revealed insights into participants' experience with both Remix Portal and with the surrounding social configuration. These insights support the validation of Remix Portal's design, and in the case of the work presented in Chapter 4 especially, validation of the social configuration mediated by Remix Portal.

This thesis makes a methodological contribution by developing a process to incorporate user input into the design of multi-layered interfaces, as described in Chapter 7

A number of conceptual contributions are offered by this thesis: First, the literature review led to the production of a framework for understanding music mixing skills acquisition, as presented in Chapter 2.4. Second, the concept of local learning ecologies (Hodgson and Spours, 2013) was extended from a focus on transitions from school into employment or further education, to include the idea of transitioning into participating in community activities. Third, the thesis presents the concept of the show-and-tell feedback interface, as described in Chapter 5, which is intended to improve feedback upon creative, non-text modality artefacts for those learning in remote and/or asynchronous settings. Fourth, the potential for multi-layered interfaces to support the acquisition of domain knowledge is advanced. A final conceptual contribution involves the integration of cognitive load theory (Oviatt, 2006) and flow theory (Csikszentmihalyi, 1990; Nakamura and Csikszentmihalyi, 2014), as presented in Chapter 7.

1.7. Thesis outline

This thesis comprises eight chapters, beginning with this introductory chapter. Chapter 2 contains a review of relevant literature. The format of this chapter was inspired by Crook and Sutherland (2017) who asserted that the development of educational technologies should be based upon a solid understanding of how people learn, and accordingly the literature review is organised around the presentation of learning theories. An explanation for how learning occurs at an individual level is presented, with the focus on cognitive theories of learning. The chapter then moves on to cover interpersonal learning, with a focus on apprenticeship learning, learning from worked examples, and learning from feedback. HCI work which attempts to support these processes is also covered. The chapter then hones in on learning in relation to music mixing, and a learning framework is proposed based around four key music mixing competencies identified within the literature. Finally, the chapter surveys work that explores how to make learning meaningful and engaging, and covers connected learning (Ito et al., 2013), authentic learning (Shaffer and Resnick, 1999) and local learning ecologies (Hodgson and Spours, 2013). This latter section of the literature review had a significant influence upon the work conducted in Chapter 4, whilst the earlier literature around individual and interpersonal learning had a significant influence upon all the artefact design iterations presented in this thesis, and the research presented in the forthcoming data chapters.

Chapter 3 describes the methodology used in the thesis. The rationale and implications of the design-based research approach are explained, drawing upon the work of Barab and Squire (2004). The data collection and analysis methods employed are also explained, with an emphasis on the Thematic Analysis work of Braun and Clarke (2006). Finally, an overview of the Remix Portal design iterations are presented, the data that informed each iteration is summarised, and the origins of this data explained.

Chapter 4 contains descriptions of two research studies which aimed to probe research question 1: *Can music remixing activities support the formation of a local learning ecology involving young people and established local musicians, and if so, what factors are important in the design of the tools and social configuration?* The first of these studies was conducted over three sessions at a secondary school and involved 41 student participants and three groups of musician participants. The second study was conducted at a primary school over the duration of five sessions and involved 28 student participants and two sets of musician participants. The first study involved a basic Remix Portal interface whilst the second study utilised a Remix Portal interface with embedded text feedback tools. The findings from this work revealed the potential for a local learning ecology to form around music remixing activities, due to the positive experiences reported by contributing student participants, musicians and teachers. Text-based communication helped motivate the student participants, however the data revealed that students can find it hard to interpret the more specific, corrective elements of text feedback. This indicates that text-based feedback's capacity to support music mixing-related knowledge transfer is limited due to the tacit nature of the activity. This finding motivated the work presented in the subsequent chapter.

Chapter 5 addresses research question 2: *How can we design technology to support tacit knowledge transfer through feedback within the context of music mixing skill acquisition?* The show-and-tell feedback interface was developed to explore this question. The show-and-tell concept involves feedback givers providing a demonstration of a proposed change to a creative artefact, making clear how the interface tools were used to enact this change, and using a text feedback component to communicate the thought process that underpinned the artefact change. The design of this interface is described in this chapter, along with two studies at further education colleges: One involved 12 student participants, whilst the second involved eight student participants. The findings from this work revealed that show-and-tell feedback can offer clearer and more detailed feedback than text-only feedback, and is broadly favoured by both feedback givers and receivers. This chapter culminates in a discussion of how emergent issues relating to artistic vision and control could be mitigated through design.

Chapter 6 presents work which explored research question 3: *How can we capture and use expert knowledge in the form of music mixing-oriented worked examples to support music mixing skills acquisition?* The concept explored here is for expert music mixers to provide example mixes for learners to study prior to the learners working on their own music mixes. This was inspired by the work of Sweller (2006) who demonstrated that novices perform better on problem solving tests when they are given time to study experts' *worked example* solutions prior to the activity, compared with novices who spend their time practising trial and error problem solving. Whilst music mixing represents a significantly different context to the STEM (science, technology, engineering, mathematics) context Sweller was working in, participants (both students and their lecturer) in an exploratory deployment reported experiencing significant benefits from the worked examples. The worked examples promoted active learning, supported self-paced learning, and fostered the development of key music mixing competencies including helping the student participants understand the relationships between interface tools and their impact upon the musical artefact.

Chapter 7 engages with research question 4: *How can we design multi-layered interfaces to support novice to expert transitions within the context of music mixing skills acquisition?* The work builds upon Shneiderman's (2002) conception of the multi-layered interface, and also draws particular inspiration from cognitive load theory (Sweller, 2011). A multi-layered iteration of the Remix Portal interface was created. The first half of the chapter covers the design process and was motivated by the challenge of capturing data that could meaningfully inform the decisions concerning which interface controls would be appropriate at each layer of the multi-layered interface. Three design activities involving primary school participants are presented. The second half of the chapter describes an exploratory deployment where the multi-layered interface was used at an after school club. Participants reported favouring the multi-layered interface over a single-layer equivalent, and the data suggested that multi-layered interfaces can help participants avoid the anxiety that may come from using an interface that is too complex for their level of ability, or, conversely, the frustration that may be induced by an overly simplistic interface (Csikszentmihalyi et al., 2021). Furthermore, the multi-layered might help participants acquire what Csikszentmihalyi et al. would classify as a state of flow.

The final chapter offers a discussion which attempts to integrate the findings from each chapter, as well as summarising the work undertaken and contributions made.

Chapter 2. Literature Review

> "Establishing a principled understanding of human learning should be the starting point for any design and research ambitions involving educational technology. Innovation is too difficult – and it's implementation too fragile – to risk basing it upon informal and intuitive theories of the learning process." (Crook and Sutherland, 2017)

2.1. Introduction

This chapter reviews contemporary theories of learning, beginning with theories that pertain to the individual with the focus on cognitive theories of learning including cognitive load theory (Chandler and Sweller, 1991), and flow theory (Nakamura and Csikszentmihalyi, 2014). The chapter then moves on to cover interpersonal learning, with a focus on apprenticeship learning, learning from worked examples, and learning from feedback. HCI work which attempts to support these processes is covered. The chapter then hones in on learning in relation to music mixing, and a learning framework is proposed based around four key music mixing competencies. Finally, the chapter surveys work that explores how to make learning meaningful and engaging, and covers connected learning (Ito et al., 2013), authentic learning (Shaffer and Resnick, 1999) and local learning ecologies (Hodgson and Spours, 2013).

Whilst this review does not provide exhaustive coverage of theories of learning, the theories included are highly relevant to the design and/or evaluation of the artefacts that form the foundation of the design research presented in subsequent chapters. The literature review was devised in this way in order to best serve the project's aim which is *to perform a design-based exploration of social music mixing; its tools and its impact upon learners*. Accordingly, theories of learning which did not ultimately influence the design and/or evaluation of the artefact are omitted. Table 2.1 indicates the topics covered in this review and the places within this thesis where they are of greatest influence.

2.2. Learning and the individual

This work subscribes to the idea that effective design for learning must begin with a solid understanding of the mental mechanisms which underpin learning, as technology created to fit these mechanisms will stand the best chance of fostering learning. A good place to begin may be to ask what constitutes learning. One view is that learning's goals are remembering and understanding. Instructors can test the effectiveness of their lessons by using recognition

	Chapter 4	Chapter 5	Chapter 6	Chapter 7
Cognitive learning theory		X	X	X
Cognitive load theory		X	X	X
Mayer's cognitive theory of multimedia learning		X		
Learning through multiple representations		X	X	
Flow theory				X
Explicit and tacit knowledge		X		
Instructional approaches to apprenticeship learning		X		
HCI work around tacit knowledge transfer		X		
Worked Examples and their relationship to music mixing			X	
HCI work around Worked Examples			X	
Feedback for learning	X	X		X
HCI work around digital feedback systems		X		X
Feedback within traditional music mixing learning environments	X	X	X	X
Music mixing skills development	X	X	X	X
Making learning meaningful	X			
Technology-facilitated music learning	X			

Table 2.1 Relationships between the topics covered in the literature review and the subsequent design and field work

and recall tests to gauge remembering, which indicates the quantity of learning that occurred; and transfer tests to measure understanding, which relates to the usability of the information learned (Mayer, 2005). From a psychological perspective, learning can be viewed as changes to a person's long-term memory structure (Sweller, 2005). However, information must undergo a fairly complex process before it can be integrated into a learner's long-term memory. This process is described by cognitive learning theory, which is presented in the following subsection, followed by cognitive load theory which explores key bottlenecks to the learning process, then multimedia learning and learning through multiple representations which are aspects of cognitive learning theory which are pertinent to this thesis' topic.

2.2.1. Cognitive learning theory

Atkinson and Shiffrin (1968) proposed a three stage model that describes the processes information must undergo before it can be successfully integrated into a person's memory store. First is the sensory memory stage: Information enters through the senses, and where the information is complex a learner must pay active attention in order for it to be passed to the next stage. Short-term memory stage: Information can only be held in short-term memory for around 30 seconds and during this time a learner must work with this information in order to integrate and encode it into their long-term memory store. Long-term memory is unlimited in capacity and accessing information stored in long-term memory requires retrieving it into short-term memory.

Many subsequent researchers have advanced this 3-stage model. For example, we now believe there are a number of different types of sensory memory which temporarily hold stimuli collected by our various senses. This includes *iconic memory* which holds visual stimuli, and *echoic memory* which holds auditory stimuli, as well as *haptic memory* which relates to our sense of touch (Winkler and Cowan, 2005).

A key evolution in the information processing model was to replace short-term memory with a three-component working memory model. Working memory comprises a phonological loop which handles the processing of verbal / auditory information, a visuospatial sketch pad which handles the processing of visual information, and a central executive which organises these processes and connects them with long-term memory (Baddeley and Hitch, 1974; Goldstein, 2014).

Of course, most of the information we encounter through our senses will never become encoded into long-term memory. Input to sensory memory is filtered by *selective attention* which removes unimportant stimulus and only sends through the attended to information to working memory. A person can exert control of this filter by choosing to focus on a particular sense (Cowan, 1988). At the working memory stage, information may be lost if the very limited capacity is exceeded. This was thought to be 7 items +/- 2 (Miller, 1956), however researchers now lean towards thinking 3 to 5 items represents a more realistic number, and it will vary depending upon contextual factors such as the characteristics of the individual and the nature of the information to be retained (Cowan, 2010). Regardless of the specifics, stimuli that enters working memory must be organised and rearranged into meaningful mental representation which then stand a chance of activating prior knowledge from long-term memory. If the information fails to activate prior knowledge in long-term memory then it stands a high chance of being lost (Goldstein, 2014).

Generative learning (Fiorella and Mayer, 2016; Mayer, 1996) aims to optimise learning potential given the constraints imposed by the human information processing mechanism. They claim that learning must involve three cognitive processes: (1) Selecting: Learner must pay attention to stimuli of interest, (2) Organising: They must meaningfully organise and rearrange stimuli in working memory, (3) Integrating: They must integrate information with prior knowledge in order to generate meaning. The implication of this is that educators should try and support generative learning whenever possible.

This section has thus far presented the cognitive perspective on the learning process, and has touched upon obstacles to this process in terms of working memory's limited capacity, and how learning might be optimised. The following subsection covers cognitive load theory which explores the implications of working memory's limited capacity in greater detail.

2.2.2. Cognitive load theory

Cognitive Load Theory (Chandler and Sweller, 1991; Sweller, 1988) views working memory as the gatekeeper to learning, and emphasises it's limited capacity which effectively creates a key bottleneck in the learning process. The implication is that teachers and instructional designers can best support learning by representing information in ways that do not overburden our limited working memory resources. Specifically, the claim is that a learner's working memory will face three concurrent loads: There is an *intrinsic load* associated with the difficulty inherent in the task, a *germane load* which is the burden associated with integrating information into their mental schemas, and an *extraneous load* due to the effort required to process the task instructions. When the task is challenging the intrinsic load will be high, and so the learning materials must be made as comprehensible as possible so as not to place too high an extraneous load on the learner and therefore overburdened working memory such that there is not enough resource left to handle the intrinsic and germane loads effectively (Paas et al., 2003).

A number of important effects have been observed which inform our understanding of the origin and nature of extraneous cognitive load, and these effects have important implications for the production of learning materials. Important effects which will be subsequently explained include the modality effect, the spit-attention effect, the worked-example effect, and the expertise reversal effect.

The modality effect follows from the observation that information presented in both visual and auditory modalities will exert less extraneous cognitive load than when the information is presented in a single modality. For example, presenting a diagram accompanied by spoken narration is more likely to aid learning than presenting the diagram accompanied by written text. The modality effect is consistent with the idea that working memory has separate visual and auditory processing systems, and therefore a greater quantity of information can be processed when it is effectively split between auditory and verbal modalities (Mousavi et al., 1995).

The split-attention effect describes the burden imposed upon someone when different types of information are used within a single modality (Chandler and Sweller, 1992). For example, if someone is presented with a diagram, labels and explanatory text, despite this all being visual modality information their attention will be split between these items. The extraneous cognitive load can be lowered if the information is integrated, which may be possible in the example by presenting the labels and explanations within the diagram.

The worked-example effect states that learners will face a lower extraneous cognitive load if they are given time to study example problem solutions prior to tackling similar problems themselves, compared with when trial and error problem solving or discovery learning is used as the instructional method (Sweller, 2006).

The expertise reversal effect states that whilst novices to a domain benefit from comprehensive guidance, such guidance may actually hinder learning in those with a significant amount of preexisting domain knowledge. This is explained by considering that learning involves integrating new information with prior knowledge to construct complex mental representations in long-term memory. As novices will possess little to no preexisting domain knowledge, assuming the instructional materials are clear, schema construction can proceed in a straight forward manner, building the new knowledge structures guided by instructional materials. However, schema construction is more complex for those with relevant prior knowledge as they cannot follow the instructional materials guidance alone, but instead must work to integrated the information in this guidance with their prior knowledge and resolve any conflicts or contradictions that they encounter along the way. This is substantially more demanding of working memory (Kalyuga, 2009).

Cognitive load theory and its associated effects can be operationalized by designers to improve the usability of the interfaces they produce (Oviatt, 2006). Cognitive load theory was used in this way whilst designing and/or evaluating the interfaces presented in Chapter's 5, 6, and 7.

2.2.3. Mayer's cognitive theory of multimedia learning

Mayer's cognitive theory of multimedia learning (CTML) builds upon cognitive learning theory, integrating the dual channel perspective of separate auditory and visual processing, cognitive load theory, and generative learning principles (Mayer, 2005). It serves both as an explanatory theory of how learning with multimedia can occur, and as an instructional design theory helping educators present verbal (words) and visual (pictures) information in ways that will best foster learning. A key assertion is that people learn better from a combination of text and pictures, than from text alone (Mayer, 2005, p47).

Figure 2.1 depicts the cognitive processes assumed by CTML, and how they handle the presentation of words and pictures. Pictures effectively take the top path depicted in the diagram: They enter sensory memory through the eyes, and through selective attention can be transmitted to working memory where they are handled by the image processing mechanism which will work to organise them into a pictorial model before integrating this model with prior knowledge

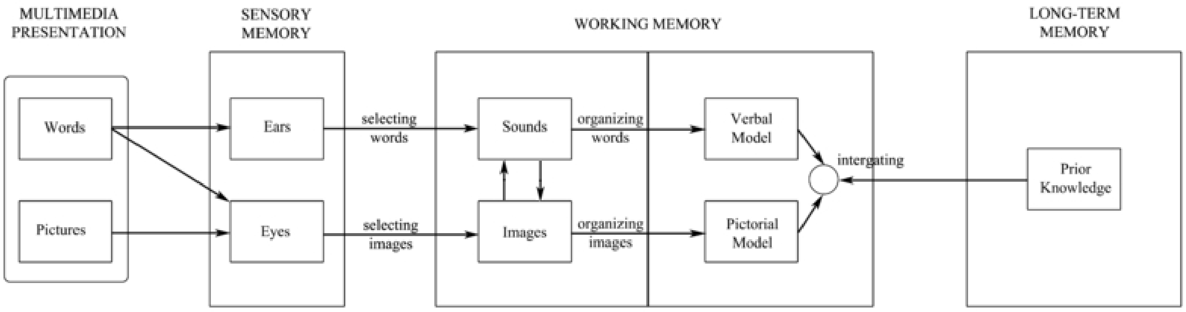

Figure 2.1 Myer's cognitive theory of multimedia learning

and placing it in the long-term memory store. Spoken words will take the lower path: They enter sensory memory through the ears, and if passed to working memory they will be handled by the sound processing mechanism. The spoken words will then be organised into a verbal information model which will then be integrated with prior knowledge before being stored in long-term memory. Written words take a slightly different path as they will enter working memory through the eyes, and will be passed to working memory as images. However, working memory must then recognise that the images contain text, realise it is better dealt with by the sound processing mechanism and pass the information accordingly. The textual information is then processed in the same way as spoken words, being built into a verbal model before being integrated with prior knowledge and stored.

There are a significant number of instructional implications arising from CTML. The overarching goal is to promote the active learning processes of selecting, organising, and integrating, whilst not overload working memory. Mayer (2005, p6) offers the following principles to support this goal:

- Multimedia principle: People learn better from words and pictures than from words alone.
- Split-attention principle: People learn better when words and pictures are physically and temporally integrated.
- Modality principle: People learn better from graphics and narration than from graphics and explanatory text.
- Redundancy principle: Information is easier to comprehend when it is presented in a single format.
- Segmenting principle: People learn best at their own pace which can be supported by segmenting media presentations into short chunks.
- Pre-training principle: People learn best when they are familiarise with key names, characteristics, and/or vocabularies before the main media content is presented.
- Coherence principle: People learn best when extraneous material words/pictures/sounds are excluded.

- Signalling principle: People learn best when important information is highlighted to them.
- Spatial and temporal contiguity principles: People learn best when corresponding words and pictures are placed near to each other spatially and temporally.
- Personalization principle: People learn best when narration takes an informal, conversational style in a familiar accent.
- Voice principle: a real human voice aids learning more than a robotic voice.
- Image principle: people don't learn better when a speaker's image is added to the screen.

Mayer's cognitive theory of multimedia learning and its associated principles were particularly useful to the design and evaluation work presented in Chapters 5 and 6.

2.2.4. Learning through multiple representations

There is a strong parallel between some of the pillars of cognitive load theory and work around multiple representations which emerged from the study of STEM (science, technology, engineering, mathematics) education. Multiple representations (Goldman, 2003) means the presentation of information to learners in multiple forms, and two approaches proved fruitful: Firstly, each information representation would be targeted towards a a different sensory system (Ice et al., 2010). Typically, one will target the visual system and one will target the auditory system. This approach is underpinned by a dual-processing assumption, as was the case with cognitive load theory. The second approach to multiple representations is to pair descriptive and depictive representations (Ainsworth, 2006). For example, early work in this area found that readers' text comprehension could be improved when pictures were presented alongside the text (Levin, 1987). This latter approach is thought to be beneficial because a depictive representation can serve to constrain interpretation of a more complex and inherently ambiguous descriptive representation, thus lightening the processing burden (Schnotz, 2002). Similarly, depictive representations can enable information searching and recognition to be handled by external perceptual processes as opposed to the cognitive operations which might be required to extract the same information from a descriptive representation (Larkin and Simon, 1987).

The work on multiple representations underpins the concept of grounded feedback, where the idea is that an easy to comprehend representation is used to help learners get to grips with a more complex representation. Wiese and Koedinger (2017) present an example using grounded feedback to help children learn fractions: They assert that it can be challenging for novices to grasp that 1/10 is less than ¼ as they may look to the denominator, realise that ten is greater than the four, and then mistakenly infer that the 1/10 fraction is greater too. In a grounded feedback scenario, the students work with the numerical fractions and submit answers in this form, but have their answers translated and returned as a graphical plot of the fraction values. These plots should be comprehensible enough to trigger a self-evaluation process and make clear to the students that ¼ is in fact greater. Thus, the depictive value plot representation serves to help the students gain competency with the more complex descriptive numerical representation.

Whilst grounded feedback is an important example of how multiple representations and feedback can be paired to enhance learning, there remains much room to explore how multiple representations might be utilised within feedback, beyond using them to trigger self-verification of task responses. Such an exploration is presented in Chapter 5.

2.2.5. Flow theory

The work presented in this literature review has, up until now, focused on work derived from cognitive learning theory. This subsection moves in another direction and focuses on the concept of flow (Nakamura and Csikszentmihalyi, 2014) which describes a specific mental state. Flow states are characterised by complete mental absorption in an activity, enjoyment of that activity, feeling energised, and loosing awareness of time passing (Csikszentmihalyi et al., 2021). Flow has been considered an optimal experience, as a person in a flow state will feel in firm control of their activity despite possibly operating near the limits of their capabilities (Csikszentmihalyi, 1990).

Flow has been studied in learning contexts, and it is believed that flow is good for learning as during flow states students are observed being deeply immersed in in a learning activity (Shernoff et al., 2014). Students are more likely to experience flow when they view the challenge associated with a task as being well matched to their own skills, and particularly when they perceive a difficult challenge but one they are well equipped to deal with. Flow is also linked with students having received relevant task instructions, and believing they have control over their learning environment (Rodríguez-Ardura and Meseguer-Artola, 2017; Shernoff et al., 2014). Flow is more likely to occur when students are engaged in individual or group work, as opposed to listening to lectures or watching instructional videos. The instructional implications of this are the educators should try to help learners achieve a state of flow by ensuring the challenges imposed by learning activities are balanced against the learners' level of skill (Csikszentmihalyi, 2000; Shernoff et al., 2014). Figure 2.2 depicts the flow channel that a person might find themselves in when a task challenge is well matched to their level of skill. As Csikszentmihalyi (2000) asserted, should the task challenge be considered too easy for their current skill level, the person will be unable to attain flow and may instead experience boredom, however, should the task challenge be considered too difficult, the person will miss out on flow and is likely to instead experience anxiety. If flow is obtained the learner should engage optimally with their work which will lead to further skill acquisition. This then necessitates the alteration of the learning tasks to increase the challenge in proportion to the learners' new level of skill, in order to try and keep the learners' within the flow channel. Flow theory proved particularly beneficial to the work presented in Chapter 7, where it was used to help evaluate the utility of the multi-layered interface explored in the chapter.

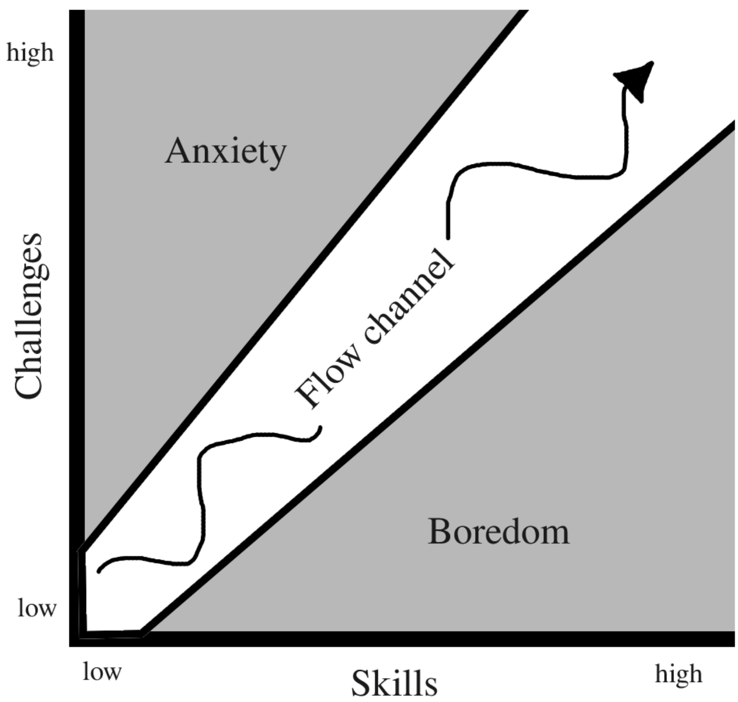

Figure 2.2 Flow theory and the flow channel

2.3. Interpersonal learning

The work previously covered in this chapter focused on learning and the individual, but learning cannot be considered exclusively at the individual level because there are social influences which have a marked impact on someone's ability to learn. Accordingly, interpersonal learning is covered in this section, however the section commences with the classification of knowledge into two types–explicit and tacit–as this lays the foundations for the discussion of learning from apprenticeships which follows.

2.3.1. Explicit and tacit knowledge

Knowledge can broadly be classified as either explicit or tacit (Smith, 2001). Explicit knowledge is that which can be codified and communicated relatively easily between people (Roberts, 2000). It is the type of knowledge found in textbooks and communicated verbally during lectures. Tacit knowledge, on the other hand, is embodied within human actions, and can be thought of as the stuff we can do but cannot tell (Polanyi, 2009). Riding a bicycle is one such tacit competency; whilst we might be able to describe how a bike is ridden, we can't give someone this information in a form that would encompass the *know-how* necessary for successful action (Polanyi, 1966).

Tacit knowledge plays a significant role in many of the things we do, as feats of perception, recognition, attention, information retrieval, and motor control are all tacit competencies (Dahlbom and Mathiassen, 1993). As the topic of this thesis involves music mixing, it is worth acknowledging here the central role tacit knowledge plays in craft-based practices (Keller and Keller, 1991; Liu et al., 2019; Sennett, 2008), including music mixing (Horning, 2004; Kealy, 1979), where sensory, non-linguistic forms of knowledge predominate (Schindler, 2015). Music educator Alton Everest eloquently describes a sound engineer's music mixing process and explains how this tacit competency is acquired (Everest, 2007):

> "Listening intently the sound engineer deftly makes a small adjustment to one of many console channels before him. He registers satisfaction at what he has accomplished by that tiny change. A bystander might listen hard without detecting any change whatsoever in the sound. Observing the sound engineer at work over a period of time would give a person a keen appreciation of his skill and artistry... How did he get this ability? It was built up by listening experiences which were built up one at a time, incident after incident, day after day, year after year"

Unfortunately, tacit knowledge is difficult to transfer between people, largely due to our inability to recognise and articulate it (Haldin-Herrgard, 2000). This is particularly problematic for our modern education systems which are constructed to efficiently transfer explicit knowledge (Collins et al., 1988). Tacit knowledge transfer has proven successful through traditional apprenticeship systems (Agyemang and Boateng, 2019) and within communities of practice (Lave et al., 1991), where long-term engagement with mechanisms such as observation, imitation and practice (Siesfeld et al., 2009) as well as demonstration and guiding (Collins, 2010) serve to facilitate this transfer. Indeed, most of the acclaimed music mixing engineers followed an apprenticeship path; starting out as assistants who learned by watching and listening as their mentors worked (Owsinski, 2013).

2.3.2. Instructional approaches to apprenticeship learning

A group of influential researchers led by Allan Collins have explored incorporating beneficial aspects of apprenticeship learning within formal education systems (Collins, 1991; Collins et al., 1991, 1988). In these contexts masters/experts can be relied upon to take a more active role in the tacit knowledge transfer process than may occur in traditional environments (Collins, 2010). This modern pedagogy involves three key processes of *modelling*, *coaching* and *fading*, as described in (Collins et al., 1988): Modelling is based on the traditional process of the apprentice observing their master's work and methods, but also incorporates the master explaining their underpinning thought process. Over time, the apprentice's observations combined with this strategic information, help them gain a detailed conceptual model of the processes involved in completing the work task. This will not only help them transition towards being able to complete the task themselves but will also serve as an interpretive structure to help them make sense of the feedback, hints and corrections that coaching entails.

Coaching describes the support the master provides as the apprentice tries to undertake the work themselves. It can involve directing the learner's attention to previously unnoticed aspects of a task, or the expert carrying out parts of the task that the apprentice cannot yet manage. The intention is to use feedback, corrections, hints, reminders and modelling to scaffold the learner to a higher level of ability.

Fading describes how the scaffolding provided via the coaching is reduced over time as the apprentice gains competency and thus no longer requires as much support.

2.3.3. HCI work around tacit knowledge transfer

A common approach taken by researchers exploring tacit knowledge acquisition within craft domains is to use sensors to measure and monitor experts' movements thus capturing the output of their tacit competency. This has been used in relation to pottery (clay throwing) (Liu et al., 2019) where visualisations of participants' hand movements were used to support their tacit knowledge acquisition through 'reflection-on-action' (Schön, 2017). It is unclear however, whether this process would support tacit knowledge transfer, by for example, having a novice reflect upon visualisations of their performance in comparison to that of an expert. This was certainly not an angle explored by the authors in this work.

An alternative but related approach involves using sensor data to create a model of an expert's physical craft activity. A system can then compare a novice's real-time performance to the expert model and offer coaching feedback to help scaffold the novice's performance closer to that of the expert, by informing them when their movements differ from the expert model (Bernal et al., 2015; Hiyama et al., 2013). Another approach uses haptic devices to let a novice 'feel' the movements that went into producing an expert's work (Saga et al., 2005).

Whilst these sensor-based approaches hold some promise for physically-oriented tacit knowledge acquisition and transfer, they fail to communicate the expert's overarching thought process so they will not help learners develop full conceptual models of the work activity. Furthermore, the complexity and cost of the necessary equipment may limit the potential for mass adoption. However, sensing challenges may be less problematic in other domains. For example, smartphones can be used to aid tacit knowledge acquisition relating to music by recording singing or detecting screen taps before feeding back, to help people perceive their pitch or rhythmic accuracy, as was demonstrated by Debevc et al. (2019). They trialled their smartphone app with 42 young people (aged 9-13) and concluded that it improved performance in terms of the participants' ability to judge musical intervals – i.e. the tonal gaps between notes – as well as their rhythmic accuracy. It should be noted that this work did not explore tacit knowledge transfer from one person to another; instead the intention was to support tacit knowledge acquisition by the individual through the feedback the system provided. Secondly, the types of tacit knowledge supported here are well matched to the modalities supported through the smartphone, with the microphone supporting auditory information, and the touchscreen supporting tactile information. Types of tacit knowledge that are not as well matched to the sensing capabilities of a smartphone are likely to be far more difficult to support at scale.

2.3.4. Worked Examples and their relationship to music mixing

Worked examples (Sweller, 2006) emerged from the study of cognitive load, and were touched upon earlier in this chapter whilst explaining cognitive load theory – see section 2.2.2. However, their significance to Chapter 6 dictates that they should be covered in more depth, and the social aspect of their creation and use means that it is appropriate to do so in this section. Worked examples involves providing an expert's problem solution for learners to study, prior to the learners trying to solve similar problems by themselves (Atkinson et al., 2000). As mentioned, the approach was born out of cognitive load theory, which views working memory as a key bottleneck in the learning process. Learning via trial and error problem solving is particularly taxing of working memory, whilst learning from an expert by studying their work is significantly less taxing (Sweller, 2006). Worked examples invoke cognitive processes reflective of this latter situation and have been shown to help learners develop knowledge that allows them to outperform peers who have been trained with problem solving practice alone; this is known as the worked-example effect (Rourke and Sweller, 2009). Worked examples have mainly been explored in STEM domains (science, technology, engineering and mathematics), where problems are well-defined in that they possess clear goals, solutions paths and expected solutions (Holyoak, 1990). However, Rourke and Sweller (2009) have argued, drawing on Greeno (1976), that worked examples should also prove applicable to ill-defined problem domains such as the arts. Rourke and Sweller (2009) reported two experimental studies where the goal was to test whether worked examples could help students develop the ability to recognise furniture designers' styles. This subject matter was judged to represent an ill-defined problem because the solution path could vary. Specifically, a designer's style will consist of a number of traits, and one could recognise their work by picking up on some combination of these traits. The combination that leads to a solution, i.e. successful identification, is likely to vary from person to person. These studies demonstrated that learning from worked examples can be more effective than learning from problem solving exercises in this ill-defined space.

The work of Rourke and Sweller (2009) described above is particularly relevant to the topic of this thesis because the problem of how to approach the task of mixing a piece of music can also be described as an ill-defined problem. It is problematic in that most music mixers (including novices), upon listening to pre-mixed audio, would consider its state unsatisfactory and a likely impediment to the music's optimal engagement with the target audience. Nearly all music goes through a mixing process prior to its public release to *"enhance the music: it's mood, the emotions it conveys, and the response it should incite"* (Izhaki, 2013, p8) and thus when a good mix is produced the problem is resolved. I would argue that music mixing represents a more ill-defined problem than the designer's styles recognition problem because the music mixing problem can lack a clear goal, solution path and expected solution, whereas the design problem only lacks a clear solution path.

Let us first consider the goal of the music mixing problem. Whilst the central goal is obviously to make the music sound better, 'better' is a subjective term. A music mixer may thus consider the aesthetic tastes of the musicians whose work they are mixing and/or those of the anticipated audience in order to try and derive a vision for what may constitute *better*. Unpacking the term in this way reveals how ill-defined the central goal of the music mixing problem is. Assuming a novice mixer does identify a goal, or at least begins mixing guided by intuition, the next challenge they face is that the solution path is not well defined. In fact, the processes successful music mixers employ (i.e. their solution paths) can vary greatly and are often a source of intrigue for amateurs and novices; books have been written on the subject such as The Mixing Engineers Handbook (Owsinski, 2013). The topic is also of interest to academic research with work published in a number of journals including the Journal on the Art of Record Production – see e.g. (Anthony, 2017), (Toulson and Ruskin, 2008), (Mynett, 2012). Finally, I would argue that the optimal solution is also ill-defined, again due to the subjective nature of the domain, because what one person would consider a great and engaging music mix may not be the case with the next person. There is another, perhaps more fundamental issue which should be addressed, and it is that novice music mixers may not even possess sufficiently developed listening skills to recognise all the problematic features of the audio (Everest, 2007, p. viii). These contextual issues separate music mixing from other domains where worked examples have been explored.

Mwangi and Sweller (1998, p174) asserted that "*the structure of worked examples may substantially compromise the benefits derived from studying them*", therefore the design of music mixing worked examples must be carefully considered as the design is so closely linked to their ability to help people learn.

2.3.5. HCI work around Worked Examples

Thus far, there has been little HCI research exploring worked examples. Mahoney (2018) represents one of the few publications in this area. Working in a computer programming education context, Mahoney created a tool to help produce worked examples which were intended to support metacognitive modelling of the expert instructor's programming practice. The tool enabled programming sessions to be recorded and annotated with information detailing the reasoning behind the steps taken. Students could then replay these sessions as animations and engage with the annotations. Survey responses from 26 student participants who trialled the system indicated strongly positive feelings towards the insights gained into the expert instructors programming process. This work is highly relevant in that it demonstrates the potential for worked examples to support cognitive modelling, albeit in a different context to the music mixing context of interest to this thesis

Aleahmad et al. (2008) described a novel tool to support the community authoring of maths-focused worked examples. They conducted an experiment asking people to create a worked example teaching Pythagorean Theorem, and then they rated the resulting worked examples, concluding that all their participants created worked examples of value. Whilst this shows the promise of crowd sourcing worked examples, the study was rather contrived in that strong scaffolding was given to support the creation of the worked examples, and such strong scaffolding may be inappropriate in a more flexible–and therefore practical–authoring system. Furthermore, the researchers did not evaluate the design of their authoring tool and therefore no lessons were shared regarding how to design tools to support the creation of worked examples.

Lui et al. (2008) developed a tool which enabled students to share their laboratory work as worked examples for the potential benefit of their classmates. The authors claimed that the advantage of their system is that it is capable of presenting a range of problem solutions within the worked examples, and they go on to argue that studying several of these could generate a set of schemas which will strengthen students problem solving abilities. However, it is unclear from the reported results how often and how deeply students were engaging with more than one worked example per problem. The results did reveal that students were more confident in the worked examples when they knew they came from the instructor, and less confident when they believed the worked examples came from a peer. This finding reveals an obstacle that researchers may need to address should they take this kind of approach forward.

HCI researchers are frequently concerned with collecting evidence which can inform the design of their artifacts. The design of systems to support the production and/or consumption of worked examples should similarly be evidence driven. To this end, a number worked example studies become relevant. For example, (Joentausta and Hellas, 2018) revealed the importance of including subgoal labels with worked examples. That is to say, they demonstrated via experimental work that worked examples are more effective when the steps used to solve a problem are clearly demarcated so as to help a learner understand the process by which the problem was solved. Similarly, Salden et al. (2008) indicated that adaptive fading of the worked examples can lead to higher learning gains compared with non-faded worked examples. This was evidenced through tests conducted after participants had engaged with the worked examples. However, this work was not at a scale, and the reporting not in sufficient detail, to give a great deal of confidence in the generalisability of these findings.

2.3.6. Feedback for learning

Feedback has been cited as one of the top influences upon learning and achievement, ahead of factors like whether students are assigned homework, their socioeconomic status or the size of their classes (Hattie and Timperley, 2007). Within the research community there is a general orientation towards viewing feedback as information provided to someone in order to try and reduce the gap between their current level of ability and a desired level of ability (e.g. (Sadler, 1989)). Effective feedback requires that recipients are able to make sense of the information they receive, and understand how they can use it to enhance their future performance (Boud and Molloy, 2013). However, students can have a particular problem with written feedback due to difficulty in deciphering the language and terminology used by their tutors (Carless, 2006), and whilst face-to-face feedback presents opportunities for clarification (Boud et al., 2013), its ephemeral nature can hinder information retention (Ryan et al., 2019).

Whilst such surface level features are important, the content of the feedback is highly significant yet creating effective content is not necessarily intuitive. Shute (2008) argued that effective feedback will contain both verification and elaboration information, with the verification component conveying the correctness of a learners' work or performance, and the elaboration component providing explanation, worked examples or guidance. Kluger and DeNisi (1996) showed that feedback addressing correct aspects of performance is far more effective than feedback addressing incorrect aspects. Hattie and Timperley (2007) identified four targets towards which feedback is typically aimed and argued that feedback's effectiveness is closely linked to the selected aim. Least effective is feedback focused on the recipient as a person and disconnected from the central task e.g. "you're a great student". Feedback aimed at the learning task will be more effective, however the benefits do not always propagate beyond the immediate task context. The third classification is feedback aimed at improving the recipients' strategic and problem solving skills more broadly – they call this *process level* feedback. Finally, feedback may be targeted towards improving the recipient's self-regulation, which would encompass feedback intended to help and encourage recipients to self-evaluate, remediate, and ultimately become confident, self-directed learners. Hattie and Timperley (2007) claim that the very best feedback will contain an appropriate mixture of task, strategy, and self-regulation feedback.

Shute (2008) takes a simpler approach to feedback content classification, distinguishing between facilitative and directive feedback: Facilitative feedback tends to be non-specific and is intended to guide the learner towards self-reflection and undertaking their own revisions and conceptualisations. Directive feedback, in contrast, is more specific and informs the learner of what needs to be fixed or revised. Elaborate, directive feedback is capable of scaffolding learners to higher levels of ability through the inclusion of models, cues, prompts, hints, partial solutions, and direct instruction (Hartman, 2002), which overlaps significantly with the concept of coaching (Collins et al., 1988). There is evidence that directive feedback, in comparison to facilitative feedback, can decrease cognitive load (Moreno, 2004) thus enhancing learning (Kluger and DeNisi, 1996; Sweller et al., 1998). Furthermore, knowledge retention may be enhanced when directive feedback contains the correct answer (Phye and Sanders, 1994).

Who gives the feedback matters too. Palloff and Pratt (1999) found that task-domain experts are likely to produce higher quality feedback due to their enhanced ability to analyse and frame problems in the domain. The feedback recipient's perception of this level of expertise is also important, with feedback more likely to be dismissed when it is perceived to come from a non-expert (Gielen et al., 2010).

Whilst much is known about how the content of feedback and perceptions around the expertise of the feedback giver can impact learning, a potentially significant but less explored factor influencing its effectiveness relates to the way the feedback information is represented. As described earlier in this chapter, learners have been shown to benefit when feedback is presented using multiple representations (Ainsworth, 2006; Ice et al., 2010; Wiese and Koedinger, 2017). Whilst much of the multiple representations work centred on STEM subjects (science, technology, engineering, mathematics), it appears relevant to the creative arts too. For example, researchers investigating an online photography critique community found some participants had adopted a practice of downloading, revising and re-uploading photos in order to demonstrate proposed edits, instead of trying to describe them via text alone. This naturally occurring use of multiple representation feedback was performed in order to compensate for the limitations inherent in text-based feedback representations (Xu and Bailey, 2012). Multiple representation feedback may therefore be beneficial in a range of similar artistic domains where people are working with non-text artefacts.

An important issue relating to feedback within artistic domains is that 'correct' in these contexts is frequently considered more a matter of subjective aesthetic judgement than objective truth (Bergmann, 1994; Tinapple et al., 2013). Moving away from single-expert feedback can be useful in many domains (Cho and Schunn, 2007) but may be particularly important here because if aesthetic sensibilities are mismatched, purposeful artistic choice could be misinterpreted as oversight or error. Critique sessions can overcome this issue and are common within formal arts education, where learners receive feedback from multiple individuals and benefit from the range of unique perspectives this entails (Tinapple et al., 2013), in a manner not dissimilar to the previously described photography critique community that operated in an informal learning context.

2.3.7. HCI work around digital feedback systems

Many researchers have put effort into developing computer systems that support the provision of feedback to learners. They are often motivated by a desire to reduce the burden that creating feedback places upon instructors, particularly when education occurs at scale, and a number of strategies aimed at tackling this problem are emerging. One such strategy involves creating systems that can produce computer-generated automatic feedback (Gramoli et al., 2016; Malmi et al., 2002; Suzuki et al., 2017), another approach is to focus on the reuse of instructor's written feedback (Ngoon et al., 2018) or the grouping of submissions with similar errors to enable the instructor to send one piece of feedback to many learners (Head et al., 2017). Further strategies involve looking to alternative sources for feedback, including peers (Cho and Schunn, 2007; Shannon et al., 2016; Tinapple et al., 2013) and the crowd (Dow et al., 2013; Wauck et al., 2017).

A common view is that when feedback is created by non-expert educators, it may lack the quality necessary to enhance learning unless these feedback givers are adequately supported throughout the process (Kulkarni et al., 2013; Ngoon et al., 2018; Yuan et al., 2016). Researchers designing feedback systems typically address this by creating mechanisms to scaffold the feedback creation process in some way. For example, Ngoon et al. (2018) start with the belief that feedback should be specific, actionable, and justified. They implemented a text analysis system that would monitor feedback as it was being created, and would inform the feedback giver when their text matched any of these criteria (i.e. when it was specific, actionable, and/or justified). Essentially this helped produce more effective feedback and also helped to train the feedback givers to produce higher quality feedback than may otherwise have occurred without support.

An alternative approach to supporting non-expert feedback provision was taken by Shannon et al. (2016). Working in a class presentation context, they tried to support the production of feedback that is relevant, copious, timely, diverse, and reflected on. Their system enables feedback seekers to set questions that will serve to guide the feedback givers when reviewing their work. Whilst the authors claimed a successful evaluation, their study design did not involve direct comparison between their system and any other feedback systems or approaches and therefore the validity of their claims could be questioned. Yuan et al. (2016) approached the challenge by developing a rubric which exposes different dimensions of a task, and thus encourages feedback givers to broaden their feedback by addressing these dimensions. This was claimed by the authors to significantly improve the feedback created by novices in a creative design context. However, it is unclear whether this improved non-expert feedback ultimately translated into improved designed artefacts or enhanced learning. Other types of structural device aimed at supporting feedback givers include the use of directed questions, such as *"was the material easy to understand, well organized and free from redundancy?"* (Miller, 2003), or adding sentence openers to text-entry boxes that feedback givers use, thus giving them something to elaborate on (Baker and Lund, 1997). Whilst the previous two citations evidence the benefit that scaffolding can bring to the quality of the feedback produced, it should be noted that some researchers raise concerns regarding the potential for heavily structured feedback creation mechanisms to harm feedback givers' motivation (Gielen et al., 2010) and to hinder their natural communication (Lazonder et al., 2003).

The above descriptions should give some indication of the wide variety of approaches that researchers have explored in relation to the provision of feedback through digital system. Yet there is little work exploring the potential that feedback technologies centred around non-text-based, or non-verbal information representations might have upon learning. The work presented in Chapter 5 aims to help address this gap.

2.3.8. Feedback within traditional music mixing learning environments

A solid understanding of how feedback operates within traditional co-located, music mixing-focused learning environments should be gained before any serious attempt can be made towards designing and developing a digital tool based around these processes – as was an objective of this thesis with the resulting work presented in Chapter 5. What follows is a description of a typical feedback scenario based on countless observations over the course of my career in music education. This is followed by an analysis of how feedback information is represented within the scenario, and the purpose towards which the feedback is aimed.

> *A novice sits behind a music mixing desk in a recording studio. They have spent a considerable amount of time listening to a piece of music, noticing features within the music they would like to enhance or correct, and have attempted to use the controls set out on the mixing desk to adjust these aspects of the music. This process goes on until the novice feels they cannot improve the music any further, at which point they go and find their mentor – an expert music mixer - and ask them for their feedback. Upon listening together the expert notices aspects which they feel require additional processing. They try and describe what they are perceiving to the novice, "the bass guitar sounds too muddy" or "it sounds like you're going for a dance track,*

> *in which case I think you should increase the volume of the kick drum to make it more in keeping with the norms of the genre". They then offer to show the novice the corrective processing they would apply to fix the issue. The novice accepts and watches as the expert selects one of the dials from the hundreds housed within the mixing desk, and as the expert twists it the novice listens in order to try and tune into the dimension within the music which the dial is impacting. The expert gives a running commentary; explaining what they are listening for and why they chose the specific dial. When the expert has finished applying the corrective processing they toggle a button beside the dial to switch their processing contribution off and on, in order to help the novice identify the sonic change their processing has imparted. Perhaps they adjust more controls on the mixing desk in a similar manner, trying to further refine the musical artefact, or perhaps they stop there having demonstrated how to correct the most obvious flaw.*

In the example above, feedback is represented in three distinct forms: (i) Auditory/words; as the expert describes their actions and thought process. (ii) Auditory/music; information is encoded within the music and the act of switching between pre/post audio processing states via the on/off button helps the novice comprehend this information. (iii) Visual information detailing the way tools were used to enact the proposed change is communicated as the novice watches the expert interact with the mixing desk.

Literature from the field of multiple representations - see section 2.2.4 - provides insight into why this combination of representations might provide effective feedback. The auditory/words offers a descriptive information representation which provides insight into the thinking that underpins the expert's actions. Such descriptive information is important in order for learners to receive what Hattie and Timperley (2007) would cite as *process level* feedback, which can inform the novices strategic thinking going forward. Yet descriptive representations can face problems with ambiguity, and this problem is particularly acute in the field of music production where it can be very challenging for novices to gain a vocabulary which accurately maps to sonic features within a piece of music. This problem is itself an area of active research activity - see for example (Zheng et al., 2016). The term *muddy* is one such ambiguous descriptive representation. The auditory/music representation of the proposed changes serves to not only remove this ambiguity by enabling the novice to hear what the defect sounds like, but through a process of trying to integrate the auditory/music representation with the more complex descriptive representation the novice gains competency with this complex representation, thus improving their musical vocabulary.

Whilst some suggested changes encoded within the auditory/music feedback representation can be obvious, others might be very subtle to the extent that a novice may fail to notice them whilst switching between pre/post feedback processing states. From an information processing perspective, the novice must learn to control their auditory sensory memory and shift their attention over various dimensions within the music to try and identify a change. Developing these 'critical listening skills' is vitally important for novice music mixers (Corey, 2016, p. x), and it is widely acknowledged that expert music mixers will tune into different dimension within a piece of music during the course of their work (Owsinski, 2013, p. 8).

Signalling (also known as cueing) has been shown to enhance learning within multimedia contexts by guiding the attention of learners to important information (Van Gog, 2014). A form of signalling may be functioning in this context too as, the specific tool used within the mixing desk becomes apparent as novice watches the expert reach for that control and if the novice possesses sufficient prior knowledge of that control, seeing what tools the expert is using can cue their attention towards the related dimension within the audio. For example, if the expert manipulates the pan control the novice may try and tune into the music's sense of width, or if an equaliser control was adjusted then attention can be trained onto the tonal properties of the music.

This combination of feedback representations serves to give the novice a good picture of the process and reasoning that underpins an expert's artefact refining activity. This information aligns closely with traditional notions of apprenticeship where a key feature is that novices get to see how an expert works, and over time takes on more of the task activity themselves (Lave, 1997). In our example the feedback serves as a scaffolding mechanism, with the novice taking the processing as far as they can before the expert completes the refinement, *modelling* their working method for the novice which enables them to see how tools were used (via the visual information representation) and the impact these had on the artefact (through the auditory/music information representation). They also explain their thought process (via the auditory/words descriptive representation). The idea of apprenticeship is particularly relevant to learning within a music mixing context because this is the process by which most successful music mixers learned their craft, in fact it is claimed that many of the best mixers will have had more than one mentor, and thus they benefit from seeing a range of working methods and approaches (Owsinski, 2013, p. ix).

2.4. Music mixing skills development

This section is based upon descriptions within the literature of differences between novice and expert music mixers. Four key competencies were identified, as explained below, and it is proposed that these competencies serve as a framework to understand learner support requirements when developing technology to assist music mixing skill acquisition.

1. Izhaki (2013, p21) asserts that novices usually lack a clear vision for a mix, whilst Owsinski (2013, p7) reports the presence of clear visions for experts music mixers.

2. Novices will usually follow a sub-optimal process such as focusing on each musical element in isolation which can result in a mix where the elements don't knit together sonically. Experts, on the other hand, will bear in mind the reciprocal impact of a change upon other elements within a mix Izhaki (2013, p34). For example, an expert knows that making one element louder makes the other elements quieter in relative terms. Expert's therefore process elements with reference to the corresponding sonic dimension of the

whole. There are no hard and fast rules as to what constitutes a dimension. Owsinski (2013, p9) considers a mix in relation to six dimensions: balance, frequency range, panorama, dimension, dynamics, interest. Whilst Izhaki (2013, p66) considers five dimensions: time, frequency, level, stereo, depth; and Moylan (2014, p416) favours three dimensions: musical balance and loudness, spatial qualities and relationships, and pitch and sound quality.

3. Novices lack the critical listening skill necessary to identify all the features within the music that should be manipulated to better align them to the vision for the finished product (Everest, 2007, p. viii), whilst expert music mixers have highly developed critical listening skills allowing them to tune into the subtle details within a piece of audio (Owsinski, 2013, p. 8).

4. A novice will not have full command of the tools at their disposal i.e. they will not be able to optimally control sonic features within a piece of music using the controls available on a mixing desk or within a piece of music mixing software.

From this we can surmise that these four listed items represent key music mixing competencies: *possession of a clear vision for the music*, *a process centred around holistic judgements*, *highly developed critical listening skills*, and *an actionable understanding of the link between tools and musical attributes*. Developing technology to help people develop music mixing skills will therefore require targeting one or more of these competencies.

2.5. Making learning meaningful

The previous section covered the way information from other people can help a learner gain knowledge, however the input from other people can also have a significant but less direct positive impact on learning; by sparking an interest, or by simply helping people see the relevance of a topic to their own lives. This section covers such influences upon learning.

In the influential work Confronting the Challenges of Participatory Culture: Media Education for the 21st Century, Jenkins (2009) describes a vibrant set of online communities involved in creating, sharing, reshaping and critiquing a whole range of digital media - drawings, videos, writings and music to name but a few. Young people are at the heart of this *participatory culture* and music remixing is one of the activities undertaken (Cheliotis and Yew, 2009; Lessig, 2008; Prior, 2010). Whilst the primary motivation for taking part may be entertainment or personal expression (Cheliotis and Yew, 2009), participants also gain educationally through informal peer-to-peer learning, leading to the development of skills which benefit them in formal education and later when they enter the workplace (Jenkins, 2009).

Participation within such online communities requires access to specific technologies, and therefore it is worth reflecting upon whether such access requirements impose barriers to entry. In 2010, Klopper (2010) observed that a rapid advancement of technology had given rise to a flourishing intercultural exchange movement, whilst for Nakayama and Martin (2007) the tipping point came in 2007 when it became realistic for people from the most remote parts of the world to connect and collaborate with people they may never meet in person. Recently, Barnabas and Bodunrin (2021) illustrated just how accessible such creative practices have become, when they reported that young, often unemployed school leavers from the !Xun and Khwe communities within South Africa where able to express themselves through the creation of hip-hop music and accompanying music videos, and to then disseminate them online. This demonstrates how even people from some of the most marginalised communities can find ways to overcome challenges around accessing technology and the internet in order to express themselves creatively online. Interestingly, whilst the challenges around access to technology were different, hip-hop drew participants from similarly marginalised communities in its early days in the USA (Alexander, 2011), and as it spread around the world (Chang and Watkins, 2007).

Music remixing within online communities is being encouraged by established musicians who are releasing their music in a format known as stems where separate recordings are provided for each musical component that constitutes the song – as detailed in Chapter 3.5.1 – e.g. separate recordings for the drums, bass, guitars, vocals etc. These stems are often released under creative commons license, effectively freeing end users to do with them as they wish (Lessig, 2008). This movement is analogous to the open source computer programming movement: Stems give people access to the musical ‘source code’, a growing range of software tools enables people to manipulate and modify the source material, and creative commons licensing allows people to share their derivative works onwards. Creating a remix may involve, for example, adding sound effects to the vocals, replacing the drums with a drum part from another song, and changing the volume of the backing vocals. This interpretation can then be shared through the author’s social media channels and, in turn, they will receive feedback and encouragement from their peers.

The engaging and social nature of these online spaces contrasts sharply with the current approach to formal education. Some authors argue that formal education is failing to connect with the lives of learners in a meaningful way (Ito et al., 2013), and within music education this disconnection may stem from a skew towards western classical music which many young people don’t feel an affinity with (Hess, 2014). A government commissioned review found many children in England receive a sub-standard music education, and this disproportionately affects those from poorer areas (Henley, 2011). In considering how music education could be improved, the report’s author sites the need for schools to draw on local resources by forming partnerships with groups, organisations, and individuals in the local area. This call had a strong influence upon the research conducted within this thesis, particularly the study presented in Chapter 4.

A group of influential academics known as the New London Group proposed that the purpose of education is to “*ensure that all students benefit from learning in ways that allow them to participate fully in public, community, and economic life.*” (Cope and Kalantzis, 2005). A music education with a focus on encouraging students to participate in musical activities beyond the school could realise a wide range of benefits including: an increase to young people’s self-esteem and their educational engagement across all subjects (Ofsted, 2009); enhancement of their literacy and numeracy skills (Gardiner et al., 1996; Ho et al., 2003; Overy, 2003; Register, 2001); an increase to their intellectual, personal, social and physical development (Broh, 2002; North et al., 2000; Schellenberg, 2004); a boost to their creativity (Koutsoupidou and Hargreaves, 2009); a range of health and wellbeing benefits (The Royal Conservatory of Music, 2014). Moreover, at a community level it is important that we encourage young people to participate in music making activities in order to foster the next generation of musicians who will go on to make an important contribution to our social fabric and the economy (Behr et al., 2016; Henley, 2011).

Educational researchers have long understood that young people benefit from 'authentic' learning experiences, such as activities aligned with their personal interests and with the world beyond the classroom (Shaffer and Resnick, 1999). Connected Learning (Ito et al., 2013) is a contemporary approach to authentic education, which claims that young people learn best when their formal education overlaps with their personal interests, and their educational pursuits are shared with their peer groups and the online communities in which they participate. Similarly, the output of their learning is made more meaningful when it is used to make a positive contribution to their communities, with the young people benefiting from the recognition they receive for their efforts (Ito et al., 2013).

Local Learning Ecologies (Hodgson and Spours, 2013) describe these kinds of authentic, beyond the classroom connections at a local level, and Hodgson and Spours (2013) demonstrated how strong inter-organisational connections can help young people (14-19 years of age) transition into further education or the labour market. A key idea is that when schools forge links with organisations in their locality, it can broaden young peoples' experiences and relationships, leading them to develop more positive *imagined futures*, and in time to positive transitions beyond school.

2.6. Technology-facilitated music learning

Despite the benefits of authentic and connected learning, few research projects relating to technology for music education explore this area. Instead, technology is typically used to support the traditional music education paradigm by, for example, replicating traditional musical interactions within a digital device - such is the case with MOGCLASS where Zhou et al. (2011) simulated a range of musical instruments within a smartphone app.

The technology used within music classrooms typically plays a similar role in supporting traditional practices. NoteFlight (Noteflight, 2019) and Sibelius (Sibelius, 2019) for example, allow students to create a piece of sheet music on a computer screen. The main advantage of these packages is that they allow the students to hear their creations without requiring the musical competency to play the piece of music themselves which, whilst beneficial for some individuals, is not particularly transformational.

Ironically, projects that use music and technology to explore more transformational educational configurations tend to take place away from the music classroom. For example, both Earsketch (Freeman et al., 2014) and SonicPI (Aaron and Blackwell, 2013) attempt to harness young people's musical interests in order to motivate them to learn computer programming, with musical compositions being built through computer programming interfaces.

One study that does apply technology to explore a reconfiguration of music education was conducted by Gall and Breeze (2008) who investigated how music students could use pre-recorded musical loops to produce creative, collaborative compositions. This approach is a departure from the traditional ground-up view of music education, where the students build music after gaining instrumental competence. Instead, blocks of pre-composed music can be selected, and arranged by the students. The process has similarities with creating a remix although the focus is not on creatively reshaping a central piece of music as is the case with remixing, but rather on creating a new piece of music from scratch. The collaborative aspect of this research derives from the students working in pairs. The qualitative methods employed by the researchers revealed the engaging nature of the activity, and its high cultural relevance to the student participants, however little music creation and manipulation took place beyond basic selecting and positioning of the available loops. Therefore, significantly more work could follow to explore how the activity could be configured to support the development of music-making skills, (including music-mixing skills) and to map across a wider area of the music curriculum. I built upon aspects of this basic but promising approach to music education in Chapter 4, by exploring how similar activities involving the arrangement and manipulation of pre-recorded musical elements could serve as a bridge between the students and the musicians who contributed the musical elements. Whilst Gall and Breeze did not appear to engage their participants in questions around who made the loops they were using, such questions were central to the work presented in chapter 4. Furthermore, a goal of this thesis was to explore how such activities could be configured to enhance music mixing skills development, and to understand the role interface design could play in supporting this, whereas Gall and Breeze used an off-the-shelf music making platform and did not critique the interface, nor did they explore skill development, focusing only on the potential for creative expression.

Online participatory communities are shaped and supported by the tools at their disposal. Music remixing communities initially adopted software created for sound engineers working in recording studios, but now a range of online collaborative music production platforms are starting to emerge (Blend, 2017; Indaba Music, 2017; Looplabs, 2017; Ohm Studio, 2017). These operate at a global scale and are designed around offering opportunities for entertainment and creative expression. We are not aware of any work exploring their configuration to support local community connections or educational advances. Academics have however studied the composition of the communities engaging with these online music remixing tools. Prior (2010) describes their emergence, with online digital infrastructures enabling young people to pool knowledge and collectively progress from being passive consumers of music, through intermediary roles providing feedback and commentary, to customisation and dissemination (i.e. remixing) at which point they are effectively demonstrating a new status as active contributors. Benkler (2006) finds remixing communities as being composed of groups of loosely connected, widely distributed individuals who work cooperatively, openly sharing resources without managerial commands. He terms this configuration *commons-based peer production*. Cheliotis and Yew (2009) studied the ccMixter remixing community and present participants as being motivated to participate through opportunities for (i) self-expression through the creation of content, (ii) building social relationships during the creative process, (iii) furthering community practices by creating, reusing and sharing content. Furthermore they draw our attention to the role remix contests can play as a catalyst for action. These contests are often organised around musical content supplied by well-known musicians and the ensuing contest can provide an ideal platform for community members to demonstrate their creative and collaborative skills.

A useful input to online remixing communities comes in the form of music production demonstrations presented on YouTube. A prime example of this is the 'Against the Clock' series established by FACT magazine (FACT magazine, 2014) in which high-profile music producers from the electronic dance music (EDM) genre get 10 minutes to produce a track from start to finish whilst being filmed. This video series gives viewers a chance to study the musicians' working methods and equipment, and thus has the potential to make an excellent learning resource. Unfortunately, the authors of this video series disabled all comments for these videos on YouTube, which reduces the opportunity for community members to discuss the content, to seek clarification and so forth. Also, it has also been suggested that some of the videos are pre-rehearsed (WorkingOnAFreshName, 2019), which if true, goes against the stated spirit of the challenge and may give the misleading impression that producing high quality pieces of music is quick and easy, when the reality for many is that it can be a laborious, but ultimately rewarding process.

Another potentially useful resource for music remixing communities is offered by SoundCloud.com which is an audio uploading, streaming, and sharing website which has found favour with DIY musicians (Hubbles et al., 2017). Playback is enhanced with collaborative features including 'likes' and social media sharing, as well as a time-stamped comments feature that enables users to insert comments at particular points within the audio, with the comment being visible for four seconds once the specific point is reached during playback (Birch, 2013). This could facilitate music production critique, with the time-stamped comments enabling the critique-giver to target their feedback to specific sections within a track, which may reduce some ambiguity within their feedback. A study by Hubbles et al. (2017) explored the comments left by SoundCloud.com commnunity members and found that a small proportion of users made good use of the time-stamped comments to speak to precise musical moments with great effect, relaying observations about instrumentation, rhythm, vocals, stylistic peculiarities, genre designations and song structures; however, the vast majority of comments were found to be inarticulate about musical substance. Similarly, Kossmann et al. (2022) concluded that SoundCloud.com comments, when directed at the music's author, tend to be oriented towards trying to foster emotional bonding, or towards encouraging the circulation of the music. So, whilst high quality critique is not the norm on SoundCloud.com, it does offer suitable tools to support such processes. The focus should then be on supporting people to gain the skills to successfully participate in critique activities.

2.7. Conclusions

This chapter presented a review of literature relevant to the aim of this thesis which is *to perform a design-based exploration of social music mixing; its tools and its impact upon learners*. The chapter initially focused on presenting a general, cognitive perspective upon learning, and a cognitive perspective upon obstacles to learning. The focus then moved to related areas of particular significance to this thesis including multimedia learning theory and multiple representations. Flow theory was also covered within this section. Flow theory informed the data collection and analysis following the deployment described in Chapter 7 which addressed the research question: *How can we design multi-layered interfaces to support novice to expert transitions within the context of music mixing skills acquisition?* Multimedia learning and multiple representation helped inform to the work presented in Chapter 5 which addressed the research question: *How can we design technology to support tacit knowledge transfer through feedback within the context of music mixing skill acquisition?*

The review then moved on to explore interpersonal learning and engaged with literature around apprenticeship learning, tacit knowledge, and learning feedback. The focus then moved to the details of how feedback serves learning within traditional music mixing contexts. The literature presented in this section had a particularly significant influence upon the work presented in Chapter 5 which addressed the research question: *How can we design technology to support tacit knowledge transfer through feedback within the context of music mixing skill acquisition?* This section also reviewed literature around worked examples and this underpinned the work presented in Chapter 6 which addressed the research question: *How can we capture and use expert knowledge in the form of music mixing-oriented worked examples to support music mixing skills acquisition?*

A short section then presented literature which noted differences between novice and expert music mixers, and from this a framework was derived which covers four key music mixing competencies. The implication is that designing to support music mixing skills development will necessitate supporting one or more of these competencies. This work therefore influenced all the design work that follows.

The review then moved on to cover ideas about how to make learning meaningful, with a key theme being the advantages of bringing outside experts into formal education. This literature was particularly influential to the work presented in Chapter 4, as it helped both formulate and explore solutions to the research question: *Can music remixing activities support the formation of a local learning ecology involving young people and established local musicians, and if so, what factors are important in the design of the tools and social configuration?*

Finally, technology-facilitated music learning was covered and this literature helped shape each iteration of the designed artefact that is central to this design-research thesis.

Chapter 3. Methodology

3.1. Introduction

This chapter details the methodology via which this thesis' aim and subsequent research questions were tackled. The chapter begins by explaining the contextual influences upon the chosen methodology, and then goes on to detail the data collection and analysis methods. A section is dedicated to giving an overview of the artefact at the heart of this design research, the study data that contributed to the design iterations, and sign-posting readers to the relevant sections within this thesis. This is followed by an explanation of how field studies were established and how participants were recruited. Finally, a short section documents the ethical considerations this research entailed.

3.2. Foundations of the methodology

3.2.1. Research context

The methodology with which I approached my research problem was, to a large extent, influenced by the research group I belong to. Open Lab's Centre for Doctoral Training in Digital Civics emerged in response to Newcastle University positioning itself as a civic university, embedded in, and responsive to, its local context. This was encapsulated in the vice-chancellor's call for staff to consider "*not what are we good at, but what are we good for?*" (Olivier and Wright, 2015). Digital Civics research is therefore agenda-driven, and broadly involves exploring the role technology can or could play in reshaping service provision, with a particular emphasis towards place-based, bottom-up models where service users have a greater say in service design and delivery (Vlachokyriakos et al., 2016).

Newcastle University set three themes for local action: aging, social renewal, and sustainability (Olivier and Wright, 2015). With education and (re)training widely acknowledged as key components of social renewal (Department for Levelling Up, Housing and Communities, 2021), it should be no surprise that the Digital Civics place-based agenda, following on from the University's stated themes and in line with the grants received from national funding bodies, takes an interest in novel education approaches that might support social renewal within the North East of England and beyond. It is for this reason that a key foundation of my work was to select an approach to education that aligns with Digital Civics' concerns, which led to the identification of the Local Learning Ecologies approach (Hodgson and Spours, 2013). Local Learning Ecologies aligns with the Digital Civics research agenda in that it is similarly interested in a reconfiguration of relationships within the local area. Its aim is to improve the opportunities young people experience during their formal education with the intention of fostering better outcomes for them and reducing the number of young people not in employment, education, or training. This, therefore, links closely with the theme of social renewal. Specifically, and as described in Section 2.5, Local Learning Ecologies is about moving away from education institutions operating in isolation with their young learners effectively cloistered, towards a model more akin to a partnership between education institutions and local businesses, with the young people benefiting from their interactions with these local businesses. This parallels Digital Civics interest in reshaping service provision.

Newcastle University's Digital Civics research was developed within an Human-Computer Interaction (HCI) department and therefore researchers naturally apply HCI methods to this problem space. These are therefore the methods I drew upon when conducting my own research. At a high level, the field of HCI is concerned with: "*seeking to both understand and improve how humans interact with technology*" (Hudson and Mankoff, 2014), or as Hewett et al. (1996) puts it: "*the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them*". Whilst early HCI work favoured laboratory investigations, the field evolved following the lead of Brown (1992) who argued that attempts to study variables in isolation, as is the goal of laboratory settings, will lead to an incomplete understanding of their role within more complex, natural settings. In order to improve ecological validity, much HCI research now takes place *in the wild* where highly functioning prototypes are given to users in their natural environments in an attempt to explore how the technology can change or disrupt behaviour (Chamberlain et al., 2012). My work followed this path, as I deployed a high functioning prototype into classroom settings, and explored how attitudes towards learning, and the potential for learning to occur, were impacted as a result. As Rogers (2011) observed, designing in the wild necessitates evaluating prototypes in situ, and this involves observing and recording what people do and how this changes over suitable periods of time. Mindful of this, I aimed to conduct field deployments (Siek et al., 2014) over a number of weekly sessions, to give sufficient time for interactions with the prototype to induce a change within the participants.

HCI researchers typically use iterative design processes as the successive evidence gathering stages offers a form of rigour (Wolf et al., 2006). My study design aligned with this, as I conducted five distinct field deployments and the evidence gathered from these led to three major iterations of Remix Portal's interface design, as depicted in Figure 3.1. These separate field deployments allowed me to observe similar patters of changes within the respective participants, which helps strengthen claims about the designed artefact's impact upon users. The two field deployments presented in Chapter 4 are a good example of this, as they produced very similar results despite differing user profiles and other contextual differences.

As described above, I designed and implemented an artefact and used field deployments to evaluate its impact upon users. Such design research is a cornerstone of HCI, however Sanders (2008) noted distinctions between the philosophical positions from which researchers approach design research. One key distinction is whether the researchers believe that expertise resides more

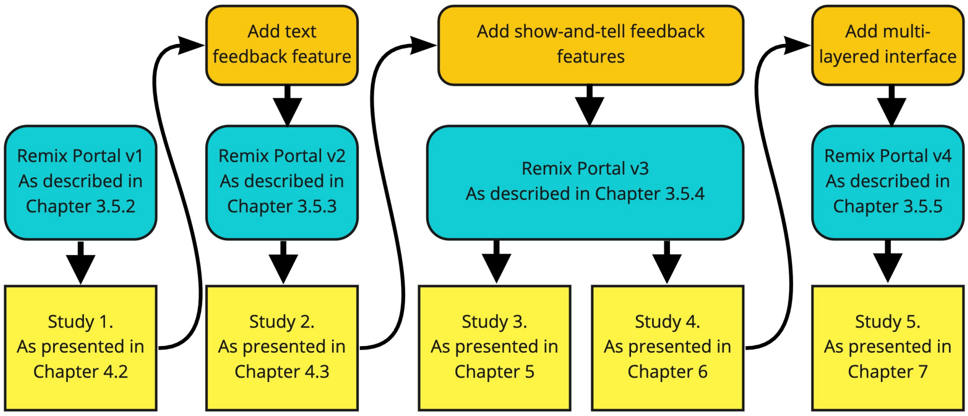

Figure 3.1 Field studies and their link to Remix Portal design iterations

with the designer or more with the participants. Those who lean towards *designers-as-experts* are more likely to employ User-Centered Design (Norman and Draper, 1986) or Critical Design (Raby, 2013) approaches, whilst those who lean towards *participants-as-experts* may favour Participatory Design methods (Muller and Kuhn, 1993). I reflected upon this, and considered the expertise I had developed as a musician, music producer and music technology educator over the past two decades. I then considered that the participants I intended to work with would be new to music remixing activities and accordingly would possess little domain expertise. I therefore favoured a User-Centered Design approach where, as is common, I would play a personal role in the design process (Löwgren, 1995, p. 87).

The discussion above reflects an important consideration for HCI researchers, concerning their epistemological disposition (Boehner et al., 2007). Addressing this directly, I would consider myself a pragmatist (Biesta and Burbules, 2003), feeling comfortable aiming for constructive knowledge which may be usefully applied to improve the situation within the research context, as is common with pragmatic approaches to research (Goldkuhl, 2012). I was of the opinion that the problems associated with education are best solved in context, and that it would be very difficult to reduce the complex social phenomena to the type of data measurable via quantitative methods alone. Instead, I believed the relationships between the participants, designed artefacts and the context of their use would be important, and that a focus on the details of these contexts and the events that occur within them, and my subjective interpretation of participants' responses to them would lead to the output of useful knowledge. Therefore, I, as the designer of the educational interventions and the interpreter of the data, could not be a truly objective presence within the research, and instead I would embrace my role as an active participant, working with the various stakeholders to improve the designed artefact and improve learning outcomes for these stakeholders. This epistemological position is consistent with the design-based research methodology which guided my work.

3.2.2. Design-based research

Design-based research (DBR) is a popular methodology within the learning sciences (Anderson and Shattuck, 2012; Barab and Squire, 2004). It emerged near the beginning of the 21st century in response to a 'credibility gap' in education research (Levin and O'Donnell, 1999). At that point, education research typically either employed traditional scientific methods based around controlled experimentation, leading to criticism of being divorced from real-world complexity and problems of educational practice or, on the other hand, research was conducted in authentic but 'messy' setting and was criticised as being unscientific and lacking rigour (Collective, 2003). DBR addresses these issues by coupling empirical educational research in naturalistic settings, with theory-driven design (Collective, 2003). A central position of DBR is that theory must work hand-in-hand with design interventions, as interventions will help generate theory, and theory must inform the design of interventions (Easterday et al., 2014). According to Easterday et al.: *"Theory derives its purpose from application and application derives its power from theory"*. For this reason, DBR tends to distinguish between *grand theories* and *"theories that work"*, and concerns itself with the latter (Tiberghien et al., 2009). The output of DBR should therefore be effective educational interventions which improve teaching and learning in real-world settings, as well as theory and design principles which can be used to both inform future designs and improve practice and research in educational contexts (Anderson and Shattuck, 2012). For Barab and Squire (2004), this coupling enables those engaged in DBR can offer a "*joint commitment to research and service*".

A key distinction between DBR and other methodologies employed in education research is the incorporation of designed interventions, deployed into real-world learning settings. According to Collective (2003), this enables DBR projects to enact and explore learning conditions which theory indicates should be lead to positive outcomes, yet are underexplored or are poorly understood. Furthermore, DBR can lead to knowledge of how, when and why educational innovations work in practice, and understandings of the relationships between learning theory, designed artifacts and practice, as well as to updated theoretical understandings.

Whilst there appears to be consensus on DBR's commitment to the dual purpose of improving practice and advancing theory, as well as to treating participants more as collaborators than as research subjects (Wang and Hannafin, 2005), the processes by which DBR is applied can vary between researchers (Easterday et al., 2014). This has led to criticisms of DBR as being underdeveloped (Anderson and Shattuck, 2012; Easterday et al., 2014). This is not helped by the fact that some leaders in the field appear unkeen to make low-level stipulations. For example, Collective (2003) simply advises researchers to choose *"methods that can document and connect processes of enactment to outcomes of interest"*. A meta-analysis by Anderson and Shattuck (2012) found that DBR researchers typically either measure learning outcomes or student attitudes, with the methods used to measure learning or probe attitudes varying. Easterday et al. (2014) asserts that some researchers view DBR as a form of qualitative research used to assist discovery and address problems of meaning, as opposed to verifying an existing theory. However, others are of the opinion that DBR is best suited to a mixed methods approach, using qualitative and quantitative methods within field studies and laboratory experiments (Brown, 1992; Kelly, 2006). For example, Levin and O'Donnell (1999) see field studies as a precursor to controlled experimental work which could validate theories developed within the field studies. Obrenović (2011), on the other hand, see's DBR as performing a 'pioneering role' in exploring new research territory that other research methods will go on to 'occupy'. Accordingly, the ability to produce trustworthy knowledge using DBR without a controlled experimental component, or experimental work following on, may be questioned by some. The more scientific take on DBR clashes with those who are of the opinion that design-based work cannot be generalised, and therefore design cannot be accommodated within scientific research (Buchanan, 1992). The design work that precedes field deployments is often assisted by data collected through human-centred techniques such as observation, interviewing, surveys, data analytics (Easterday et al., 2014). Similar techniques are often used during an evaluation stage, post-engagement. However, as mentioned above, other techniques can be employed.

A recurring criticism of DBR relates to researchers' objectivity. As Barab and Squire (2004)[p10] put it: *"if a researcher is intimately involved in the conceptualization, design, development, implementation, and researching of a pedagogical approach, then ensuring that researchers can make credible and trustworthy assertions is a challenge"*. This conflicts with a typical view from the sciences expressed by Norris (1997), that researchers must possess skepticism, commitment and detachment. This obviously becomes more difficult when the researcher must also be the advocate for the approach taken and has invested significant energies into producing the design interventions. Anderson and Shattuck (2012) acknowledge this issue too, and believes this creates a significant challenge for researchers employing DBR, stating: *"a certain wisdom is needed to walk this narrow line between objectivity and bias"*. However, Anderson and Shattuck also acknowledges that in qualitative research traditions, instead of trying to eliminate bias and maintain objectivity, it may be useful to treat the deep understanding of the topic that researchers often possess as an important resource. And this could be particularly important in design work, where the design activity can draw upon and benefit from the the researchers' intuitive and tacit knowledge accrued over the years they have been engaged in the topic (Obrenović, 2011). Others defended DBR by noting the opportunity to choose methods which can mitigate issues of objectivity and reliability, such as thick descriptive datasets, systematic analysis and data triangulation (Collective, 2003), and in terms of generalisability, making the reasoning behind claims explicit, public, and open to critical reflection and discussion (Obrenović, 2011).

Most researchers using DBR appear to subscribe to the idea that the design work requires multiple iterative cycles. This poses a challenge in that such work may require longitudonal studies which will necessitate a high level of commitment from all stakeholders (Collective, 2003). Such relationships may be challenging for researchers to establish and maintain, especially if they have limited time to conduct their research, as would occur during the course of a PhD Anderson and Shattuck (2012). The solution is for senior researchers and academic departments to cultivate relationships over long periods and create opportunities for new researchers to step in and effectively hit the ground running. This issue impacted my own research when the teacher I had been working with moved to a new role and I was unable to continue working with her students. Ultimately, I opted to deploy the designed artefact in a range of learning contexts, reasoning that this would broaden the picture I would collect about how learners were impacted by the designed artefact, and would therefore lead to findings with better generalisability.

A further criticism of DBR concerns the research findings. Collective (2003) acknowledges that: *"causality can be difficult to decipher and disambiguate"* because in messy, complex, naturalistic learning settings, researchers and teachers have to make many decisions over the course of the design's deployment in order to optimise learning, and it can be very hard to understand how these decisions influenced the outcomes discovered. Anderson and Shattuck (2012) acknowledges that most DBR studies do not demonstrate 'what works', but instead focus on the production of thick descriptions of the context, the challenges encountered, the development process, and the design principles that emerged.

In the opinion of this researcher, non of the issues described above represent insurmountable problems, and many reflect underlying epistemological differences between differing research factions. As DBR is a broad church and not particularly prescriptive of tools and method, it puts the onus on the researcher to carefully consider how it is applied, and what methods, tools and approach they accommodate within their implementation. Within the research presented in this thesis, qualitative methods are mainly used for data collection purposes within the methodology, however this is not exclusive as quantitative methods are part of the mixed methods approach used within Chapter 5. Qualitative, human-centred methods (interviews and surveys) were the main tools used to support the evaluation of the designed artefacts, with subjective interpretation of the data following their application. Qualitative, human-centred methods were also used in combination with theories to inform the design of subsequent interface iterations. The theories which influenced the design include cognitive load theory (see Chapter 2.2.2), and conceptual work around tacit knowledge (see Chapter 2.3.1) and multiple information representations (see Chapter 2.2.4). The design work also contributed to the development of theory around the acquisition of music mixing skills (see Chapter 2.4), and the integration of flow theory and cognitive load theory (see Chapter 8.3.3), as well as contributing design principles.

Whilst the learning sciences represent a distinct field from HCI, DBR has significant crossover with HCI methods. This crossover gave me confidence that the methods I adopted would be suitable for application within education settings. For example, Barab and Squire (2004) report that design-based research takes an interventionist approach and is involved in creating a tangible design that works in complex social settings – this parallels HCI's field deployments. There is also a "*joint commitment to research and service*", which entails: "*meeting the immediate needs of the participants*" (Barab and Squire, 2004), thus design-based research is also overtly agenda-driven (Brown, 1992). This aligns well with the agenda-driven HCI research of Open Lab. Furthermore, design-based research advocates for iterative approaches to design where "*development and research take place through continuous cycles of design, enactment, analysis*

	Research	Design
Purpose	general knowledge	specific solution
Result	abstract	situated
Orientation	long-term	short-term
Outcome	theory	realisation

Table 3.1 Differences between research and design, from Stappers and Giaccardi (2017)

and redesign" (Fallman, 2003), and also calls for the triangulation of multiple sources of data (Fallman, 2003).

Barab and Squire (2004) describes the learning sciences as interdisciplinary, and it appears clear that it has been influenced by HCI and related, design-oriented fields. The fact that major components of the methodology applied within this thesis are not just born of HCI, but are shared with learning sciences, should provide some assurance of their suitability for this thesis' topic.

Comparing design-based research with Research through Design

Research through Design (RtD) is a research approach popular amongst the HCI community, that marries the methods, practices and processes of design practice with academic research's drive for knowledge production (Zimmerman and Forlizzi, 2014). Artifacts are created as proposed problem solutions, and are iteratively and systematically refined and reflected upon (Schön, 2017). According to Zimmerman and Forlizzi (2014), the output of a RtD process should include the designed artifacts as well as knowledge taking a form such as: novel perspectives that advance understandings of a problematic situation; insights and implications with respect to how specific theory can best be operationalized in a thing; new design methods that advance the ability of designers to handle new types of challenge; artifacts that both sensitize the community and broaden the space for design action.

RtD emerged in response to discontinuities noted by the HCI community between academic research and design practice. For example, Blackwell (2004) noted that research communities favour the novelty of a solution over its quality, whilst the reverse is true within design practice. Similarly, Stolterman (2008) claimed that academia's interest in *the existing and the universal* is at odds with design practices' interest in *the non-existing and in the creation of an ultimate particular.* Stappers and Giaccardi (2017) summarised key differences identified by the HCI community as per table 3.1.

There is significant overlap between RtD and DBR: Both methodologies engage with complex, real-world problems, and both methodologies centre around design practice. Distinctions between the methodologies are subtle: Whilst RtD employs design practice to foster positive real-world change, it perhaps does not as explicitly claim to represent a joint commitment to research and service as DBR does. DBR focusses on designs informed by learning theory, whilst RtD appears less conscriptive regarding the use of theory as an input to the design process. Finally, DBR is committed to treating participants more as collaborators than as research subjects, whilst I do not believe such a consensus exists within the RtD community at this point in time. Perhaps the most important distinction between these methodologies, from my perspective, relates to the communities where the methodologies are employed, with RtD emerging from the HCI community and DBR emerging from the learning sciences community.

Whilst RtD could be considered a suitable method of enquiry for this research project, and despite considerable overlap with DBR, I will follow the guiding principles of DBR over RtD, due to its tighter focus on learning and education, and its popularity amongst the learning sciences research community. I believe this latter point makes it more likely that my work will be accepted by learning science researchers and therefore more likely to influence future research within their sphere. I hope that this choice of methodology would also be accepted by the HCI community given HCI's interdisciplinary composition and the wide range of methodologies that are accepted within the field.

Comparing design-based research with action research

DBR can be considered a hybrid methodology (Wang and Hannafin, 2005) that adds a design component to existing research methodologies (Frick and Reigeluth, 1999). One such methodology that shares many features is Action Research (AR) (Avison et al., 1999; Stringer, 2008). AR similarly aims to produce improvements on the ground, tends towards qualitative data collection methods, and at a higher level, AR and DBR have been described as having a very similar epistemological foundation based upon pragmatism (Cole et al., 2005). However, AR and DBR tend to view participants differently, with AR more aligned with the idea of teachers becoming researchers and using AR to solve their own workplace problems, i.e. the researchers *are* the participants (Kuhne and Quigley, 1997), whereas DBR distinguishes between researchers and participants and typically restricts collaboration between the two to the evaluation and refinement of the researchers' designed artefacts. DBR, therefore, tends to try and couple the design and research expertise of the researcher with the contextual expertise of the teachers/participants, whereas AR puts more responsibility for conducting the research (and possibly creating design interventions if that is to form a part of the AR) upon the participating teachers (Anderson and Shattuck, 2012).

Whilst I liked AR's commitment to solving real-world problems, I was not deeply embedded in the research context, nor working as a teacher. Therefore, I thought the best course of action would be to work collaboratively with teachers, and I would rely upon them to surface contextual issues, and I also considered their longstanding relationship with the students to be a valuable source of information. Furthermore, whilst both DBR and AR are committed to solving local problems, only DBR is also committed to advancing theory, even if this takes the form of context dependent design principles (Barab and Squire, 2004). For these reasons, I felt my research goals stood a better chance of being achieved if I followed DBR, and therefore I rejected AR as the guiding methodology for this project.

3.2.3. Importance of Developing Design Rationale

MacLean et al. (1989) asserted that: "*A design rationale is not a record of the design process – it is a co-product of design along with the artefact and itself has to be designed*". The work

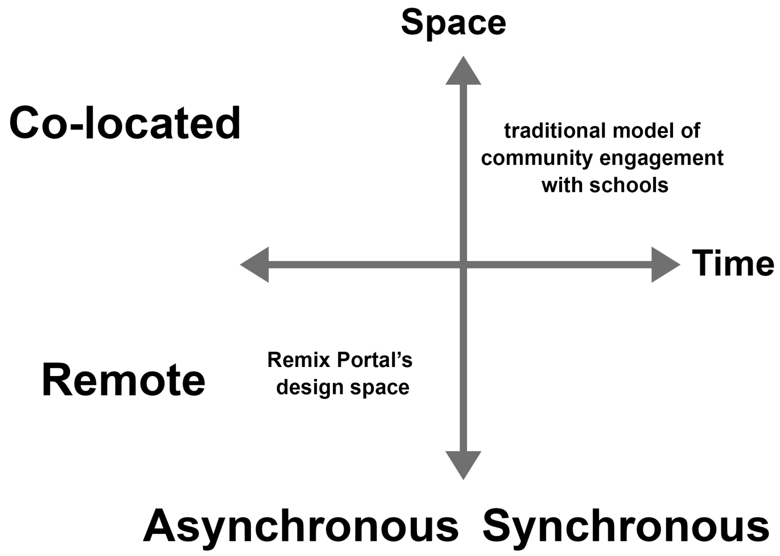

Figure 3.2 The design space differs from traditional community/education interactions due to its remote and asynchronous nature

presented in this thesis proceeds in this spirit, and therefore, where possible, a design rationale is included for every significant Remix Portal iteration. Each design rationale includes descriptions of the potential design options available, explanations of the criteria by which these options were evaluated, and justifications for the options which were ultimately selected. As MacLean et al. (1989) went on to argue, such design rationale should not only aid the production of effective artefacts, but should allow the designer to effectively argue why the chosen design is appropriate. Therefore, embedding the production of design rationale within the methodology should add to the rigour of the design research and should therefore strengthen the contribution that this work offers.

3.2.4. The Design Space

The work presented in this thesis represents a reconfiguration of way musicians are included within formal education. The shift can be seen on the time/space matrix presented in Figure 3.2. Traditionally, such interactions are co-located and synchronous. For example, professional musicians may work part-time for the school providing instrumental lessons, or the school might invite a musician to give a demonstration to the students. Possibly, these students will be given some instruments to play along with. But consider that many active musicians within our communities have full-time jobs. This makes it hard for schools to leverage their expertise using this traditional model. Furthermore, many schools are hesitant to allow visitors in to the school environment to interact with students without rigorous prior vetting. We therefore considered whether remote and asynchronous interactions would make a suitable alternative. This could enable musicians to work educational engagement around their schedule whilst lowering the 'risk' from the schools perspective.

3.3. Data Collection Methods

The following subsections describe and justify the data collection methods used during the research presented in this thesis.

3.3.1. Individual Interviews

Individual (one-on-one) interviews are the most common qualitative data collection methods (Wilson et al., 2016). Interviews can be categorised based on the level of structure the interviewer applies. At one end of the spectrum lives structured interviews where all interviewees are asked the same set of questions. Semi-structured interviews are more flexible, with the the interviewer free to change the order of the questions depending upon the interviewee's responses, and additional questions can be asked on the fly to prompt and probe in more depth as the interviewer deems necessary. At the other end of the spectrum, unstructured interviews (also known as open or non-directive interviews) forgo a detailed interview guide, leaving the interviewer free to follow what the interviewee says, and to aim for as detailed a solicitation of information as possible (Brinkmann and Kvale, 2015). Regardless of the approach to structuring, King et al. (2018) recommends qualitative researchers use open-ended, non-leading questions, focusing on personal experience, and aim to build rapport with the interviewee.

The interview technique I employed leaned more towards the unstructured end of the spectrum, as the individual interviews were often carried out immediately after participants had used the designed artefact, so I would generally bring a few questions into the session, or topics I wanted to cover, I would add others based on what I had observed during participant interactions with the designed artefact, but would mainly follow what the interviewee said, trusting that they would be trying to give me information that they believed would be useful to me. I therefore tended to probe and gently guide as I deemed appropriate. As the research went on, I reflected upon my interview approach and came to believe that fruitful results were coming from a flexible, low-structured interview style, and there were very few occasions where I would realise after the fact that I had forgotten to probe an area or ask an important question. I was therefore, confident to continue with this interview approach.

Individual interviews were conducted with college students during the 4th session of the field deployment described in Chapter 5.6, as well as with secondary school students during the 4th session of the field deployment described in Chapter 7.5.1. I deemed it appropriate to use individual interviews here because, in both cases, I judged that by the fourth deployment session I had established sufficient rapour with these participants that they would be able to speak to me relatively uninhibited. Furthermore, these sessions did not have as stringent time constraints as some of the other deployment sessions described in this thesis, making one-on-one interviews feasible.

Individual interviews were conducted with all the teachers and college lecturers who allowed me to work with their students during the field deployments, as well as with the solo musician who provided feedback during the study described in Chapter 4.3.

3.3.2. Paired Interview

Paired interviews, also known as joint interviews (Wilson et al., 2016), is a method for collecting qualitative data which involves interviewing two people simultaneously to understand how the pair perceives the same event or phenomenon (Arksey, 1996). They are often thought of as a method which lies between a one-on-one interview and a focus group (Morris, 2001).

Paired interviews have been recommended over one-on-one interviews for interviewing children or teenagers with pre-existing relationships, as having the support of their friend can encourage participants to be more forthcoming, open and articulate (Morris, 2001), enabling them to *fill in the gaps* for one another (Houssart and Evens, 2011). I therefore considered this an excellent method for data collection within my research as I would be dealing with child and teenage participants who may benefit from the support of a classmate during the interview process. The pairing might also serve to lessen the power imbalance that can be problematic in individual interviews (King et al., 2018). Paired interviews, in comparison with one-on-one interviews, would also better accommodate the contextual constraints I faced during some of the field deployments. These constraints consisted of having very little time to conduct data collection due to the limited number of sessions I had with the participants, and the teachers' desire to maximise the time their students spent engaged in music making activities. A further advantage of paired interviews is that, in comparison to focus groups or group interviews, it helps people be heard who might remain silent within a larger group format (Wilson et al., 2016).

Houssart and Evens (2011) described paired interviews as tending to unfold as the participants interact with each other. I therefore used a semi-structured format and gave preference to following the directions the participants took rather than sticking to an interview schedule. Wilson et al. (2016) noted the importance of aiming for equity between the two interviewees, and so if I thought one of the pair was being somewhat reticent I would prompt them to contribute by asking them if they agreed or disagreed with what their partner was saying. Of course, this had to be done sensitively and in respect of the fact that the participants are not obliged to contribute.

Paired interviews were used with primary school children during the 5th session of the field deployment described in Chapter 4.2.2, as well as during the session with college students described in Chapter 6.2.2.

3.3.3. Group interviews

Fontana and Frey (1994) described a group interview as: "*the systematic questioning of several individuals simultaneously in formal or informal settings*". There is significant overlap between group interviews and focus groups, with the latter being described as: "*a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research*" (Powell et al., 1996, p499). Morgan (1996, p12) points out a key distinction, in that group interviews are conducted between the interviewer and the participants, whilst focus groups aim to generate more interactions within the group based on topics suggested by the researcher. The method I employed ultimately better resembled group interviews because although I attempted to initiate discussion between the group members where possible, I found I had to steer the conversation by probing and prompting.

Group interviews can be used informally, taking place in a field setting where a researcher stimulates and guides a group discussion with a topical question, and they are well suited to the collection of subjective, qualitative data (Frey and Fontana, 1991). I used group interviews in this manner, asking questions which aimed to probe the participants experiences of using the designed artefact. I would typically have a few set questions I wanted to ask, I would formulate a few more based on the behaviour I had observed during the preceding artefact engagement, and others would be generated on the fly as the interview unfolded.

I used group interviews because of their noted efficiency (Frey and Fontana, 1991), which was important as I had to accommodate time constraints imposed by the teachers and lecturers who were keen to maximise the time their students spent engaged in music making activities. These constraints did not allow for as many one-to-one or paired interviews as I may have otherwise desired. I also used them to solicit a range of opinions between the group members. However, Frey and Fontana (1991) warns that group dynamics must be carefully managed in order for the group interviews to prove fruitful. To achieve this, I drew upon my teaching experience to ensure equity amongst participants. For example, when working with the school-aged participants I would ask for a show of hands in response to a question, and then I would choose people to respond, to ensure that everyone got a chance to contribute. I would also ask question such as: "*did anyone have a different experience?*", in an attempt to ensure the data I was collecting reflected the experiences of all group members. I would also try and keep the groups as small as was practical which on occasions meant splitting a class in half and conducting two group interviews. This was only possible when time allowed.

Group interviews were used during the third session of the field deployment reported in Chapter 4.2.2, as well as the first and third sessions of the field deployment reported in Chapter 5.6, and the first and second sessions of the field deployment reported in Chapter 7.5.1.

3.3.4. Survey

Surveys were used to collect both qualitative and quantitative data during the course of this thesis. Their use for qualitative data collection was due to their efficiency. Specifically, participants would be able to complete the surveys themselves, leaving me free to teach the group or attend to problems the participants might be having. This contrasts with the interview data collection methods which would place a significant burden on my time. Furthermore, I reasoned that the surveys might overcome some of the articulation issues young participants can face in interview situations (Morris, 2001) as participants could take their time when formulating a response, which might lead to something more considered.

Surveys were also used to collect quantitative data, in the form of responses on likert scales. These would typically take the form of 5-point scales from *strongly disagree* to *strongly agree* – these surveys are available in appendix A and appendix B. This data contributed to the evaluation of the designed artefact and served as a means of data triangulation (Carter et al., 2014) and to provide a backdrop against which the qualitative findings could be understood.

Surveys were used in the third and fourth sessions of the field deployment described in Chapter 5.6, as well as in the first section of the field deployment described in Chapter 7.5.1.

3.3.5. Novel data collection methods

A criticism of HCI research relates to a perceived gap between empirical findings and actionable design ideas (Crabtree and Rodden, 2002; Hughes et al., 1992). I encountered such a problem during the course of this thesis, in that I had empirical findings that convinced me to explore a multi-layered interface, yet I had insufficient data to meaningfully inform the design of this interface. I therefore came up with a set of novel data collection methods to generate implications for design (Sas et al., 2014). These methods engaged users in tasks and resulted in the collection of data that targeted specific aspects of the interface design. The resulting interface was deployed in Chapter 7. The method described in Chapter 7.3.1 involved a game where participants would use a modified version of Remix Portal that allowed them to switch between a secret mix and a user-controllable mix. Their challenge was to alter the interface controls to modify the sound of the user-controllable mix to match the secret mix as closely as possible. This produced data on accuracy per interface control type, from which we could infer which interface controls were harder to use, and therefore which may be better left to interface layers participants would likely encounter later in their user journey.

The method described in Chapter 7.3.2 involved a paired, paper-based exercise where participants were asked to numerically rate each control in terms of how useful they found it. The rationale was that controls participants deemed more useful would make better candidates for inclusion on lower interface layers (i.e. participants should encounter highly useful controls before they encounter less useful controls).

The method described in Chapter 7.3.3 involved a group, paper-based rank ordering exercise where the group members were asked to work together to order the interface controls based on how useful they found them. Whilst this method is very similar to the previously described method, it was interesting to see which the participants would prefer, and should the numerical ratings fail to adequately separate the controls, the rank ordering should be able to provide a better differentiation.

3.4. Data Analysis Methods

Whilst mixed methods were employed within some of the studies presented in this thesis, the research leans heavily towards the collection of qualitative data as it was considered that the qualitative data may yield insights which could improve the designed artefact during the next design iteration. The qualitative data consisted of audio recordings of the interviews and written responses to survey questions. I manually transcribed this data in order to gain a deep appreciation of the content. Following this, I engaged in thematic analysis as described below, or used Activity Theory to structure the analysis.

3.4.1. Thematic analysis

Thematic analysis (Braun and Clarke, 2006) is a method developed to help researchers identify salient patterns within a data set, then name and report these patterns. It is well suited to analysing data from a range of predominantly, but not exclusively, qualitative sources (Pidgeon and Henwood, 2004), and has proven particularly adept in the analysis of data self-reported by participants and conveying their thoughts and feelings, given its ability to identify and describe both explicit and implicit ideas within the data (Guest et al., 2012). It was therefore considered a good fit for the data set that resulted from each field deployment.

Braun and Clarke (2006) describe a six-phase thematic analysis process, and the analysis that followed each of this thesis' field deployments followed this same process. Firstly, the researcher must familiarise themselves with the data. To this end, I listened closely to the audio recordings of the interviews and opted to manually transcribe them in order to spend time getting *into* the data. I also spent time studying the written survey responses.

The second phase specifies the production of initial codes. I worked towards this by highlighting passages within the data corpus that in light of my research questions, I deemed as salient. I wrote a brief description for each of these passages to serve as the initial code.

The work then moved towards searching for themes (phase 3). For the analysis I conducted early in the thesis, I would transfer the initial codes to post-it notes which I would then move around on a large table trying different groupings, however, later in the course of my work I grew to prefer performing this task within a software environment, moving text within a word document. This made it easier to keep the original text extracts close to the codes which I found advantageous. I would always try out a range of groupings before settling upon a set I felt represented the meaning within the data optimally, and where each theme was clear and distinct, as Braun and Clarke stipulate that: *"Data within themes should cohere together meaningfully, while there should be clear and identifiable distinctions between themes."*.

Once I had established a set of themes, I would then take a break from the analysis in order to return with fresh eyes so that I could meaningfully review the themes (phase 4). In several cases, this review process led to the merging of overlapping themes in order to create sufficient distinction, or the reorganisation of some themes as sub-themes of others. I was at times aided in this review process by my supervisor or fellow research students.

The fifth phase of the analysis involved attempting to find fitting, descriptive names for each theme, and to define each theme, capturing what the theme is about and why it is meaningful.

The final phase of the thematic analysis involved writing about the themes, and this served as a good opportunity to share my work and to receive feedback on it, which led on occasions to reflection and remediation.

3.4.2. Activity Theory

Activity Theory (Bødker, 1991; Kaptelinin and Nardi, 2006; Nardi, 1996) is an analytic framework that served a formative role in HCI's development, as it helped researchers move beyond the paradigm of designing technology to support predefined, workplace tasks, to an era where researchers would not assume knowledge of a person's motivation or desires and would instead work to try and understand and then support these (Moran, 2003). Activity Theory's origins lie with Soviet psychologists operating in the 1920 and 1930's, who were trying to find a way to integrate the influence of community into their psychological work which had previously been limited to dealing with the individual human mind. The resulting *socio-cultural perspective* viewed the individual mind as being produced through interactions with society and culture, and therefore to understand the mind one must understand the context in which it exists (Kaptelinin and Nardi, 2006).

Central to Activity Theory is the idea that activities involve *subjects* which are usually but not exclusively people, and they work on *objects* which are things in the world that they are motivated to transform or attain. Objects can be physical things (like a bicycle) or less tangible things like knowledge or designs. Tools serve to help the subjects transform the objects of their activity. From an HCI perspective, this means that the technology being developed should not be viewed as the central element, but rather as a tool that mediates the relationship between people and the objects of their activities, i.e. people do not work *on* computers but *through* computers (Bødker, 1991). Therefore developing a deeper understanding of human behaviour becomes imperative.

Leontiev (2014) classified activities into three layers. The top layer consists of the activity itself, which is oriented around the object being transformed. Below this lies *actions*, which are units of activity each linked to a goal (or sub-goal), and collectively the actions reflect the set of steps necessary to successfully transform the object. Whilst actions are performed consciously by human subjects in activity systems, the layer below actions – *operations* – reflect unconscious behaviour that contributes towards the completion of the actions. Kaptelinin and Nardi (2006) give an example of an activity system with the object being an attempt to gain a driving license: This requires actions including arranging driving lessons, studying the highway code etc., and operations which develop over time such as the automatic use of the gears, accelerator and brake pedals to control the car. Nardi (1996) asserts that studying the actions layer via qualitative research methods can be productive as people tend to have little trouble describing their goals, and from this motives, object and operations can all be uncovered.

Engeström (2015) advanced activity theory by shifting the focus from individual activity to collective activity. His contribution resulted in the diagram depicted in Figure 3.3. Whilst earlier work had defined the subject / object relationship mediated by tools, Engeström added a third element in the form of community to the subject / object relationship. Furthermore, he added rules and division of labour to demonstrate the components that mediate between subject / community and object / community respectively. Activity Theory does not see these mediating components as merely shaping the activity, but they too are shaped as the activity proceeds.

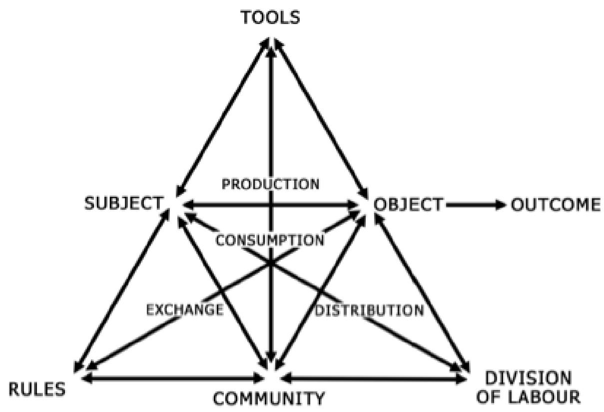

Figure 3.3 Structure of a Human Activity System

For example, we adapt tools based upon our experience using them, and we similarly exert our influence to shape the rules and division of labour that mediates the activities we participate in. Furthermore, they don't just shape our behaviour, but they ultimately come to shape our mental functioning as over time we come to *internalize* elements of our participation. Engeström viewed activity as a complex process which may be best represented through networks of ever changing activity systems, with their changing nature driven by a desire to resolve tensions or contradictions within the activity systems. Therefore, to understand an activity, one must understand how the elements of the activity system change over time, and how the activity system relates to other activity systems i.e. how it relates to work driven by other goals or desires.

3.5. Remix Portal iterations overview

Iterative design was a central component of the methodology used to conduct the research presented within this thesis, with field deployments producing data which when analysed, informed changes to the design of the artefact used in subsequent field deployments. This section aims to provide an overview of the artefact design iterations, and of the data that contributed to each iteration. Sign-posts are provided to guide the reader to the locations within this thesis that describe the emergence of the data that contributed to each design iteration, as well as to guide the reader to descriptions of each design's deployments.

The designed artefact is Remix Portal, an online music remixing and communication application. Whilst the design of the interface underwent significant modification over the course of this work, with 3 major interface iterations as depicted in Figure 3.1, certain aspects of its design remained consistent throughout, so this section shall commence by explaining components common to all designs.

3.5.1. Components common to all Remix Portal versions

Remix Portal runs in Google Chrome and Firefox web browsers, which creates the potential for participants to continue using the tool to develop their remixing abilities outside of deployment sessions. This was considered a significant advantage over traditional, installed applications where access outside of the classroom may have been far more challenging to provide. Remix

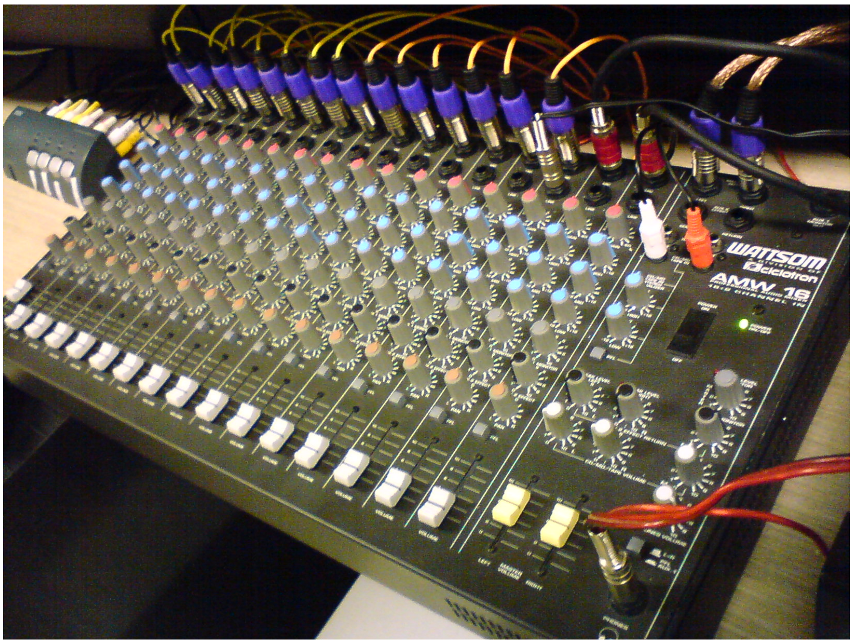

Figure 3.4 A traditional, physical music mixing desk

Portal's interface was built using standard web programming languages; HTML, CSS, javascript and jQuery. The audio processing was delivered via the web audio API which allows complex, low-level audio playback and processing code contained within modern web browsers to be controlled via javascript. At the back end a MySQL database stores the interface parameter settings associated with each saved music mix.

The interface design follows convention by emulating the layout of a traditional, physical audio mixing desk (see Figure 3.4). Whilst specifics vary, all interface iterations share the following core components:

- A series of vertical 'channel strips' containing knobs, buttons and a slider, with each channel strip enabling the user to shape the sonic properties of one audio element. See Figure 3.5-a
- Each channel strip contains a drop down box which enables the user to swap the audio element it processes. See Figure 3.5-b
- The top-right of the interface contains controls that process all of the audio. i.e. the processing is applied after the audio elements have been merged together. See Figures 3.5-o and p
- The lower-right contains playback controls including play, pause, and stop.
- A drop-down box enables the user to switch to a new mix. This will trigger all the knobs and sliders to change to the positions associated the new mix, and the processing applied to the audio will change correspondingly. See Figure 3.5-k

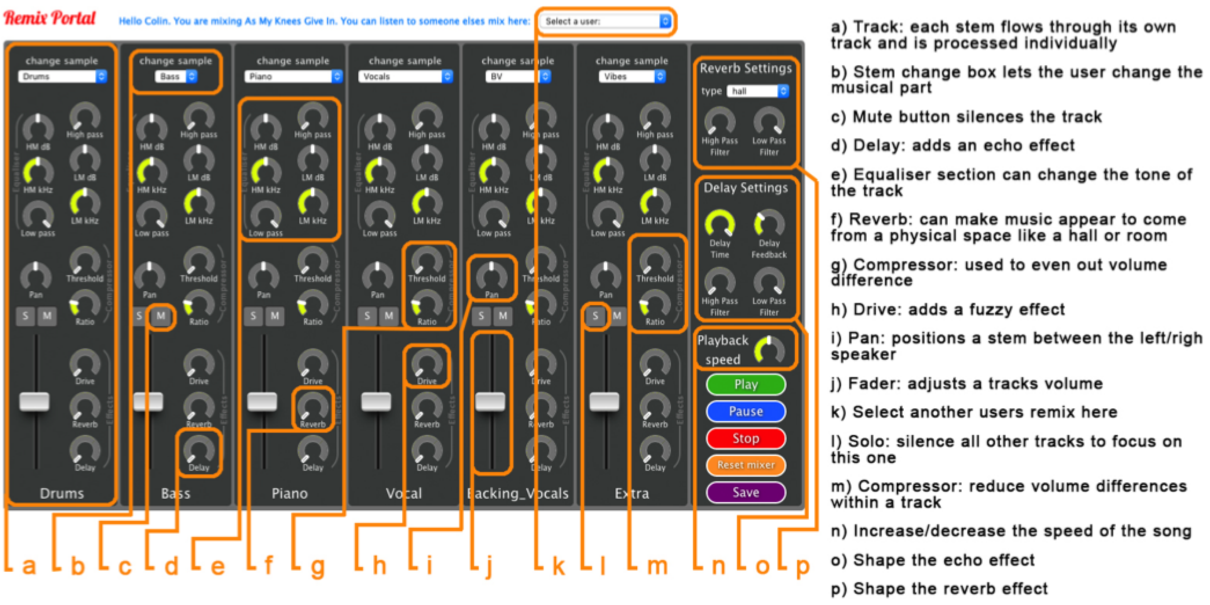

Figure 3.5 Overview of a Remix Portal interface

- The playback controls contain a *save* button. This records the positions of all the knobs, sliders and buttons and the associated processing of the audio as a new *remix* and adds a label to the remix selection drop-down box so users can recall this remix thereafter.

Audio stems

Audio stems are a set of audio files which together form a song or piece of music, and these were the musical components upon which Remix Portal was built. For example, stems for a typical pop song may comprise an audio file containing the drum part, an audio file containing the bass part, another for the lead vocals, one for the keyboards and so on. A key stipulation is that all stems should start from the same point in time, which makes it easy to synchronise audio files in music production applications (Nichols, 2017). The purpose of stems is to facilitate music remixing by giving remixers' easy access to the underlying musical components. For example, a remixer could remove one stem, and add sound effects to another. This creates powerful opportunities to reshape the music in ways which are often impossible to do when a remixer only has access to a conventional, stereo audio file because stereo effectively locks the musical elements together and any processing applied to one element will impact other musical elements which overlap in time and frequency. There are no rules as to what components should be separated into each stem, however, convention dictates that elements most likely to be modified or replacement should be given their own stem; for example, vocals and percussion (Hillman, 2019).

Stems are becoming a popular format for music remixers' as they are application agnostic and thus can be used in the vast majority of music software applications. They offer great potential for musical transformation and manipulation whilst simultaneously having a relatively small file size which supports network transfer (Bennett, 2016).

Stems differ from the audio files associated with a software recording session in two key ways. Firstly, audio files associated with music recording software (usually referred to as Digital

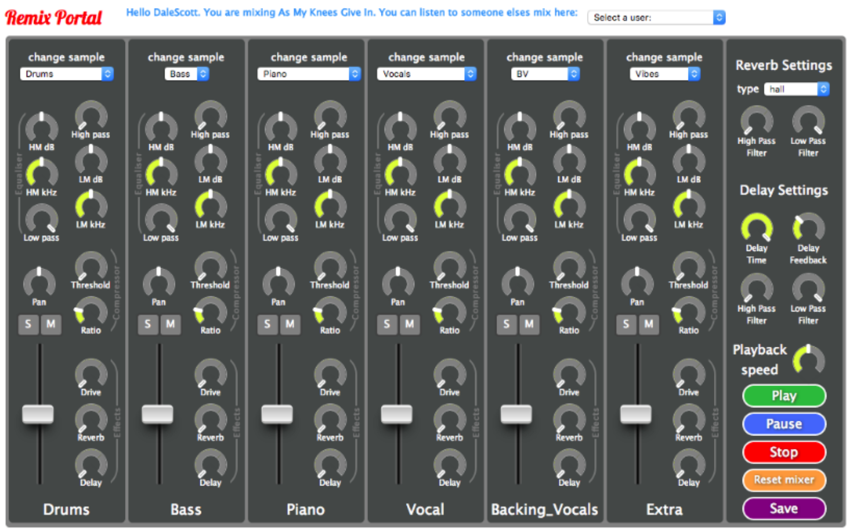

Figure 3.6 Remix Portal - interface 1

Audio Workstations or DAWs) will not necessarily be aligned in time, and thus require additional metadata to synchronise them. Secondly, these software sessions may well have tens, even hundreds, of audio files. Stems typically have a much lower number of audio components - usually between 4 and 20 and are thus much more manageable by non-expert users (Nichols, 2017).

The process of creating stems usually takes place in the original recording application. Audio files will be grouped together to reduce the total number of files that the stems will contain. For example, a drum kit may well have been recorded with eight or more microphones, producing eight or more audio files. The resultant audio files are likely to be grouped together, possibly with other percussion parts, to create a single stem. Secondly, each group will be processed to ensure the output stem file starts from the same point in time as the other stems. In practical terms, when the audio files for a group begin later than those in other groups, silence is inserted at the beginning of the stem to ensure it starts from the same position as the other stems (Nichols, 2017).

3.5.2. Version 1

The first iteration of the Remix Portal interface was used in the study presented in Chapter 4.2. The interface can be seen in Figure 3.6. A basic web page listing the three song choices was created, and clicking a song link opened up Remix Portal with the selected song loaded. To facilitate data collection, between selecting a song for remixing and the Remix Portal interface loading, a pop-up modal would appear which asked users to input their name. Remixes could then be saved against the entered name.

The design of this first iteration was informed by music mixing software convention and my expectation of the capabilities of the target user group based upon my years of experience teaching young people music production skills.

Figure 3.7 Remix Portal - interface 2

3.5.3. Version 2

The deployment reported in Chapter 4.2 provided evidence that led to the following changes to the Remix Portal interface. Firstly, text feedback facilities were integrated into Remix Portal. These could be accessed through a slide-out sidebar as depicted in Figure 3.7. The blue border to this side-bar is used to expand and collapse the feedback panel. Secondly, to further simplify the Remix Portal interface for lower ability users whilst retaining deep functionality for more capable users, *pro* buttons were added to key sections of each channel strip. Clicking a *pro* button would reveal, or hide if already visible, additional interface controls. Users would first encounter the basic interface (pared down from iteration 1) as Remix Portal loaded, and then could choose to expand the number of controls available to them via these pro buttons. A third change involved the addition of question mark buttons placed beside each section of the channel strip, which led to tutorials about the associated controls. These support materials helped provide opportunities for self-paced and out-of-class learning.

This second Remix Portal interface was used in the deployment at a primary school, as reported in Chapter 4.3.

3.5.4. Version 3

Data from the deployment reported in Chapter 4.3 led to a desire to explore a feedback method that was less oriented around verbal / textual information. This resulted in a *show-and-tell* feedback method which was integrated into this third Remix Portal interface iteration. The workings of this interface are detailed in Chapter 5, but a brief summary is also included here.

As can be seen in Figure 3.8, key interface changes which support the show-and-tell feedback method include a green *add suggestion* button placed near the top of the feedback panel. This button records any changes a feedback giver has made to interface control positions. The next thing to note is that some text feedback is accompanied by an *audition suggestion* button. When a user presses this button interface controls which were altered by the feedback giver move to these positions which yellow boxes used to indicate which controls have changed. The underlying audio processing will change accordingly to reflect these new control positions and the changes the feedback giver has made to the music. Pressing the *audition suggestion* button a second time will turn off the feedback auditioning and return the interface to its previous state.

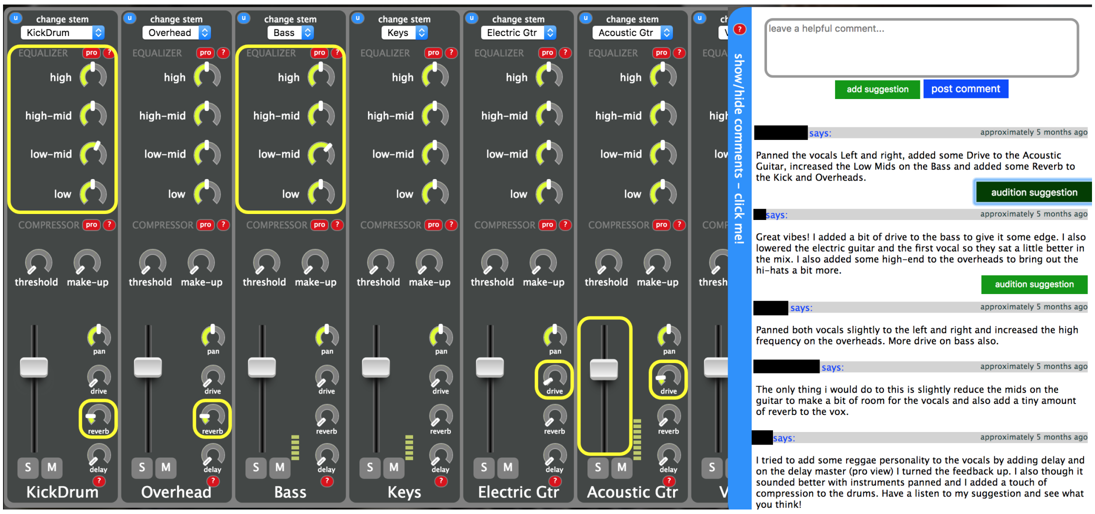

Figure 3.8 Remix Portal - interface 3

This interface was used during the field deployments reported in Chapter 5, and was also used to support the study presented in Chapter 6.

3.5.5. Version 4

The data from the study reported in Chapter 4 revealed the tension between providing an easy, accessible interface and one with deep functionality. A formative attempt was made to resolve this in interface version 2 via the *pro* buttons which added and removed additional controls. Interface version 4 takes this concept further via a multi-layered interface. As can be seen in Figure 3.9, to the left of the interface is a set of radio buttons which enable the user to switch between the five interface layers. Each successive layer adds controls and therefore increases in complexity whilst providing greater processing capabilities. This interface is explained in detail and explored in Chapter 7. This chapter also details the user research and novel data collection methods which were used to inform its design.

3.5.6. Origins of the Remix Portal interface

My chosen design for the initial Remix Portal interface was undoubtedly influenced by my experience using music production equipment (hardware and software) over the past two decades, in my capacity as a musician and music producer, and as music technology educator. This experience will have also influenced the solutions I chose for the problems identified over the iterative design process. I will therefore reflect briefly upon design features of the music production interfaces I have used in practice and whilst teaching, and relate them to the design of Remix Portal.

My music production journey began with a 4-track cassette tape recorder, as depicted in Figure 3.10. This recorder allows four separate sound sources to be recorded (two simultaneously) and then mixed together. The controls are very basic, with control over the input signals limited to volume, and control during mixing limited to volume and pan position (i.e. position of the sound between the left and right headphones or loudspeakers) for each track. I, like many other

Figure 3.9 Remix Portal - multi-layered interface

Figure 3.10 Tascam Porta 02

music producers, grew tired of these limitations and began using a small mixing desk between the instruments or microphones and the recorder, in order to gain more control over the sound and to expand the number of sources I could record. For example, I could record a drum kit with eight microphones, adjusting the tonality of each microphone feed and its left to right pan position at the mixing desk, and have the mixing desk blend these microphone feeds together before recording the two main outputs of the mixing desk to two of the inputs on the Tascam recorder.

As I gained experience and opportunity, the complexity of the equipment I used increased until I was able to operate complex studio and live sound production mixing desks and outboard equipment. An aspect that I found helpful when transitioning to new equipment was that general design principles were almost always followed by the various manufacturers. For example, the various sound sources were organised into *channel strips*, making it straightforward to understand which sliders and dials impacted each aspect of the music. There also appeared to be a fairly well established hierarchy of controls on the channel strips, with volume and pan being top priority, then EQ/tone controls, and then *send effects* like reverb or echo.

Moving on from the Tascam Porta 02 also involved beginning to use computer-based music recording and mixing software, known as digital audio workstations (DAWs). My experience with such software now amounts to around nine different DAWs, ranging from easy-to-use but slim-featured DAWs like Garage Band, to highly featured, and highly complex tools like Pro Tools. I found these interfaces relatively easy to get to grips with due to the design paradigms they borrowed from the hardware equipment I had started with, such as the channel strip layout.

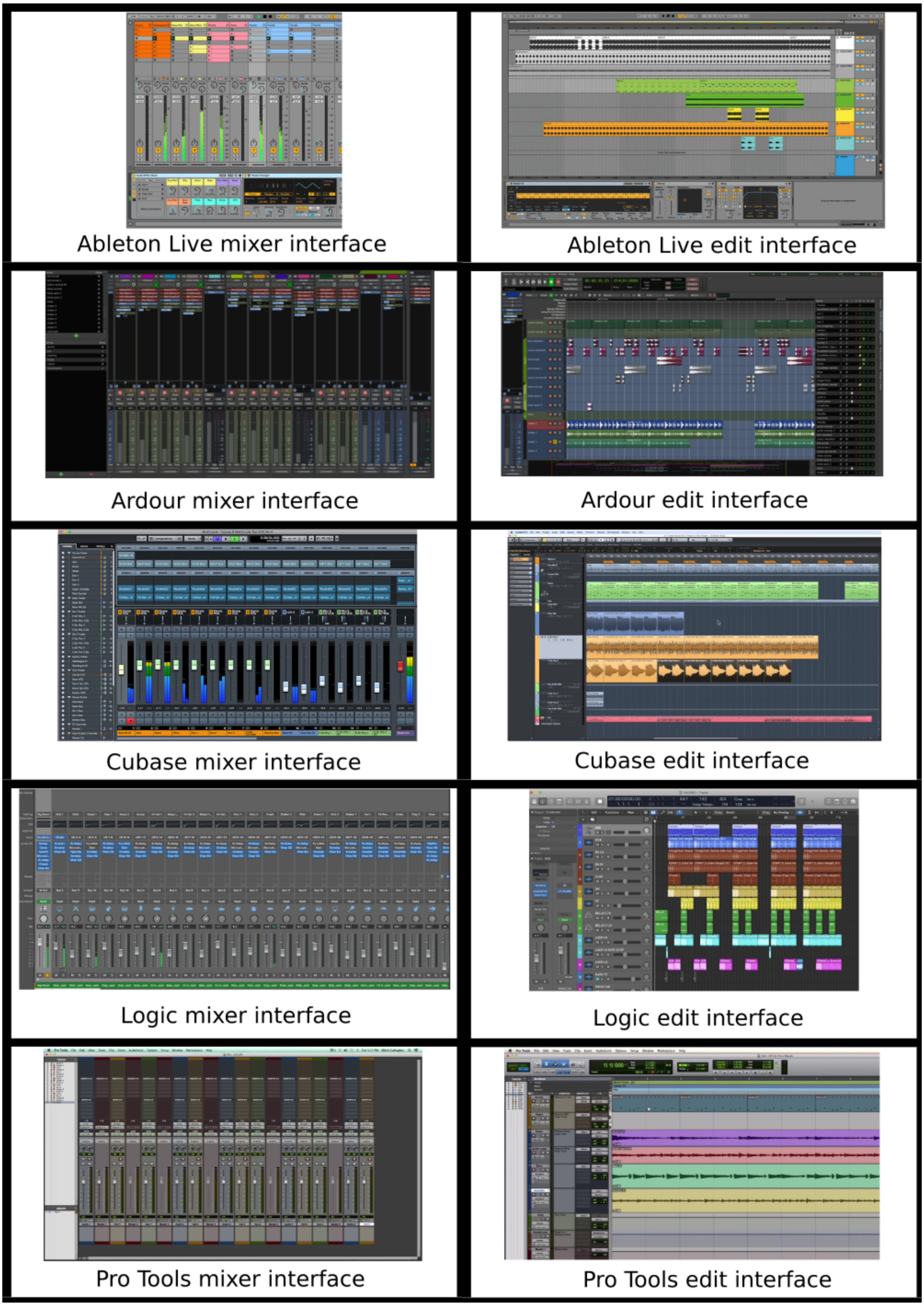

Figure 3.11 Popular DAW's mixer and edit interfaces

However, I acknowledge that people may find it more difficult to get to grips with some of these DAWs (e.g. Pro Tools) if they do not have a background in using the hardware equipment that the software interfaces are modelled upon. I certainly found this during my teaching practice, and I would generally tend to encourage people to begin with the easier to use DAWs (e.g. Garage Band) and only progress to a more complex feature-filled DAW once they were very comfortable with the basic DAW. A commonality between many DAWs is to have two main windows: a mix window and an edit window, with the mix window featuring the channel strip design pattern. Figure 3.11 shows these two interfaces on five of the most popular DAW software applications.

Remix Portal's interface is rooted in the mix interface design paradigm, featuring a channel strip for each audio component, containing a volume fader, a pan control, basic tone controls and some basic sound processing effects. It could be argued that by sticking closely to these design conventions, Remix Portal's interface is too conservative which limits the novelty it can offer. However, my motivation for pursuing this design was influenced by my experience as a musician practitioner and as an educator, and so I wanted to create a platform that could serve as a stepping stone to help users graduate to using conventional, feature-filled DAWs. I therefore felt the best way to do this was to accommodate established design conventions within Remix Portal's interface to minimise the differences between Remix Portal and the DAWs users may progress to. I reasoned that a more novel interface which did not represent these established design conventions would create an obstacle to progression once learners were ready to move on from Remix Portal to a conventional DAW.

It should be noted that Remix Portal's initial interface looks significantly less complex than the interfaces presented in Figure 3.11. I was able to draw upon my significant experience to make an informed judgement about which typical DAW features could be sacrificed in order to prioritise walk-up usability. I decided that the *edit interface* could be left out of Remix Portal, as my experience told me that novices are prone to getting into difficulty on this interface by inadvertently changing the start position of chunks of audio such that the pieces no longer sound synchronised, leaving the users feeling frustrated. Instead, I decided to base Remix Portal upon the mix interface where it is more difficult for novices to make unsatisfactory changes to the music, and thus this interface tends to cause less frustration.

3.6. Participant recruitment

3.6.1. Sourcing the musicians

The details of the participating musicians are contained within the chapters which relate to their participation. However, an overview of musicians participation is contained here to convey the broad picture of participation. A challenge for this project was acquiring original music in a form suitable for remixing, from musicians who would be prepared to maintain engagement with the project in order to provide participants with feedback upon their remixes, and to be interviewed by the researcher about their experience participating. Prior to the fist deployment at a secondary school, a contact within the North East of England music scene put me in touch with three local music groups who all agreed to participate in the project, however none were able to supply their music as stems, although they did have access to a digital recording software file for at least one of their songs. I opted to meet with the musicians, obtained the recording session file, and was then able to open their recording session and generate a suitable set of the stems. These musicians were not offered any payment for participating, but ultimately funds became available to pay some of the musicians for their involvement with the post-participation interviews. They were informed of this once these interview were arranged, and therefore the payments will not have impacted their motivation to participate in the project.

The second iteration of Remix Portal featured a stem uploader which created the potential for musicians to place their stems directly into Remix Portal. Around this time a mutual friend put me in contact with the owner of a local music magazine, who helpfully provided contact details for a large number of musicians operating in the North East of England. An email was sent out to these musicians explaining the research project and asking them if they would be willing to contribute by providing: a) a set of stems for one of their songs that young people would remix, b) written feedback upon the student's remixes music through the Remix Portal platform, c) a post-participation interview with the researcher. This resulted in three groups agreeing to participate. One of these groups contributed music via the stem uploader. One sent stems to the researcher via an online file sharing service. The final group were able to provide recording session files from which we were able to generate stems. One of these groups ceased communication shortly before the project deployment began, thus two groups of musicians participated in the second deployment - which was at Marlborough Primary.

Local musicians did not participate in the latter stages of the project where the focus shifted to interface design issues and leveraged deployment opportunities that did not necessitate input from local musicians.

Sourcing additional music

Prior to the initial deployment it was deemed necessary to have additional music with which our participants could practice remixing prior to their engagement with the local music. This was sourced from ccMixter.org, where community members upload audio files for others to remix. Careful searching within this site led me to good quality sets of stems featuring an appropriate creative commons license, which would enable me to reuse these stems within the Remix Portal site.

Many of the songs on Remix Portal feature alternative musical components that users can switch to using a drop-down menu at the top of each channel. For example, a drop-down menu may enable a user to replace an original drum stem with another stem featuring an electronic drum machine part. These alternative stems were created by myself and required a significant amount of effort to ensure harmonic and rhythmic synchronisation with the music as a whole.

3.6.2. Sourcing music remixers / student participants

Student participants were all sourced through their teachers or lecturers. The teachers and lecturers were sources through existing contacts within my research group, through contacts within the north east music scene, or I had a prior relationship with them from my time as a college lecturer. All student participants were given the option to opt out of data collection. Specifics for each group of student participants are described in the relevant chapters.

3.7. Ethical Considerations

Resnik (2010) acknowledges: "*Researchers must adhere to ethical norms to ensure trust, accountability, mutual respect, and fairness*". In this spirit, each faculty within Newcastle University has a process for assessing the ethical implications of prospective research projects. The work presented in this thesis was approved by the SAGE ethics committee after the submission of a full ethical assessment form. Furthermore, I liaised with each key contact (teacher or lecturer) at the educational institutions and discussed my research plan to ensure the research would be considered ethically acceptable from their perspective. I also provided information sheets to participants and within the school contexts their parents/guardians, prior to the studies commencing. These sheets explained the purpose of the research, the activities that it would involve, the data that would be collected, and it provided an easy mechanism for people to opt out. Additionally, all participants were informed in-person at the beginning of each research study, that they could withdraw from the research at any stage and request that their data be deleted. Where possible, participants were debriefed at the end of each research study and given the opportunity to ask questions and generally feed back their experience. This provided a mechanism via which I could identify and then address issues, to reduce the chance of participants experiencing similar issues in the future. However, ultimately no issues were uncovered during these debriefing sessions.

3.8. Limitations

The educational settings this research was conducted within imposed a number of constraints upon the research. Most significantly, they meant that longitudinal studies could not be conducted due to the teacher I was working with changing jobs mid-way through the project which resulted in me losing access to her students, and there being insufficient time for me to establish a longitudinal study at a similar venue. It was therefore not possible to collect evidence of behaviour changing over time. Instead, I focused on collecting evidence of changes in attitude, as is common in much education-oriented design-based research (Anderson and Shattuck, 2012), and which we take as an indicator of potential future behaviour change. Similarly, we were unable to measure learning gains as the school were not keen for us to devote time to pre- and/or post-tests. However, it should be noted that reports of participants using more interface controls and, particularly during the study reported in Chapter 7, participants choosing more complex interface layouts, reflects learning gains in a similar fashion to the *levelling up* method proposed by (VanLehn et al., 2011). Furthermore, the designed interventions were strongly informed by theory which suggests how behaviour might be influenced, and so this adds another strand of evidence to claims that the designed interventions were successful. For example, the literature tells us that effective feedback will aid learning (Hattie and Timperley, 2007), therefore, when systems are judged to offer improved feedback it should follow that they will help improve learning. Whilst it would have been preferable to observe behaviour change and to measure learning gains over a substantial period of time, I consider the methods we used sufficient to convincingly answer our research questions.

3.9. Work conducted prior to the PhD

I actually began my exploration of this topic whilst studying towards an Masters degree. During this time, I created the first iteration of the Remix Portal remixing software and I ran the deployment presented in Chapter 4.2. I present this work here because data analysis occurred during my PhD studies, and the findings from this analysis are an important contribution and inform the work that follows in this thesis. This work was ultimately published in the paper: *Remix portal: connecting classrooms with local music communities*, in the proceedings of the 8th International Conference on Communities and Technologies, 2017. To reiterate for clarity, the first of the five deployments presented in this thesis occurred prior to officially beginning the PhD; all data analysis occurred during the PhD; the initial Remix Portal interface was created prior to the PhD but it went through three significant design iterations over the course of the PhD, as reported in Chapter 3.5.

3.10. Conclusions

To summarise, this thesis contains Human-Computer Interaction research, where a designed artefact was deployed in the wild, data was collected during these field deployments and used to evaluate and remediate the artefact's design prior to the next field deployment cycle. These field deployments and the evidence they produced was considered sufficient to convincingly address this thesis' aim and to answer its research questions.

Chapter 4. Designing to Support the Inclusion of Community Musicians within Formal Music Education

4.1. Introduction

The review of the literature in Chapter 2 covered, amongst other things, ideas around how to make education more meaningful and engaging. I considered work that argues for learners to receive an authentic and connected learning experience (Ito et al., 2013; Shaffer and Resnick, 1999). This can be achieved by opening up schools to create learning opportunities for students through interactions with people beyond the immediate school community, for example experts within the wider local community. The learning topics must also be adapted to better align with the interests of the learners. Furthermore, the output of students' school work should not be an end in itself but should offer the opportunity to make a meaningful contribution to this extended community and receive recognition in return where contributions are valued. Work around local learning ecologies describe how schools can reach out and build the necessary links through which these positive interactions can occur (Hodgson and Spours, 2013).

The two studies presented within this chapter represent attempts to explore the application of this broad philosophy within a music education context. Specifically, the aim was to address the research question: *Can music remixing activities support the formation of a local learning ecology involving young people and established local musicians, and if so, what factors are important in the design of the tools and social configuration?*

This work was inspired by the emergence of an online participatory youth culture, as reported by Jenkins (2009), involving young people remixing and sharing music with a community of like-minded individuals. I reasoned that participants must find the activity (or set of activities) engaging and meaningful, due to their continued participation. I also considered that such activity aligns well with the ideas behind the Connected Learning movement (Ito et al., 2013), with participants having the opportunity to engage with, and contribute to a community through their remixing activity. This made me keen to explore whether music remixing practices could work within formal music education settings, hence the work that follows.

Two studies are presented within this chapter: one at a Secondary School and one at a Primary school. The broad concept is consistent across the studies and it involves the school students remixing the music of established local musicians, and interacting with them via an online tool developed for the project. The hope was that the interactions would help the students feel like they were participating in a wider musical community, and that an authentic experience would be presented by sharing remixes with the works' original creators. With regards to the Primary school study, it should be noted that only data relating to a potential local learning ecology is

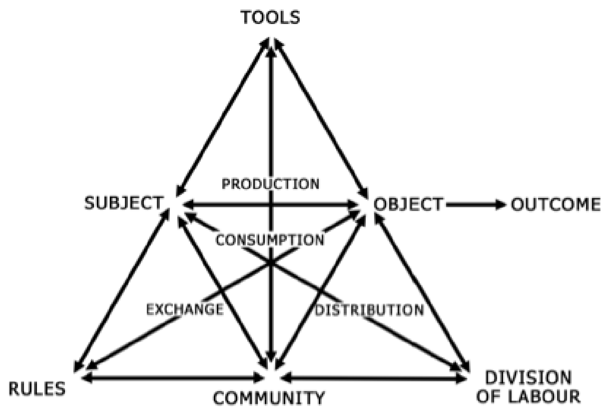

Figure 4.1 Structure of a Human Activity System

presented in this chapter, and data relating to the student participants' use of the music remixing interface is presented in Chapter 7 as it directly preceded the work on multi-layered interface design which forms the subject matter of that chapter.

As explained in Section 3.9, the deployment at the secondary school was conducted prior to beginning the PhD, however all data analysis was conducted during the PhD and the findings from this analysis shaped the direction of the work presented in this thesis. This deployment is therefore described in full for clarity, with the disclosure that the findings, discussion, and all work relating to Activity Theory represent the new work conducted during the PhD.

4.1.1. Activity systems in music remixing

As set out in Chapter 3, Activity Theory is an analytical framework which can be used to analyse the social setting surrounding an activity from the varying perspectives of the people involved. Engeström's interpretation of Activity Theory asserts that activities should be studied at a community level, as opposed to an individual level, and analysis should focus on the ways tools, rules and divisions of labour mediate the interactions between subject (the 'doer'), object (the item being worked on) and community (the other actors involved in the activity) (Engeström, 2015). Figure 4.1 represents the relationships between these key components of the activity system.

The music remixing landscape can be explored using Activity Theory by considering as 'subjects' the students, teacher, contributing musicians and myself as the researcher. It is also possible to compare activity systems across informal and formal contexts. Furthermore, Activity Theory considers the way objects (e.g. music) are produced, distributed, exchanged and consumed by the community members. Mapping out the landscapes in this way and then comparing them can draw attention to contradictions both within and between the activity systems which expose problems for the transposition of remixing activities into formal learning contexts at a local scale – problems that need to address in order for remixing to be successful in this new context. In choosing to use Activity Theory I am making the assumption that the number and nature of the contradictions observed can reveal the potential for a music mixing based local learning ecology to succeed.

Informal context's activity system

We can infer the activity systems operating within informal, online remixing communities from descriptions found within academic literature. This literature tells us that young people are motivated to participate for self-expression and the building of social relationships, as well as to support the activities of the community at large (Cheliotis and Yew, 2009). This community comprises "loosely connected, widely distributed individuals" (Benkler, 2006) and the object they are working on is a shared pool of musical content. This work is mediated by music production and social networking tools, which are often integrated into a single platform. Benkler (2006) informs our understanding of how objects are distributed and exchanged within this system, pointing to minimal firm rules but a set of norms around cooperation and the open sharing of resources. This resource sharing is supported by online file repositories, which are the cornerstones of remixing platforms. My conception of the division of labour is informed by Cheliotis and Yew (2009) who identify remix contests organised around content contributed by well known artists as triggers of activity.

This activity system served as a baseline against which I could compare the activity systems I would go on to observe during my project deployments.

4.2. Secondary school deployment

This study came about because a key contact, a music teacher at the school, had participated in a research project during the previous year with a member of my research group. My colleague subsequently introduced us and suggested we might work together. The teacher was supportive of my project and agreed that one of her classes could participate for 55-minutes per week over the course of three weeks. During the initial conversations I probed the teacher's perception of the students' potential capabilities around computer interface use and music remixing. This information shaped the design of the music remixing tool which I would create for the project. In the context of this thesis, this represents the first iteration of the Remix Portal web application and interface.

4.2.1. Design considerations

Much of the functionality of Remix Portal parallels that of contemporary online music remixing applications, such as the ability to create, save and share remixes, however this iteration of Remix Portal deviates from typical offerings in a number of ways:

1. I limited song choices to those created by local musicians due to the research goal of exploring remixing at a local scale.

2. I modelled the applications interface on a traditional audio mixing desk (and did not include an 'edit view' as found in most other platforms). This was motivated by the desire to support the teacher's curriculum goals and in this case a lesson had been planned around the (often overlooked (Ofsted, 2009)) mixing stage of the music production process. This

maps to the curriculum aim of "ensuring all pupils understand and explore how music is created, produced and communicated" (Department for Education, 2013).

3. Due to having limited time with the 12-13 year old participants I opted to trade deep functionality for ease of use by integrating musical stems that mesh together harmonically and rhythmically, and by providing no way for the users to unlock this harmonic and rhythmic fit. Reflecting upon my own experience as a novice digital music maker, I reasoned that such simplicity would reduce the likelihood of the novice user group experiencing frustration.

4.2.2. Study design

Remix Portal was deployed within a music classroom and used during three class sessions. A range of qualitative data were collected during these sessions.

Student participants

Two classes of 12 and 13-year-old students (41 total) from a secondary school in England participated. Music is a compulsory subject for these students and these sessions constituted their formal music education for these three weeks. Project information sheets and opt-out forms were distributed to parents prior to the project commencing. However, class participation was mandatory, and so the opt-out just related to the data collection element. This approach was approved by Newcastle University's ethics committee. Ultimately, no students were opted out of data collection.

Musician participants

Three groups of musicians agreed to participate in the project. They were sourced through a contact in the North East music scene. Each individual had over a decade of experience in an amateur or semi-professional capacity, and all were estimated to be over 30 years of age. The music these groups created could be broadly described as belonging to lyric-based pop or rock genres. They were initially offered no payment for their participation, although once the main components of their participation had been completed and final interviews had been arranged, I was able to offer payment for participation in these interviews as a goodwill gesture. I am therefore confident these payments had no influence on their motivation to participate in the research project.

The first stage of participation involved the musicians supplying music in a format suitable for remixing. None of the participating musicians were able to provide music in the optimal *stem* format, however they all had access to the software used to record at least one of their original songs. All the musicians opted to give me a copy of these recording session files so that I could process and output the stems myself, and then upload them to the Remix Portal library.

Following the school sessions, I held an evaluation session where I captured the musicians' responses to hearing the children's remixes and conducted an interview exploring their experience of participating in the project. Two of the musicians were able to make this session, leaving one group unrepresented.

Procedures

Each class participated during their weekly 55-minute music lesson over the course of three weeks. The first week was devoted to teaching the students how to use the components within Remix Portal's virtual mixing desk interface. The students had one computer each and used this to access the Remix Portal website. I delivered this lesson, and provided each student with an instruction booklet to support the teaching. The teacher remained in the room, ready to deal with any behavioural issues which may occur. During the lesson I would demonstrate a couple of interface components and then give the students roughly five minutes to experiment with using these interface components to effect a remix. By the end of the lesson the students had experimented with all of the interface controls and had produced a remix of a song by a well-known (non-participating) pop singer. Remix Portal's save and share facilities were disabled during this training phase. No data was collected this week.

The second week focused on the students applying the remixing skills they had acquired. Each student was given five minutes to select one of the songs created by the local musicians before spending the next twenty minutes creating their own remix version of this song. They then participated in a twenty-minute peer evaluation session where they paired up, listened to each other's remixes and then gave constructive feedback using the school's *what worked well?* and *even better if...* format. Following this, they were given five minutes to revise their remixes in light of their peers' suggestions. No data was collected this week.

During the third week, each class was split into two groups (making four groups in total) and they spent half their time in a group interview session with me and the other half was used to remix one of the two remaining songs. Each group interview contained around ten students. The group interviews were audio recorded and these audio recordings were later transcribed and thematically analysed.

The class teacher was also interviewed following the school deployment, and here interview was similarly audio recorded and transcribed.

4.2.3. Findings

The students' activity system within formal education

The data evidences that some of the students saw opportunities to experience similar outcomes to subjects operating within informal, online remixing contexts (as described in 4.1.1), including peer recognition and support. This was most apparent during group interview discussions around whether the students would like to share their remixes with their social networks (even though sharing was not actually possible during the project due to a school-wide ban on social media): "*Not to sound modest at all... [I would share it] so people can see how talented I am*" (group C, student 5), or "*[I would share it] to get an opinion*" (group D, student 4). A small number of students however, appeared to either not recognise these potential outcomes or view them as unattainable:

> "There's no real need [to share my remixes with my social networks] because nobody cares what I do at school" (group C, student 6).

This student does not appear to believe that peer recognition can be an outcome for them. Why anticipated outcomes can vary between contexts can be explored by identifying differences across the components of the informal and formal activity systems. Therefore, the following sections - differences between the rules dimensions of the informal and formal music remixing activity systems, differences between the tools dimensions of the informal and formal music remixing activity systems, and differences between the community dimensions of the informal and formal music remixing activity systems - present an analysis which focuses on Activity Theory's key dimensions of rules, tools and community; and reports differences between how these dimensions are experienced in informal, online music remixing settings, and the classroom deployment setting.

Differences between the rules dimensions of the informal and formal music remixing activity systems

Even though I imposed no strict rules during the activity, it would appear the students brought with them the norms of school. This would explain the previous quote "*... nobody cares what I do at school*". Additionally, norms can influence the way subjects view the community within the activity system, with some students finding it hard to grasp that the relationship is not just between students and teachers: "*I thought it was just teachers [who will listen to my remix], ah crumbs*" (group A, student 1). However, those who were aware of the extended nature of the community appear to benefit motivationally:

> "I think some people might have not worked as hard, but it's the fact that the people who wrote the songs are going to be listening to it - you want to impress them" (group A, student 5)

Differences between the tools dimensions of the informal and formal music remixing activity systems

Benkler (2006) identified that within informal, online music remixing communities, key tools consist of music productions software to create the music remixes, and social media platforms to distribute the resulting remixes and to enable the participants to collect recognition for their work. When comparing this to the situation within the formal classroom setting, a lack of access to social media platforms in the classroom due to the aforementioned school-wide ban is apparent. In the informal context these mediate the relationship between the subject and community, however during our sessions sharing only happened class-wide, mediated by functionality built into Remix Portal. The remixes were played to the musicians later by me. Whilst the students did not complain about not being able to share their remixes on social media, when asked how I could improve Remix Portal their answers centred around adding social features such as Facebook-style ‘like’ buttons and comments boxes, confirming that the social dimension is important to them.

A less significant change to the tool dimension can be attributed to my Remix Portal design decisions. I was faced with the challenge of designing for a group I was yet to meet, and was only able to gather information about them during a brief meeting with their teacher. I wanted to avoid the risk of making the interface too complicated for them, and therefore I opted to trade deep functionality for ease of use. Whilst I observed interface appeared well suited to the capabilities of the majority of the class, some of the more advanced students suggested I add complex features to the tool, for example: “*Record what you are doing as it plays along so you can play that to other people*” (group D, student 1). This raises the potential for some of these students to get frustrated with the tool as it stands, which might affect their motivation to participate in the activity as a whole.

Differences between the rules dimensions of the informal and formal music remixing activity systems

Motivated by the desire to encourage engagement with the local music scene, I decided to restrict the community aspect of the formal activity system to a local scale, as opposed to the global scale commonly found within informal, online contexts. I observed positives and negatives as a result of this decision. On the negative side, having a small community means having a smaller pool of musical content, and I received lots of requests to include music that better matched the listening preferences of the participants; a representative comment being: “*make the songs more popular, more modern*” (group D, student 5). Had I cast my net wider to pull in more music, I would have stood a better chance of obtaining songs that match the subjects’ existing listening preferences, and this in turn may have boosted some of the subjects’ motivation. Having said that, I did see evidence to suggest that the activities may influence listening preferences, with many participants saying the act of remixing made the music interesting to them. Also, keeping the musical choices local helped many of the students deepen their understanding of the local music scene:

> “Everyone expects it to be the big famous people that you listen to, but we’ve got people living next door to us that are just as good.” (group A, student 6)

I also saw evidence of it encouraging experimentation, with one student challenging himself to start with a piece he did not like and then remix it into a more contemporary style, although when asked if he had been successful in this endeavour he answered:

> “No. It was a really bad failed attempt...It’s just some of the things you hear now just weren’t an option to change it to.” (group A, student 3)

The teacher’s activity system

The teacher’s activity system looks a little different because she is primarily motivated to work towards educational goals (this is her object) and therefore the remixing activities she is presiding over are viewed as an action aimed at transforming the lesson into desirable educational outcomes. Her motivation to support remixing activities is dependent upon her believing that these actions can transform the lesson into the desired outcomes, and so it is important that I understand what her desired outcomes are and that I try to support them.

A central concern of hers, as revealed during our initial meeting, is that every music lesson should align tightly with the national music curriculum. This led us to co-design the project around the hard-to-reach curriculum aim of "*ensuring all pupils understand and explore how music is created, produced and communicated*" (Department for Education, 2013).

Upon first demonstrating Remix Portal to her she expressed great enthusiasm for its potential to engage and motivate her students: "*oh they're going to love this!*". At the end of the project the students did report enjoying the remixing activities:

> "It was fun learning about the different ways you can change music... you know how you added the delays and reverbs and stuff." (group B, student 1)

The teacher observed a particularly big improvement in the engagement of students who find the normal keyboard performance classes difficult, stating:

> "I think some of the ones who find keyboard difficult were interested in it because it was like an alternative where they didn't have to perform anything themselves." (teacher)

Even the students who did not like the music they were remixing appeared to be engaged in listening, and were noticing features about it:

> "Because when you tried to change it you could hear all the bits that were bad so it just stood out more, it was like 'oh bad' and it hit me in the face. (group C, student 3)"

In addition to benefiting engagement, I collected evidence of the remixing activities promoting deep, active learning:

> "It made you think 'How did they manage to mix it all together?' and it made you concentrate on what you were doing so you could do it better into like your way that you wanted to listen to it in. (group D, student 2)"

During the course of the project I identified more of the teacher's values. One aspect related to the skills she believes contemporary musicians require:

> "Music is being made so electronically these days that I think it is really important for them to know how to do it if they want to go into that area of life." (teacher)

She also saw value in the remixing actions serving as an intermediary to open up other educational opportunities for her students:

> "We've got this room with Ignite [software] and MIDI keyboards with all these settings on which we never use, and now the students know what they are about." (teacher)

This statement demonstrates a tension within her activity system; she has been unable, up until now, to make use of the tools available to her class to work on educational goals around electronic music. However, by participating in this research project and receiving my input, she is able to effectively fill the labour gap and thus her object can be worked on.

The musicians activity system

The musicians I worked with had not participated in remixing communities prior to this study. They were focused on creating, playing and furthering the spread of their music, and as such their musical careers represent the object in their activity system. The two musicians who were interviewed informed me that involvement in the project came primarily because they thought it could serve as a vehicle which could benefit their musical careers: Firstly, they believed they would gain from hearing the students' reimagining's of their work:

> "It is always really interesting hearing how someone else would approach mixing your song, because people are just going to have a different take on it, and that's really fascinating to see as well." (Musician 1)

When I played the remixes to these musicians they expressed great enthusiasm for what they heard, and stated that they would be keen to contribute more music in the future. Secondly, they talked about how they felt indebted to enthusiastic music teachers who had nurtured their passion for music and how they now wanted to give something back. They thought that contributing stems to the remixing project would support youngsters' musical development and therefore be a worthy contribution. Thirdly, the musicians valued the promotion that they could gain from having their music used within these activities: "*at the end of the day I think it just allows your music to go further*" (Musician 2).

The musicians responded very positively to the remixes they heard and the process appeared to excite them creatively as they frequently made comments such as:

> "That's amazing, that's amazing (laughs)... again great... really, really interesting ideas going on." (Musician 1)

They also made specific comments like:

> "I think I've only ever flanged drums like maybe once in my life but I think I'm going to do it more - that sounds great." (musician 2)

The musicians indicated that they would be very keen to be involved in a project like this going forward, sighting benefits including the promotional opportunities that exist through having their work remixed and shared on social media, the creative opportunities that exist from feeding off what the remixers are doing, as well as the chance to help young people develop their love of music.

The researcher's activity system

My own motivations as a researcher should be made clear as this influenced the design of Remix Portal and was influential when co-designing the lesson activities with the class teacher. I was trying to work with two objects: i) the strength of the relationships between the students and the local musicians, and ii) the students' engagement with their formal music education. The rules within the activity system were, essentially, inherited from the contexts I was operating in, in order to keep community members onside. For example, I had to adhere to school policy by not attempting to link Remix Portal to social media.

The division of labour aspect was important because this dictates the configuration of the relationships between the students and local musicians, with the local musicians supplying the stems and the young people remixing them. The tool's design was intended to support this division of labour and where the tool had to be restricted (due to school rules) I was able to make up for this by playing the remixes to the musicians in person.

I collected some evidence that the act of remixing may be able to increase the students' interest in local music. In group D, although few students reported initially liking the song they would go on to remix, half agreed that the process of remixing made it interesting to them. Similarly, most students reported not looking up or caring about the band they were remixing, however when asked if they thought it was cool that bands like this are coming from their local area, all students responded that they did think it was cool:

> "I think it's good that... everyone expects it to be the big famous people that you listen to but we've got people living next door to us that are just as good." (group A, student 6)

Similarly:

> "I think it's cool because it's not like well known people. You can discover different people and different music and you might like it." (group B, student 1)

Some students even thought that by sharing their remixes on social media they could help their local musicians:

> "...because if other people liked it they might share it on and then it might get somewhere instead of being just like low music." (group D, student 1)

There was also evidence that connecting the participants to the musicians via Remix Portal improved their engagement, as the following exchange within group A demonstrates:

> "I think some people might have not worked as hard, but it's the fact that the people who wrote the songs are going to be listening to it - you want to impress them." (group A, student 5)

Student 1 from group A then interjected: "*Really?... I thought it was just teachers, ah crumbs*". Researcher: "*Do you wish you'd worked harder now?*", same student: "*Yes... crumbs*".

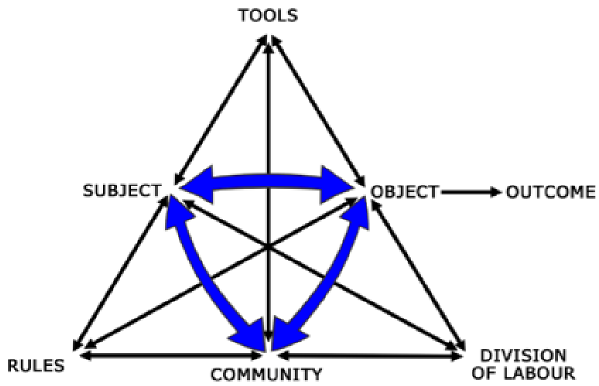

Figure 4.2 Strong connections linking subject, object and community and are vital to the health of an activity

4.2.4. Discussion

Looking at the data through the lens of activity theory and from the differing perspectives of the stakeholders involved brought to my attention the importance of supporting each party's desired outcomes. I gathered strong evidence to suggest that these outcomes can be achieved: evidence of students being entertained, as well as gaining knowledge and appreciation of their local music scene; teachers seeing the educational benefits; and musicians appreciating the creative ideas returned within the remixes. However, when comparing each stakeholder's activity system, I identified tensions which may impact upon the ability to sustain a local learning ecology in this environment. For example, the positive motivation demonstrated by the musicians, researchers and students appears dependent on a strong and visible connection between students and musicians emerging from the production and consumption of the musical stems, as depicted in 4.2.

The ability to create this strong connection faces challenges due to the imposition of school rules (4.3) which prevent the use of social media within the classroom and therefore remove a channel that could facilitate the development of this strong connection at the subject/community juncture. This issue was circumvented during the project by me acting as a go-between, taking the remixes to the musicians and gathering their responses, however an alternative would need to be found once I withdraw from the project. The developers of some technologies used within schools have found other ways to add social features within their products. For example, Time Table Rock Stars (MathsCircleLtd, 2022) introduces social features by enabling the teacher to group students, therefore controlling who can participate in the social interactions. However, whilst this may be acceptable to school leaders when groups comprise of children within a school, it may prove significantly more challenging to expand the groups to include adults beyond the school environment, as would be desirable for Remix Portal where external adult musicians would need to participate.

Another tension relates to the teacher's desire to align lessons with the music curriculum. This places an emphasis on: "*vocal and/or instrumental fluency, accuracy and expressiveness*" (Department for Education, 2013) and so it is perhaps unsurprising that her main recommendation for improvements to Remix Portal is to enable students to record their own performances into

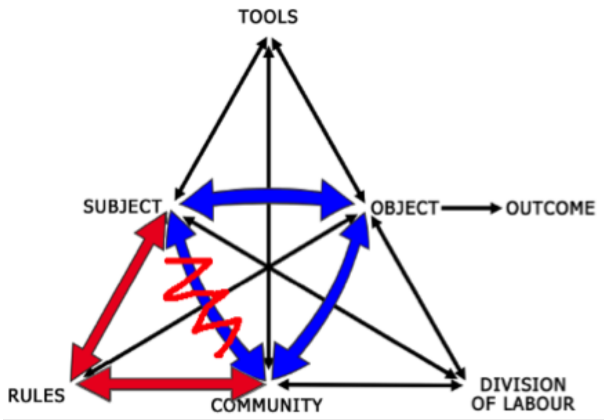

Figure 4.3 Strong rules can impact the flow between subject and community

the software. Offering this facility may encourage her to use Remix Portal within more of her lessons, however it is possible that this change to the activity would demotivate some of the students who had appeared to engaged because, as the teacher put it: "*it was like an alternative where they didn't have to perform anything themselves*".

Such tensions present a design challenge. How can I configure remixing activities to accommodate all of the stakeholders' activity systems and their implicit motivations and constraints? In the long-term however, it may be the case that the stakeholders motivations could change to align with the central activity. For example, at the start of the project the musicians were motivated to participate in order to further their own musical activities, and this project provided an opportunity for them to benefit from the creative ideas returned in the remixes and as a way to promote themselves. However, by the end of the project, both the musicians who were interviewed expressed an interest in creating music specifically for the remix project as opposed to donating existing music. Similarly, lots of the students asked me to add music which matched their current musical tastes, yet I saw evidence of the local music becoming interesting to them through the act of remixing, giving rise to the possibility that these activities may shape their musical tastes over time and thus the tension would be reduced.

In the short-term, ways to mitigate the problem of my withdrawal from active participation in the project should be investigated. For example, I should address the issue of me teaching the lessons. The class teacher had expressed that music technology is a weaker side of her teaching, yet she believes it is an important topic for her students to cover. Her motivation to participate in the project was likely influenced to some extent by my ability to help her address this shortcoming, and whilst I was primarily focused on the learning her students would take from the activities, she reported learning from the activity as well: "*I have learned about what some of the things did because I didn't know. Like the Lo-fi one. And I think that will help me teach the students.*". She reported plans to use Remix Portal with next year's classes. So perhaps the incidental development of the stakeholders through their involvement in the activities could 'fill in the gap' left by my withdrawal.

A step back could allow me to continue co-designing lessons and tools but no longer acting as a force to mitigate the tensions within the system. And through a co-design process, as the stakeholders come to appreciate the positions of the other parties involved in the activities, it may be possible to configure the activities and their supporting tools to further reduce the tensions. For example, it may be possible to co-design social media-type features with the teachers, to address their concerns whilst still providing the required connectivity between the subject and community. These could then be integrated directly into Remix Portal, circumventing the need for third party social media tools or a go-between. Such a step back could also free the researcher to think about designing additional activities that could support their agenda, for example, working on building upon the relationships between the students and established musicians by e.g. having them visit the class and feed back on the remixes in person, or getting the students involved in playing concerts with the musicians or helping with their recordings.

Unfortunately a follow-up study at this site was not possible as the teacher received a promotion into senior management which took her away from music teaching.

4.3. Primary school deployment

I was put in touch with a teacher at a local primary school by a contact in the North East music scene who knew this teacher was looking to find engaging learning opportunities for her students. I met the teacher, explained the project and we agreed upon running weekly, 55-minute sessions over the course of five weeks. Participation would serve as the students' music class time for the school term.

An issue identified in the previous deployment concerned school rules constraining communication between the musicians and students. At the beginning of this new deployment I obtained permission to facilitate text communication between the musicians and students through Remix Portal, under the proviso that messages would be screened by me prior to the students receiving them. This enabled me to rework Remix Portal to incorporate this functionality.

I had two aims for this deployment. Firstly, I wanted to conduct a similar study to that presented in the first half of this chapter, however with Remix Portal's enhanced communication facilities, to see how they impacted the connection between the students and musicians. This study would also involve younger students, different musicians and a different teacher, and thus should strengthen the confidence with which I could comment on the generalisability of findings from this chapter's work. This portion of the deployment is described in this chapter. The second aim was to capture data about the participants' interface use. This portion of the study is described in Chapter 7 as it laid the foundation for the multi-layered interface work which is the subject of that chapter.

4.3.1. Design considerations

In light of the findings from the secondary school deployment, a number of changes were made to the Remix Portal interface. Firstly, as mentioned above, the application was extended in an attempt to create a holistic environment which could facilitate the capture and presentation of text feedback from the musicians to the students. This was achieved by adding a slide-out sidebar

Figure 4.4 Comments panel: collapsed (left) and expanded (right)

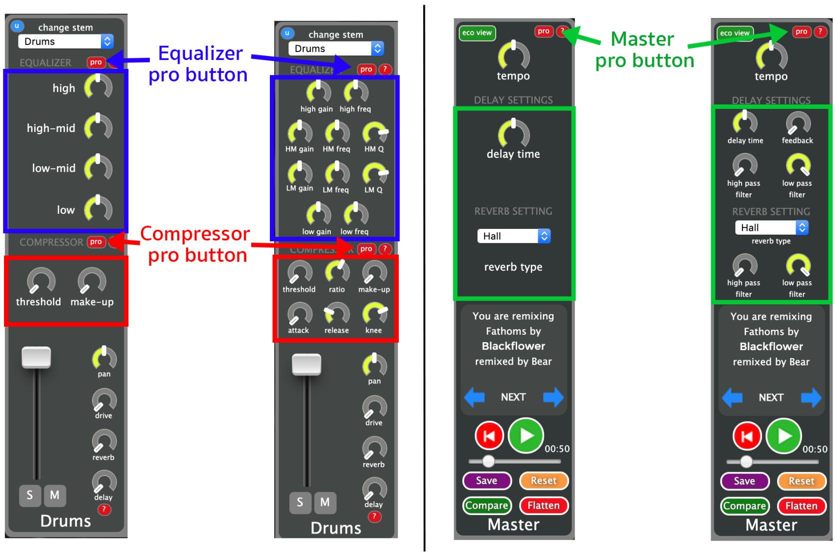

Figure 4.5 Interface Pro modes

to the interface which houses a *comments panel* consisting of text-entry box and submission button, along with an area below this where submitted comments are displayed (see figure 4.4).

Due to a desire to simplify the interface for a younger audience, yet to maintain enough functionality to satisfy more capable students, a basic multi-layered approach was pursued. A pared-down interface was presented along with ‘pro’ buttons which, when clicked, added controls to the interface (see figure 4.5). These ’pro’ buttons actually served to toggle these additional controls between hidden and visible, and thus clicking one a second time removed the additional controls. Three types of pro button were created; one to reveal (or hide) additional equalizer controls as denoted by the blue annotations in figure 4.5, one to reveal (or hide) additional compressor controls (denoted by the red annotations), and one to reveal (or hide) additional master channel controls (green annotations).

4.3.2. Study design

Student participants

The students all belonged to the same year 6 primary school class, and thus were between 10 and 11 years of age. There were 28 students in total, and they were recruited through their teacher. A small number of students were off ill over the course of the five deployment sessions. Two students missed the first week and so I gave them remedial work whilst the rest of the class were participating in week 2's main data collection activity - the remixing game described later. No further participant data was omitted from students who had not attended all sessions, and thus all data collected was submitted for analysis. This group had little prior knowledge of music remixing, evidenced by the fact that only around one quarter raised their hand when asked who had previously heard of music remixing.

Musician participants

Three groups of musicians agreed to participate in this deployment, none of whom had contributed to the previous study. They each provided one piece of music which was added to the Remix Portal library, however shortly before the project deployment was due to begin one group ceased communication and therefore played no further part in the study. The two remaining groups comprised a solo artist and an indie rock band. The solo artist was an experienced, semi-professional musician in her late thirties, and the music she provided can be described as folk-electronica. The indie rock band had been playing together for several years although all members had been involved in other bands previously. The band members were estimated to be 25-40 years old. They contributed an indie rock song.

Procedures

During initial discussions about the project, the teacher made clear her desire for the students to work in pairs and for individuals to remain anonymous. We agreed upon a plan whereby she would assign the students into pairs and give each pair an animal pseudonym. There would be two groups of three due to the limited number of computers available. I would lead the sessions and the class teacher would observe and step in if behavioural issues arose.

Session 1: The objective of this first session was to introduce the student participants to music remixing. We started with a listening activity where I played original music followed by a remixed version, and facilitated a discussion about the differences they could perceive between the two versions. Following this the students were arranged into their pairs (or threes) around the computer workstations. I introduced them to Remix Portal and gave them a lesson in the basics of remixing which they followed on their computers. I would demonstrate the use of a control type and then give the groups several minutes to put their headphones on and experiment with this control on their own computers, listening carefully and discussing the setting with their partner(s), so as to create their own interpretation of the music. At the end of the session we had just enough time to listen as a class to excerpts of some of their remixes, comparing before and after processing.

Session 2: The session began with a remixing game, where the students used a modified Remix Portal interface and attempted to adjust the mixer controls to make their remix match the sound of a 'hidden' remix. The intention was to capture data concerning control use and listening ability which could inform the design of the next multi-layered interface. This activity is discussed in more detail in chapter 7.

The next activity involved the groups listening to the remixes from the previous week and discussing within their groups which remixes they liked and why, and how interface controls had been used to achieve the sounds they could identify within the remixes. For the remainder of the session the groups were challenged to create a quick and experimental remix.

Session 3: The objective of this third session was to socialise the students into the feedback giving and receiving processes. Each group spent the first 15 minutes picking a song from the Remix Portal library and creating a remix. They were then asked to listen to each other's remixes and leave a text comment which might serve to help the receiving group improve their remix. Following this, they were given time to read the comments left for their group. Finally, we listened to the remixes as a class.

Session 4: The objective of this session was to introduce and remix the work of the local musicians. The students were informed from the outset that the local musicians would be listening to these remixes and providing feedback. As we had two participating music groups prepared to give feedback, we randomly assigned the student groups to remix one or other of the musicians' music, creating a 50/50 split and therefore an even burden of feedback for the musicians. I briefly talked to the students about who these musicians were, showed them some pictures from their websites, and explained what genres of music they played before setting them to their task. They were given 15 minutes to remix the track. Whilst they were remixing they were tasked with filling out a form rating each control sets usefulness between 0 and 10, data which is addressed in chapter 7. They were then given another control rating task to complete which is similarly detailed in chapter 7. The remainder of the session was spent revising their remixes from the previous week in light of the feedback left by their classmates.

Session 5: During this final session the groups explored the feedback the musicians had left for them. The solo musician had also created a short video for the class as a whole, telling them how much she had enjoyed listening to their remixes and that she hoped they kept up their interest in music making. Each group then participated in a short (approx. 4 minutes) semi-structured interview probing their reaction to the feedback, their thoughts around participating in the project as a whole, and their musical background and intentions going forward. I was assisted in this interview capture process by a colleague from my research group, with her interviewing half of the groups and me interviewing the other half. I deemed the assistance vital given the constraints imposed by the 55-minute class slot. Essentially, the doubling of interviewers meant I was able to come away with twice the quantity of interview data, although 4-minutes per group is still not a lot of time to conduct detailed interviews. These interviews constitute the student data which is analysed and presented in this chapter.

Musicians participation: Our solo musician and one of the bands had agreed from the outset to provide feedback on the student remixes of their work, in addition to providing the music to be remixed. Between sessions 4 and 5, I contacted these musicians to let them know that the remixes had been created and to ask them to leave text feedback through the Remix Portal interface that week. I provided written instructions covering how to access the remixes and how to submit written feedback. I asked them to try and make their feedback encouraging whilst also suggesting how the remix might be improved. I left the specifics of feedback composition up to them.

I was able to meet our solo musician after the project and conducted a semi-structured interview probing her experience participating in the project. This interview was transcribed and thematically analysed. Unfortunately, the other musicians were unavailable to meet for an interview.

4.3.3. Findings

The students' perspective - Autonomy

There was a strong sense that the students enjoyed participating in the remixing activities, and two reasons for this stood out. Firstly, most students' answers reflected the heightened creative freedom the activity offers in comparison to conventional music lessons, for example:

> "We normally just listen to what the teacher tells us to do [in music lessons], but this [Remix Portal] is our own if you know what I mean?" (student from group 1)

And:

> "I get to remix my own... well the songs... I get to remix them and make them my own" (student from group 3)

One student explained how this creative freedom changed the way they think about music making more broadly:

> "I like playing the guitar normally - I used to play, like, Sam Smith songs and now I could do, like, my own like rhythm to Sam Smith or something like that." (Student from group 4)
>
> Researcher: "You mean, still his song but putting your own twist on them?"
>
> Student from group 4: "Yes"

This demonstrates that the students felt empowered to use the tools provided by Remix Portal to transform the music into something more befitting of their musical tastes. This is good evidence that Remix Portal offers a suitably low barrier to entry.

The students' perspective - Responsibility

The second substantial motivating factor concerns involving local musicians in the activities through the feedback process. For example, when asked how receiving feedback form the musicians made them feel, one group responded: "*Proud, because I treated it [their music] like my own*" (student from group 5). And when this same group was asked to consider whether their engagement with Remix Portal might have been any different if they were not going to receive feedback from the musicians, they responded: "*I think we would have played with it a bit but I* *don't think we'd have properly made a song like we've been trying to do*". Interestingly, group 6 even referred to the musicians as celebrities, which indicates the esteem they held the feedback givers in. Another group offered the following when reflecting upon learning of the musicians' involvement:

> "I didn't know that the musicians were going to be listening to it and when they did I just thought "that's inspiring", like, it's inspiring you to do more, because...I didn't think a musician would listen to something like... us, because we're just like ordinary kids right?" (student from group 2)

The benefits of involving musicians may have, in part at least, been due to the fact they were the music's originators, as opposed to their status as authentic musicians alone:

> "It's [the feedback] coming from the person who made [the music] and if you did it with the teachers it's not their music so they wouldn't know [how it should sound]" (student from group 3)

Similarly:

> "It would be really different [if the feedback came from teachers] because, like, the teachers are something different to the person who made the music."(student from group 2)

And:

> "It made me feel much more confident that [the musicians] had left us some tips because it's their own song so they know how to make it better. "(student from group 8)

There was a strong sense that the motivational impact would not have been as significant had the teacher been the sole feedback provider:

> "[feedback from the teacher would have been] less useful than the musicians. . . because [the musicians are] like a proper artist." (student from group 4)

And:

> "If it was the teacher it would be, like, different because they give you feedback like every day where if it's the musician it's making you want to do more and more." (student from group 2)

Also:

> "[feedback from a teacher would have been] really different because the teachers we already know and we wanted to find someone new that we didn't know and get their opinions. . . it depends what teacher it is because if they are from a different school it would have been okay but if they're from our school we would have known who it was so we want someone different to message on our comments."(student from group 7)

The students' perspective - Feedback utility

One of the groups expressed appreciation for the directness of the musicians in contrast to the approach their teachers typically take:

> "Teachers will do mostly questions on your work and the musicians tell you, like, what's good and what needs improving." (student from group 1)

However, I did find some evidence that the students did not always know how to operationalize the feedback from the musicians, as the following conversation evidences:

> Student from group 3: "I really liked that they said it was good, but when they said to change some things I didn't know how to do it."
>
> Researcher: "Do you mean you didn't know how to use the controls on Remix Portal to make the change they suggested?"
>
> Student from group 3: "Yes"

Issues with operationalizing feedback could, in part, be due to the limited contact between the musicians and students and therefore the limited ability to construct a shared vocabulary and for the musicians to gain an understanding of the students' competency.

The positive input from the musicians may well have enhanced the students' musical confidence and sense of autonomy. For example,

> "At first we were like "oh it's just a song we can do it" but now we are like "it's a song what we're improving" so I want to like... share it but then other people might not like it so you've got to think about... you've got to make it so you like it and don't listen to what anybody else says you've just got to go with what you think's good" (student from group 2)

It is worth pointing out that whilst the students where universally positive about the feedback they received from the musicians, their responses to the text feedback they received from their classmates were less positive. Some demonstrated mixed feelings:

> "Some of them [the feedback comments] were helpful, because, like, someone said turn the tempo down so I did" (student from group 3)

Others, cited the potential for the peer feedback to create conflict:

> "On our other songs we had them [volume faders] like really high and people were like putting nasty comments saying like "ouch my ears" and things like that" (student from group 9)

This serves as a reminder of the need to socialise students into the feedback giving and receiving process.

One of the musicians offered to provide a video to be played to the class as a whole, as an additional piece of feedback. This was highly appreciated by all the students we asked, due to its "*exciting*" (student from group 8), "*inspiring*" (student from group 1), and "*really nice*" (student from group 2) content, and all agreed that it would have been great if the other band could have made a video too. One of the groups explained why the video was particularly significant to them:

> “Yes [the video was appreciated] because you wouldn’t really expect that from anyone, like if somebody made a website like this you wouldn’t really think that somebody who actually makes music would put a video back to you” (student from group 4)

These findings illustrate the positive impact upon students’ motivation of widening the community involved in school music activities, to include authentic local experts.

Beyond the general encouragement that the video offered, it also appeared to serve an important secondary function, in that it helped the students interpret and trust the text-based feedback they received:

> “I liked it [the video] because you don’t know if she’s being genuine [in the text comments] but when you see the video and that she’s happy and that she loved it then you feel more confident” (student from group 1)

Several of the students pointed out that seeing the musician’s facial expressions is key for them:

> Student from group 3: “Because [the video contains] not just words and it’s helpful with facial expressions as well, like how you say it, because you could say “oh it was good” but mean it in a sarcastic way.”
>
> Researcher: “So it was easier to know exactly what she was saying? ”
>
> Student from group 3: “Yes.”

Similarly:

> “[the video feedback] is a bit different [to text feedback] because you get to see [the musician’s] expressions and because she gets to tell you in-person, not just on a screen [as text]” (student from group 7)

Students also reported difficulties interpreting text-based feedback without a video component, especially when these were authored by their peers:

> “Yes, they were helpful but because we didn’t get a video I didn’t know if they were saying it in a nice tone or not. Because some of them were like “oh it’s too loud!!!” with exclamation marks you didn’t know if they were just being helpful or not” (student from group 1)

And:

> “We felt a bit awkward because people like put them [the comments] in caps and we didn’t know if they were shouting at us like "IT IS TOO HIGH YOU NEED TO PUT IT DOWN"” (student from group 5)

When asked how Remix Portal could be improved, the main suggestion was to incorporating video feedback into the application:

> “Maybe put little [video] recordings so you can understand more about the comments that you get. So if people could get an iPad and record a video on it and say what they think instead of typing it… because we can get more of an understanding of how they are trying to say it.” (student from group 5)

This finding draws our attention to the importance of the *means* of connecting students with the wider community, and in this context video clearly has advantages over text.

The teacher’s perspective - Enriching experiences

The motivation of the teacher was to provide an enriching learning opportunity for her students:

> “It was something really different for the children, yet it fitted with the curriculum, but it was a different approach to it and with the class I’ve got I thought they would really engage with it.” (teacher)

This motivation went beyond fulfilling curriculum obligations which became apparent as we reflected upon involving local musicians in the project:

> “Oh they [the students] absolutely loved that. They benefited so much because the excitement you could see when you said local musicians... they were just like “oh wow” because they felt like they were really making a difference. And we’re really doing that at school at the moment where it’s all that relevance of learning. And really trying to work on that is something that we as a leadership team are looking at at the moment, and so I really think it brought that relevant learning. And the songs where they could choose rather than us saying "this is what you’re going to listen to, this is what you’ve got to analyse, this is what you’ll do with it". So it was really good that they had that real, like, approach to it” (Teacher)

Whilst this project satisfied her objective of providing relevant learning, she explained that involving a wider community in school activities is something the school staff often have trouble achieving: "*we do really struggle sometimes with the budget and getting people to come in*".

The teacher’s perspective - Inclusion

When reflecting upon the impact of the project upon her students she cited the transformational effect it had on one student in particular:

> “One of the boys in my class is autistic and he really came to the fore and he was able to express his opinion on the music, and I’d noticed when he’s been at keyboard club that he’s an able musician but I’d never seen that in terms of understanding the theory behind it but you could see that that was… and his confidence really grew because he was the one who could kind of take the lead roll a little bit. And he really led it with other people whereas in other subjects he hides out of the way but he really did lead.”

The musician’s perspective - Giving back to the community

The solo musician was driven primarily by a sense of wanting to expand the young people’s musical experiences. She had previously attempted to include young people in her music making activities:

> “I actually asked around in pubs if it would be possible to put on an all ages show, but it’s just not possible here because of the drinking laws.” (solo musician)

She also had a small amount of music teaching experience and described having to teach a "stuffy" curriculum where she had little autonomy to bring her own musical interests and ideas to the fore. She expressed appreciation for the opportunity to be involved in a novel approach to music education, citing the aim of exposing young people to a variety of contemporary music styles and connecting them with these musicians as being particularly motivational. She related this to her own education, describing going to a music school but not *feeling* like a musician until she discovered a fringe music scene aged around 16. Her motivation to participate may have been influenced by her place within the music making community:

> “I’m not precious about my music as it’s not my primary source of income. Maybe if it was... I don’t know if I’d feel any different in this particular instance but I’d probably be more precious about it in other areas but it’s not what I make money from, it’s just kind of for fun. So if I can help people achieve something with it then even better.” (solo musician)

From an Activity Theory perspective, the object she was working on was the students’ musical development. However, latterly she reported being surprised and very appreciative of the musical ideas returned within the remixes:

> “One of the first ones I listened to was like super heavy sloth [band]. They’d slowed the track down, put the drive up and I just thought, "wow this song is just so much better! I love this. I might take this for myself or write a new song." It was just so brilliant. I loved it.” (solo musician)

And in reference to another remix she commented:

> “In fact that inspired me because I’m recording at the moment and I’m thinking "oh yeah, you know what? Maybe I should do this, maybe I should do that, or maybe

> I should just stick drive on everything" (laughs). Because I usually just tend to go with a minimalist approach and now I'm just thinking "nah, screw that! Let's just go full on..." (laughs)" (solo musician)

Discovering this benefit may enhance her motivation to participate in future projects like this, and thus may represent a shift in the activity system with a secondary object developing.

I asked the musician to assess how onerous participation felt to her:

> "The hardest part was finding the song in the first place. I had to break into my old laptop which hardly works any more and extract the song. Because I realised that I haven't kept a library as well as I thought in terms of finding my old album stems. So that was kind of fun in its own right, actually finding them again... But it's been super easy going. You haven't asked really much of me at all" (solo musician)

She did, however, acknowledge the challenge of composing feedback when I enquired:

> "Yes, it was a bit tricky because I don't know the students, know what level they're at, so I mostly just stuck to being positive." (solo musician)

The musician feeling relatively unburdened by involvement in the project is encouraging from the perspective of the potential sustainability of the process, however further exploration may be required to ascertain how best to configure the musicians' participation to aid students' knowledge acquisition.

4.3.4. Discussion

Much of the data we gathered and analysed during this deployment shares similarities with that obtained from the (previously reported) secondary school deployment. Thus, many of the conclusions we drew from the initial deployment receive further supporting evidence. Central to this was my assertion that involving local musicians in school music lessons can have a positive impact upon the students, and once more, our student participants responded very positively to the involvement of the musicians and found the remixing activities enjoyable and engaging.

Analysing our data through the lens of Activity Theory renewed my belief that remixing activities have the potential to satisfy the objectives of all key stakeholders. Our solo musician felt she was able to make a positive contribution the musical development of the students without the expenditure of significant effort and latterly came to appreciate the creative ideas expressed through the remixes. The teacher was satisfied that the remixing activities could meet the demands of the national curriculum whilst offering an engaging activity for her students. Evidence that the objectives of the key actors could be satisfied indicates the potential for the sustainability of the activity. We also saw further evidence that the Remix Portal tool (albeit with a modified interface) offers a suitably low barrier to entry, empowering students to control the music and sculpt it to suit their tastes after only a few lessons.

Whilst most of the data we collected closely reflected that from the secondary school deployment, we also observed some differences. For example, our musician did not appear to view the project as potentially beneficial to her musical career, as our former musicians had, although she did share their desire to 'give back'.

A significant change in this deployment setting was the communication that took place between the musicians and the students. We learned from the secondary school deployment that students thought they would like more direct communication with the musicians, and this was borne out in practice in the primary school setting, with students responding positively to the feedback they received from the musicians. This communication required approval from the school as it differed from their default position of not permitting computer mediated contact between students and non-school adults. This is understandable as it reduces risk and workload around safeguarding. My project was made an exception under the proviso that messages from the musicians would be screened by myself prior to being passed to the students. It remains to be seen whether other schools would be happy with this exception to their rules and whether, ultimately, a teacher would be prepared to take on the additional work involved with reviewing comments, in place of me.

4.3.5. Limitations of these studies

Whilst I did empirical work within formal learning environments, I had to use secondary data sources to inform my understanding of informal, online communities – centrally: (Benkler, 2006; Cheliotis and Yew, 2009). I believe my comparison between the formal and informal contexts' activity systems may have been more robust had I been able to collect both sets of data myself.

Secondly, I was only able to offer a limited number of song choices to the students due to the labour involved in finding musicians who were willing to donate stems and provide feedback. Had I been able to offer a wider variety of music to choose form then I anticipate many more students would have been able to find something to work with that matched their preexisting listening preferences. This would have aligned better to the values espoused by those advocating for 'authentic learning' and may have altered some students' motivation to participate.

The nature of the schools settings meant that in both deployments I had very limited time performing interviews as the teachers were keen to maximise the time the students spent *doing* music. This resulted in many interviews and focus ending even when interesting information was still emerging.

4.4. Chapter conclusion

The goal of the work presented in this chapter was to explore whether music remixing activities could support the formation of a local learning ecology involving young people and established local musicians. Two deployments were presented, one at a secondary school and one at a primary school. Along with the student profiles, the teachers and musicians differed between these settings. Both settings utilised a bespoke music remixing tool (Remix Portal) to facilitate the remixing activities. Activity theory was used in both settings to explore the motivations and experiences of the parties involved and to evaluate the potential for the sustainability of the activity.

From the first deployment I learned that the students, musicians and teacher felt positive about their participation and therefore we might conclude that potential exists for the formation of a local learning ecology on this basis. I identified similarities between the experiences of our student participants and the reported experiences of young people participating in informal remixing communities, including a desire to share remixes for recognition and support. However, some issues were identified, the two most significant of these are the communication problem and the labour gap. The communication problem being the difficulty in establishing close links with the participating musicians due to school rules preventing messaging between the students and adult outsiders. The labour gap problem relates to the brokerage I had to do to recruit the musicians to the project and the technical support I was able to provide in order to teach the remixing lesson content. I saw good evidence that the teacher's confidence and skills with music technology improved through her participation in the project, culminating in her planning to use Remix Portal with the following year's student cohort without my support. Their is therefore potential to close at least part of the labour gap.

The second deployment provided a very similar picture of positive experiences had by students, musicians and teacher. These therefore served to solidify many of our findings. Importantly, during the first deployment only indirect communication between students and musicians was possible, and students reported a desire for improved communication. I was able to facilitate this in the second deployment by building a text feedback mechanism into Remix Portal. The resulting in-app feedback was very well received by this second cohort of students, confirming the value of good student/musician communication channels and demonstrating that the communication gap can be successfully addressed. Whilst this communication had a very positive impact on the students enthusiasm for their music class, more work should be done to learn how best to maximise knowledge transfer that could result from the feedback. We also learned that video feedback can be particularly important to some students, as it can help them interpret the sentiment behind text comments. The importance may be related to age but more work is required here to make a statement with any certainty.

Chapter 5. Designing to Support Knowledge Transfer via Feedback

5.1. Introduction

In Chapter 4's second deployment I evidenced that students can find feedback from musicians highly motivating, however I identified issues in relation to the students making sense of and acting upon the text-based feedback to improve their remixes. Following this work, I saw an opportunity to explore a novel feedback method which I hoped might improve the intelligibility of the provided feedback, particularly for our participants who are newcomers to music remixing activities and therefore do not yet possess a sophisticated vocabulary encompassing words commonly used to describe auditory features of music.

The work presented in this chapter explores a Remix Portal design iteration which aims to optimise the learning potential of feedback. Whilst my focus is on the learning of music mixing skills, as music mixing shares many similarities with other craft-based practices, the work presented in this chapter is discussed at a higher level, and my intention is to offer a contribution which extends beyond the field of music mixing into the broader area of skills development within creative digital media practices.

It is widely accepted that feedback is one of the most powerful influences upon learning and achievement (Hattie and Timperley, 2007). One would expect therefore, that it could play a significant role in helping people acquire creative digital media skills including music mixing skills. However, I contest that learners engaging in creative digital media practices whilst operating in non co-located and/or asynchronous environments face a significant obstacle to receiving meaningful feedback upon their work. This is because creative digital media practices are artistic and craft-based in nature (Kealy, 1979; Ohanian and Phillips, 2013), and accordingly are underpinned by tacit knowledge – a highly embodied and impossible to fully articulate form of know-how. It is this articulation issue which poses the most significant problem for those learning in environments which are remote from those teaching them or offering feedback, as was the situation with our participating students and musicians in Chapter 4.

Within face-to-face learning environments teachers can overcome this articulation issue by incorporating demonstrations into their feedback and instruction; some may even directly manipulate a learner's creative artefact to communicate information. However, communicating a demonstration of a creative artefact manipulation can be hard to achieve via conventional digital infrastructure and, in practice, text remains the dominant medium for remote/asynchronous feedback upon creative digital artefacts. This leaves the feedback giver to *describe* what flaw they perceive in the artefact, or perhaps more helpfully, to describe how they think the artefact should be changed. The second deployment reported in Chapter 4 matched this scenario. Descriptions can be problematic as people often use high-level terms that do not map to low-level interface parameters which a feedback recipient could manipulate. Such communication gaps are a known problem and an active area of research particularly within the music mixing research community – see for example (Huang et al., 2014; Mecklenburg and Loviscach, 2006; Pardo et al., 2012; Seetharaman and Pardo, 2014; Stables et al., 2016; Zheng et al., 2016). Even if this mapping problem can be resolved, ambiguity will remain regarding *how much* an interface control should be changed by in order achieve what the feedback giver would perceive as the correct amount of processing. Consider a scenario where someone is seeking feedback online about a photograph they have taken. Amidst the typical encouraging comments (e.g. "looks really nice") the feedback seeker might see a comment such as "perhaps a little too washed out?". A novice photographer may not know what *washed out* means, and this comment does not directly map to any control found within common photo editing software. Even if an image manipulation application like Photoshop had a *more/less washed out* slider, the comment does not contain enough information to allow the feedback seeker to know when they have adjusted the slider to achieve what the feedback giver would perceive as right amount of corrective processing. Consider also that it is nearly always possible to take corrective processes too far and end up causing an alternative problem.

It must be stated that this assessment only applies to practices where the creative artefact is not text-based in nature, because existing infrastructures can adequately accommodate demonstrations of manipulations of text-based artefacts. For example, a programmer might post a snippet of troublesome computer code on a forum, community members can copy and edit this code and post back revised versions. You can imagine a similar situation for those producing poetry, stories or songs, as most word processing and document viewing tools allow tracked changes. Such demonstrations are far harder to implement where the creative artefacts are non-text-based, such as in practices like music mixing, film and photography, as feedback givers cannot easily show a proposed change via a direct manipulation of the underlying artefact. I would argue that when a feedback infrastructure does not support the non-destructive direct manipulation of the underlying digital artefact, feedback around artefact refinement may be sub-optimal, interpretive and, due to the ambiguity inherent in the *how much to change it by* question, of low resolution. These factors will therefore negatively impact the potential for learning to occur.

My work connecting community musicians with students presented in Chapter 4 provided evidence which supports this position, as it exposed the limitations of technology to communicate some important types of information. Specifically, our musicians reported some difficulties in composing text feedback in response to students' music mixes, and our students reported some issues with interpretation. This may have been exacerbated due to the students and musicians having no prior relationship, and thus little basis for shared understanding. It was clear that whilst the feedback from the musicians was very beneficial from a motivational perspective, there is room for improvement in terms of how the feedback can help students develop their skills in this domain, and so this became the motivating challenge for the work presented in this chapter.

The central question driving the work presented in this chapter is: *How can we design technology to support tacit knowledge transfer through feedback within the context of music mixing skill acquisition?* I developed the concept of **show-and-tell feedback**, which is an attempt to facilitate tacit knowledge transfer via rich, multiple representation feedback, mediated by digital tools. What follows is a detailed explanation of the concept, example system mockups for two creative digital media application areas, and an evaluation of a music mixing-oriented show-and-tell feedback interface implemented as a Remix Portal interface iteration and used to support learning on two Further Education music production courses.

5.1.1. Study aims and objectives

The aim of this study was to evaluate the utility of show-and-tell feedback in comparison with text-only feedback within the domain of music mixing. The objectives were as follows:

i To gain insight into participants' experiences as feedback recipients, comparing the use of the show-and-tell feedback against conventional text-only feedback

ii To understand the experience of experts giving both show-and-tell and text-only feedback

iii To understand the experience of peers giving both show-and-tell and text-only feedback

iv To derive insights for the design of show-and-tell feedback systems

5.2. The Show-and-tell feedback approach

At core of show-and-tell feedback is an attempt to enhance online feedback infrastructures to enable them to carry the types of information which may be found within traditional, co-located, apprenticeship-based learning environments. I believe the majority of digital feedback tools commonly used to feedback upon creative digital media artefacts and practices are not suitably equipped to support this communication given their heavy orientation towards verbal text-based feedback, as tacit knowledge is particularly difficult to verbalise. Show-and-tell feedback uses a range of information representations and modalities to enable a more holistic form of communication through feedback. Central to the concept are two components; the 'show' and the 'tell':

The show: Rich information modalities are leveraged to enable feedback givers to directly manipulate the learners' creative digital artefacts in order to demonstrate a correction. This is an important facet of coaching (Collins et al., 1988), and this demonstration can also serve to *model* the feedback giver's tool use and idea of 'correctness'. Effective coaching and modelling are precursors to tacit knowledge transfer (Collins et al., 1988).

The tell: This contains descriptive/verbal information. It will typically be conveyed via text, although other modalities could be employed e.g. the verbal information could be speech stored within an audio file. The purpose of *the tell* is to enable the feedback giver to convey the thought process that underpinned their suggested correction to the artefact. Making their thinking clear in this way is an important part of modelling. The verbal information conveyed through *the tell* could also be used to facilitate coaching, delivering the hints, tips and reminders which might scaffold the learner to a higher level of performance (Collins et al., 1988).

Here is an example of how show-and-tell feedback might work in practice. Suppose that a feedback giver perceives that a novice music mixer has failed to adequately adjust the volume of a singer's voice - setting it slightly too loud. The *show* component of their feedback could see them adjust the digital interface control that aligns to this musical component, lowering the volume of the vocal until they consider the problem rectified. They may then describe the issue they identified as well as their course for remediation in a text entry box before submitting their feedback. Because the feedback is integrated into the artefact manipulation interface, when the novice receives the feedback they will be able to see the interface control that has been adjusted, and their attention may be drawn to this through an interface annotation such as an arrow pointing to the adjusted control. The recipient will play the music and might switch between the original and feedback conditions. Upon switching they notice the difference in the volume of the singer's voice between the two conditions and see the associated interface control change position. They then look at the text-based component of the feedback which provides an explanation for the correction. The order in which they take in this information might change and is in fact unimportant, as the three types of information - interface control change, auditory change, and text-based explanation - support each other.

From a learning perspective, the goal of show-and-tell feedback is to help novices develop mental models of problem states, their names, and how interface tools can be used to resolve them. Taking the previous example, following engagement with the show-and-tell feedback the novice should be better able to select and use the appropriate tool within the interface to remedy the issue. Furthermore, when they recognise an issue they may recall a descriptor. This is important because whilst most novices would have no problems verbally describing a volume imbalance, the majority of audio issues are more challenging to describe. For example, tonality issues are associated with labels such as 'warm', 'cold', 'bright', 'harsh' and so on, with each label reflecting a particular problem state, requiring a particular course of remedial action. Sometimes the labels and their meanings are shared by the community (e.g. 'too loud') and the implied action map neatly onto the interface tools (e.g. a volume fader adjusts loudness). At the other end of the spectrum, labels for sonic features can be far more ambiguous and may require a combination of interface tool adjustments to remedy (Cartwright and Pardo, 2013).

The show-and-tell feedback approach deviates from feedback found within traditional co-located settings in two potentially beneficial ways. Firstly, the non-destructive processing capabilities of digital tools are harnessed to ensure the feedback recipient can easily and always *undo* a feedback suggestion and return to their original processing. I believe this might be particular important when feedback takes place in open forum settings, as the expertise of the feedback giver and the corresponding quality of the feedback can vary dramatically between helpful and unhelpful. Therefore it is important for the feedback giver to be able to easily dismiss the feedback, not just in terms of ignoring the descriptive (text) content but also in

Properties of show-and-tell feedback	*Traditional face-to-face feedback*	*Online text-based feedback*
Demonstration of artefact change	✓	X
Demonstration of tool use	✓	X
Conceptual knowledge	✓	✓
Feedback is persistent	X	✓
Feedback is easily undoable	X	n/a
Available to remote learners	X	✓

Table 5.1 Show-and-tell feedback compared to face-to-face and online, text-based feedback

terms of returning their artefact and tools to their pre-feedback states. Secondly, show-and-tell feedback offers persistence, so learners can review the feedback unlimited times, which can help with retention (Ryan et al., 2019) and assimilation (**?**). Table 5.1 shows characteristics of show-and-tell feedback and how these intersect with traditional face-to-face feedback and conventional online feedback styles.

5.3. Design criteria

The following design criteria builds upon the concepts of modelling, coaching and feedback detailed in the literature review, and represents my recommendations for the implementation of a show-and-tell feedback interface intended to support tacit knowledge transfer around the production of creative digital media artefacts.

- Design Criteria 1 (DC1): Facilitate modelling and the corrective component of coaching (Collins et al., 1988) by providing a mechanism via which the feedback giver can make and store changes to the artefact.
- Design Criteria 2 (DC2): Provide a mechanism that enables the feedback giver to communicate the thinking behind their artefact processing, as *process level* information helps the novice develop a conceptual model (Collins et al., 1988) and aids learning (Hattie and Timperley, 2007).
- Design Criteria 3 (DC3): Enable the feedback recipient to experience the feedback giver's proposed changes to the artefact i.e., to *play* their demonstration, which may draw the feedback recipient's attention to unnoticed and sub-optimal aspects of their work (Collins et al., 1988), and overcome comprehension issues related to written descriptions (Ainsworth, 2006; Carless, 2006; Goldman, 2003).
- Design Criteria 4 (DC4): Enable the feedback recipient to see how the feedback giver used tools to accomplish their proposed change, as *modelling* of working methods aids learning (Collins et al., 1991, 1988).
- Design Criteria 5 (DC5): Ensure the feedback recipient can easily switch to the pre-feedback state to a) facilitate close comparison between the two which can help the novice notice what may otherwise only be evident to an expert (Cambre et al., 2018; Schwartz

et al., 2016), and thus develop their sensory, perceptual tacit competency (Dahlbom and Mathiassen, 1993; Schindler, 2015), and to b) remove unhelpful feedback.

- Design Criteria 6 (DC6): Support feedback provision from multiple feedback givers, making it possible for recipients to benefit from a range of perspectives, opinions and recommendations (Cho and Schunn, 2007), and increasing the likelihood of receiving feedback matching their aesthetic sensibility (Bergmann, 1994; Tinapple et al., 2013).

I am not aware of any existing systems that are able to fully satisfy these design criteria. For example, one might assume that a video screen capture system could allow a feedback giver to record their manipulation of the recipient's artefact (creating a 'show'), whilst recording a narration to explain their reasoning (the 'tell'), but this process would fail to satisfy Design Criteria 5 which specifies the necessity to quickly and easily compare the original and feedback conditions in order to make sensory changes stand out. Furthermore, video screen capture-based feedback with narration requires additional software and hardware, and access to the source media files must usually be arranged too. It may therefore add a prohibitive overhead to an educator's workload, and so I believe the best solution in terms or end-user experience may lie in integrating show-and-tell feedback directly into media production tools.

5.4. Visual imagery-oriented show-and-tell feedback interface mockup

As stated, I believe the show-and-tell feedback concept has application beyond the relatively narrow realm of music mixing. As such, in this subsection I contribute a mockup show-and-tell feedback interface oriented towards another creative digital media domain – visual imagery. This interface is depicted in figure 5.1. The left side of the interface is used to present the visual artefact whilst the right side houses a 'feedback panel' for creating and reviewing feedback. Figures 5.1-A and 5.1-B show expanded views of the feedback panel and demonstrate its context-sensitive nature. In 5.1-A the user has clicked on a piece of written feedback (the comment by Jess) and so items above and below this are greyed out indicating their deactivation. Tool use information associated with the active feedback is presented to the left of this and takes the form of a feedback history list i.e. it shows the steps Jess went through when creating the 'show' part of her feedback (DC4). A green 'audition' button beside the text feedback enables a user to switch to the feedback giver's proposed artefact processing (DC3) or to toggle this processing off and return to the original artefact processing (DC5). Feedback submitted by other feedback givers is listed below this (DC6). Should a user click on one of these alternative pieces of written feedback, it will become active and the feedback history list will update to display the tool use information specific to this newly selected piece of feedback.

5.1-B depicts how the feedback panel would change if the user clicks to activate the text entry box at the top of the panel. The panel now enters feedback creation mode and so typical image manipulation features are added to the left-hand side of the feedback panel to accommodate leaving a 'show' feedback demonstration (DC1). These additional features comprise a tools pallet which gives access to image processing functionality, and a layers pallet (cropped out of

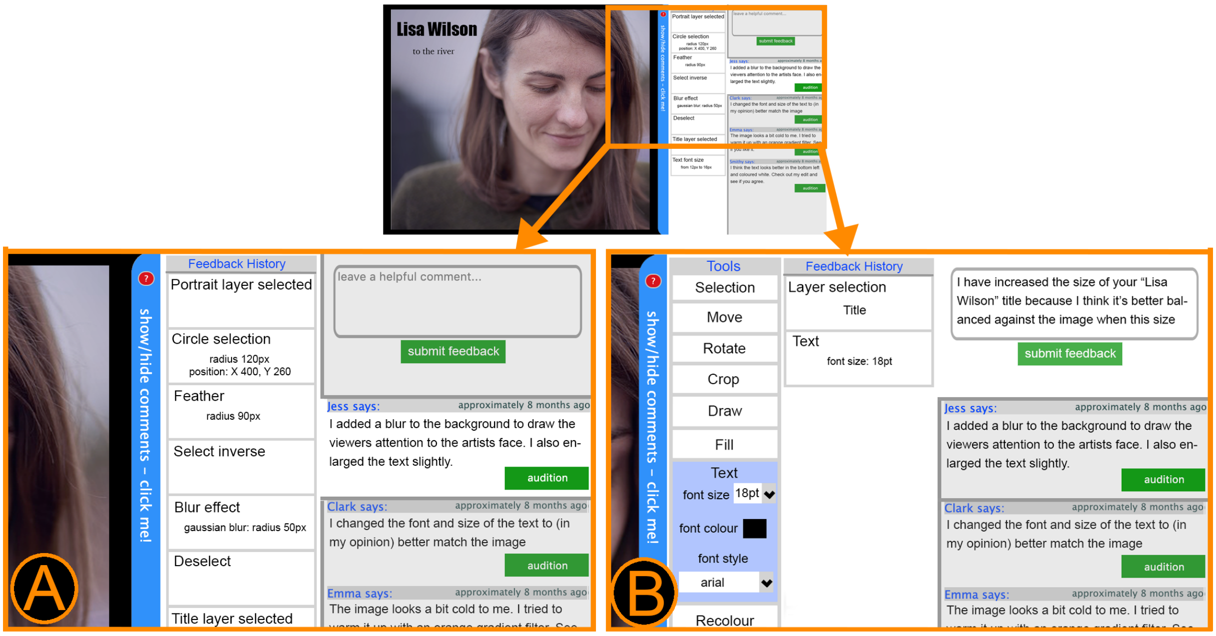

Figure 5.1 Show-and-tell feedback visual imagery interface mockup

view in 5.1-B). The text-based 'tell' component can then be typed into the text entry box (DC1) before pressing the green 'submit feedback' button to complete the show-and-tell feedback giving process.

5.5. Music mixing-oriented show-and-tell feedback interface design

Our music mixing-oriented show-and-tell feedback interface design is depicted in Figure 5.2. It shares many similarities with the visual imagery-oriented interface, however there are some key distinctions due to the differing modalities of the creative artefacts; visual in the digital imagery case and auditory in the music mixing case. This has design implications relating to screen real estate as the visual imagery-oriented interface will require space to present the artefact, tools, and text feedback components, whereas the music mixing-oriented interface only requires space for tools and text feedback components with the artefact being presented off-screen through the users' headphones or loudspeakers. A second distinction is that whilst the imagery-oriented interface used a feedback history list to convey each artefact manipulation made by a feedback giver, the music-oriented interface just presents the cumulative result of changes. These two differing interface mock-ups should therefore indicate the adaptability of the concept.

The music-mixing oriented interface also utilises a feedback panel on the right-hand side of the interface, the top half of which houses the feedback capture controls consisting of a button to record changes made to the virtual mixing desk (DC1), and a text entry mechanism for the descriptive, explanatory feedback (DC2). The lower half is again dedicated to presenting submitted feedback to the recipient. Multiple pieces of feedback can be listed (DC6) with a button beside each text comment used to toggle the feedback artefact processing on (DC3) and off (DC5). When feedback processing is toggled on, any changes that the feedback giver made to the processing will be reflected by altered dial and/or slider positions on the mixing desk and

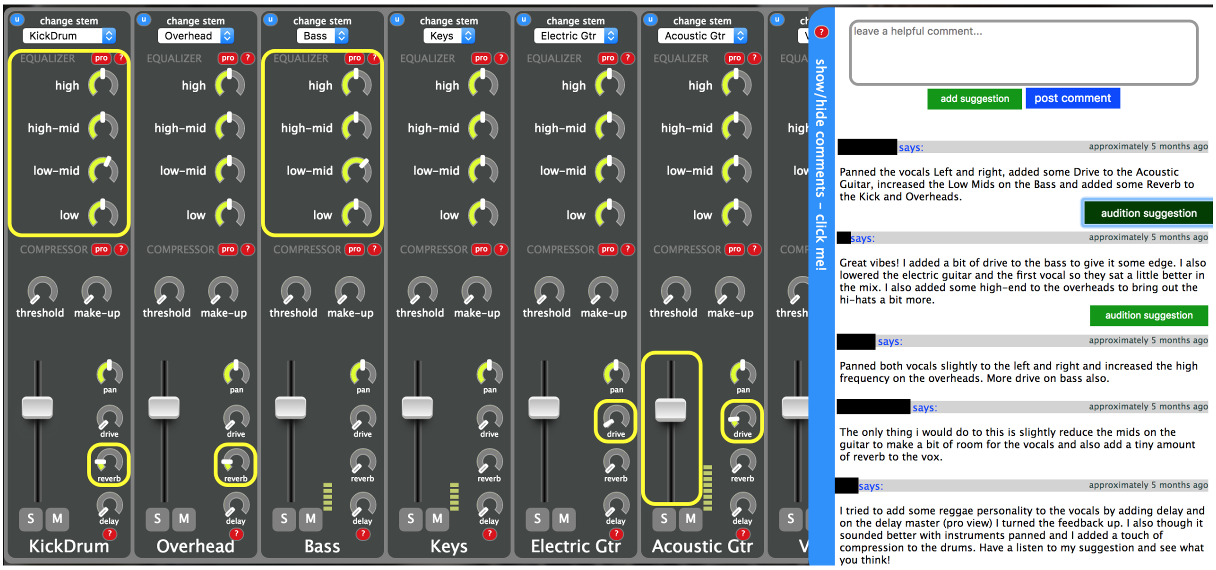

Figure 5.2 Remix Portal's Show-and-Tell interface iteration

highlighted by yellow boxes (DC4) with the intention being to draw the users attention to these changes within the artefact.

As the mixing desk GUI requires a lot of screen real estate, the feedback panel could be toggled in and out from the side of the screen by clicking the blue edge-strip of the feedback panel as depicted in 5.3. Thus the mixing desk view is maximised when the feedback panel is collapsed, yet when it is expanded mixing desk features can still be accessed by using the scrollbar to access covered areas of the mixing desk.

An additional feature was added to this interface design to facilitate the user study. This comprised a second button on the feedback authoring section of the feedback panel which enables the text feedback to be submitted alone without the additional auditory and tool representations. Study participants would therefore be able to submit either show-and-tell feedback or text-only feedback.

5.6. Study design

The music mixing-oriented show-and-tell feedback application was used to support teaching on two music production courses at post-compulsory education institutes (Sites A and B). The study was conducted 'in-the-wild' during class time and I therefore faced the challenge of trying to produce a thorough evaluation whilst minimising the time participants would be diverted from their primary educational activities by participating in this research.

For the work presented in this chapter I opted to work with post-compulsory education institutions with students aged approximately 16-19, because I was unable to conduct another study in a primary or secondary school during this period, and I had a pre-existing relationship with one of these education institutes which made it easier to get agreement for the study to run.

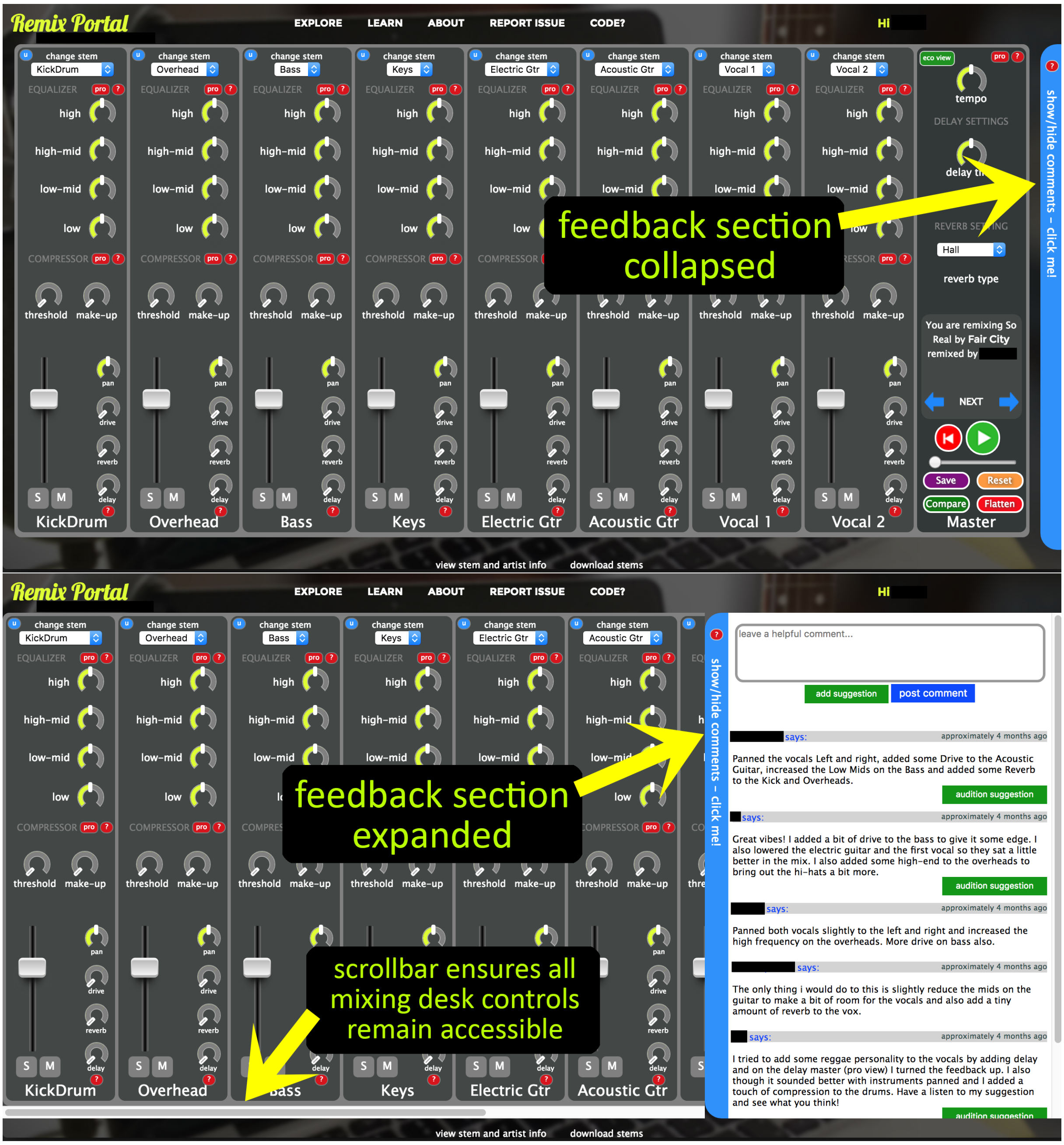

Figure 5.3 The feedback panel collapsed (top), and expanded (bottom)

5.6.1. Participants

At site A I worked with a class of 12 students who were studying on a one year introductory music production course. There was one mature student (aged 40-50, male) with the rest of the group being recent school graduates (aged 16-19; 3 female, 9 male). The majority reported having little or no music production experience prior to starting the course eight months earlier. These students were recruited through their lecturer. Whilst all of the class members participated at some point, only six of the group completed all phases of the study with the others missing one or more of the sessions. At this site, feedback was produced by three students studying on the final year of an audio engineering degree program (around four years of prior formal music production training) and six lecturers from the music and audio faculty.

The music production course at site B is taught across two campuses separated by some 50 miles. Four students are based at each location giving a total of eight student participants plus one lecturer. The students had no contact with their coursemates at the alternate location, and the lecturer had expressed a keen interest in exploring whether my technology could create a link between these two groups of students, in the hope that a wider range of influences would compensate somewhat for the small class sizes and enhance their motivation, attendance and performance, which currently gave him cause for concern. Seven of the eight students reported little or no previous music production experience and were studying on a one year music production course. The eighth student had completed this course the previous year and was now working towards a more advanced qualification. The group was all-male and contained one mature student with the rest being recent school graduates (aged 16-19). They were recruited through their lecturer. Only five of this group completed all phases of the study.

Procedures

Both deployments followed the same basic design which broadly resembled a within-subjects study, as the intention was to give students experience of both giving and receiving show-and-tell feedback and text-only feedback. There was a key difference between the study sites however, as at site A feedback came from classmates, students approximately four years further on in their studies, and lecturers (and therefore deviates from a strict within-subjects design in this regard); whilst at the second site students only received feedback from their course mates based at the alternate campus.

The broad concept across both studies was that participation should provide an opportunity for each student to receive formative feedback on the music mixing aspect of their main piece of coursework prior to its submission at the end of the academic year. Accordingly, both studies took place during the later stages of the academic year and they both followed the same four session format (depicted in 5.4), with each session lasting two hours. In the case of the deployment at site A, feedback from the lecturers and senior students was obtained during one-to-one sessions. I kept a reflective diary throughout, making notes after each session.

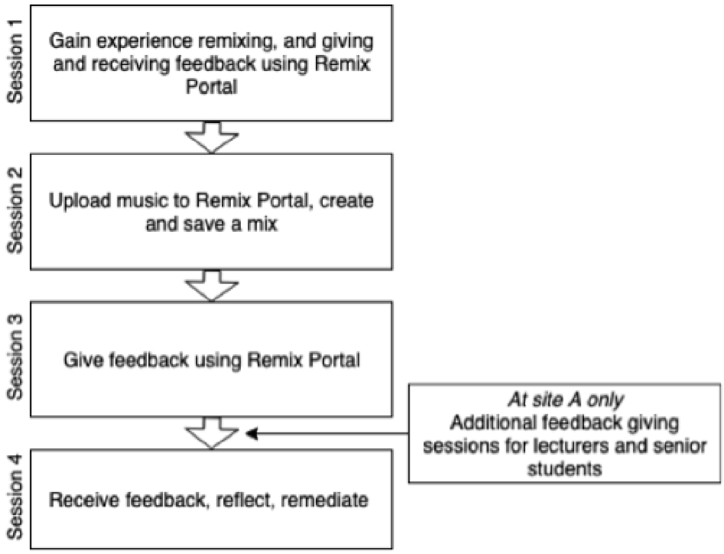

Figure 5.4 Sessions overview

5.6.2. Session 1 - Introduction

I briefed the students about the project and then gave them time to experiment with Remix Portal. Each student picked a song at random from the built-in song library, spent 30 minutes creating a mix before saving it. They then listened to two of their classmates' mixes and experimented by leaving text-only feedback for one, and show-and-tell feedback for the other. This session was designed as a taster; to check the software ran successfully on the college computers and for me to get a feel for the students' abilities in order to plan appropriate activities for the following stages of the study. Accordingly, feedback left during this first session was not used during data analysis. The session culminated in a group interview aimed at capturing the initial thoughts of the participants. This was audio recorded and later transcribed and thematically analysed by myself.

5.6.3. Session 2 - Uploading music

The goal for this session was for students to upload one of their near completion musical compositions into Remix Portal. This involved them finding their work on the institution's computers, exporting the audio files, uploading them into Remix Portal, then using the virtual mixing desk to create a mix which would serve as the basis for the feedback they would later receive.

5.6.4. Session 3 - Leaving feedback

During this session the students were instructed to *leave feedback that will help the receiver get better at mixing*. The activity was structured by giving each student a set of cards detailing who to give feedback to and what type of feedback to leave. Two such cards are depicted in figure 5.5. Green cards signified show-and-tell feedback (although it was referred to as *control change suggestion with text feedback*), whilst blue cards signified text-only feedback. The cards

Figure 5.5 Cards were used to organise the feedback authoring process

were organised to best as possible ensure each student both gave and received an even spread of text-only and show-and-tell feedback, and to ensure the first type of feedback was chosen at random with subsequent feedback alternating between the two feedback types.

Students were given 15 minutes to leave each piece of feedback. At the first site, the session culminated in each participant undertaking a short survey which sought to probe their experiences of giving feedback.

The final element of this session at both sites was a class-wide group interview aimed at gaining rich and detailed data about the feedback giving process. This was audio recorded and I later transcribed and thematically analysed this data. At site A one-to-one sessions were held with the lecturers and senior students between sessions 3 and 4, and the purpose of these was to generate feedback. These sessions followed the same procedure used in session 3, with each lecturer or senior student receiving a set of cards instructing them who to give feedback to and what type of feedback to provide. Again, these were organised to solicit an even quantity of each type of feedback, to try and spread the feedback evenly between the class members, and to ensure each type of feedback was used consecutively (to mitigate issues of presentation order bias). Their experiences were explored during a short interview which was audio recorded, transcribed and thematically analysed.

5.6.5. Session 4 - Receiving feedback

During this session the students reviewed the feedback left for them, then completed a survey which aimed to probe their experiences of receiving feedback. This survey was almost identical to the ‘giving feedback’ survey used in session 3, but with the focus switched from giving to receiving. Finally, to solicit richer data, one-to-one semi-structured interviews were conducted (lasting approximately 5 minutes per student).

5.7. Analysis

As might be expected, some students were absent from class during the deployment sessions. Table 5.2 shows the number of students present per session. In the end only 11 students participated in all deployment sessions.

	Week 1 Introduction	*Week 2 Uploading music*	*Week 3 Leaving feedback*	*Week 4 Receiving feedback*
Site 1	12	6	6	6
Site 2	8	7	7	5
Totals	20	13	13	11

Table 5.2 Number of student participants by week

	show-and-tell	*text-only*	*from classmates*	*from senior students*	*from lecturers*
participant 1	10	8	8	3	7
participant 2	8	10	8	3	7
participant 3	8	8	8	3	5
participant 4	8	7	8	3	4
participant 5	11	7	8	3	7
participant 6	10	8	8	3	7

Table 5.3 Quantity of feedback received by participants at site A

The site A deployment resulted in 103 pieces of feedback being generated (55 pieces of show-and-tell feedback and 48 pieces of text-only feedback). Of that feedback, 48 pieces were generated by the classmates, 18 pieces by the senior students and 37 pieces by the lecturers. Each student received on average 17 pieces of feedback on their submitted work. The quantity and nature of feedback received at this site is depicted in table 5.3.

Site B resulted in 29 pieces of feedback being generated with two of those pieces being provided by the lecturer who decided to stand in for an absent student. Each person received on average four pieces of feedback on their submitted work. Table 5.4 details the feedback received by each participant. It should be noted that some feedback givers chose to segment their feedback over multiple entries on the interface, and so the total number of pieces of feedback solicited is slightly lower than the total number of pieces of feedback counted as received.

Analysis began by looking at the survey responses to get a general picture of the participants' experiences of using the two feedback methods. The next task was to try and tease out insights which might explain this general picture and to shed light on the various aspects of my system's design. To achieve this the written survey responses were subjected to inductive thematic analysis and emergent themes noted, following the principles outlined in (Braun and Clarke, 2006). The

	show-and-tell	*text-only*	*from classmates*	*from senior students*	*from lecturers*
participant 7	1	1	2	0	0
participant 8	1	1	2	0	0
participant 9	1	3	4	0	0
participant 10	3	3	6	0	0
participant 11	2	2	4	0	0
participant 12	4	3	5	0	2
participant 13	2	2	4	0	0

Table 5.4 Quantity of feedback received by participants at site B

transcripts of the one-to-one interviews and group interviews were then analysed, extracting content relating to these themes, whilst remaining open to additional themes emerging (although no further themes did emerge). Finally, I undertook a triangulation process comparing the qualitative and quantitative outputs.

5.8. Quantitative results

Figure 5.6 summarises the results of the close-ended survey data collected at the end of session 4. As noted earlier, all participating (non-senior) students experienced receiving and giving both show-and-tell and text-only feedback. When asked on a bipolar scale which feedback type helped them the most to develop their mixing skills, students overwhelmingly favoured show-and-tell feedback (n=10 out of 11 - Figure 5.6A). Students also rated each feedback type's ability to help them understand what to do to improve their music mixing skills (Figure 5.6C). On a Likert scale of 1 to 5 (1:strongly disagree, 5:strongly agree), students agreed that show-and-tell feedback was helpful (avg.= 4.5) while they neither agreed nor disagreed about the helpfulness of text-only feedback (avg.=3.2). Similarly, all but one student thought show-and-tell feedback helped them the most to improve the music artefact they were working on (Figure 5.6B). In addition, participants deemed that show-and-tell feedback was better at making visible the feedback givers' working methods (avg.=4.6) compared to text-only feedback (avg.=3.5, Figure 5.6D).

Only participants at Site A contributed quantitative data concerning the feedback giving experience. Their responses showed a similar trend to that depicted in Figure 5.6, with a clear preference for show-and-tell feedback. This general preference held true for each type of participant I worked with; the novice students, senior students and lecturers.

5.9. Qualitative results

My thematic analysis of the collated qualitative data helped me understand why participants expressed a preference for show-and-tell feedback. However, it also revealed some challenges which people designing show-and-tell feedback systems may wish to address going forward. My identified themes of *clarity, level of detail, the role of artistic vision*, and *who is in control* are presented below along with supporting empirical evidence.

5.9.1. Clarity

When reflecting on feedback they had received, many participants complained about text-only feedback's lack of clarity. I received lots of comments such as "*It could sometimes be difficult to understand what someone was trying to say*" (P2), or "*Some [text-only feedback comments] were very vague*" (P3). A weak connection between the text-only feedback mechanism and the proposed changes to the artefact was evident, for example: "*[It's] hard to understand how people think it should sound without hearing it*" (P1), or "*[I didn't like] the fact you can't actually hear what they mean, only an opinion of what it should be*" (P7). This difficulty was

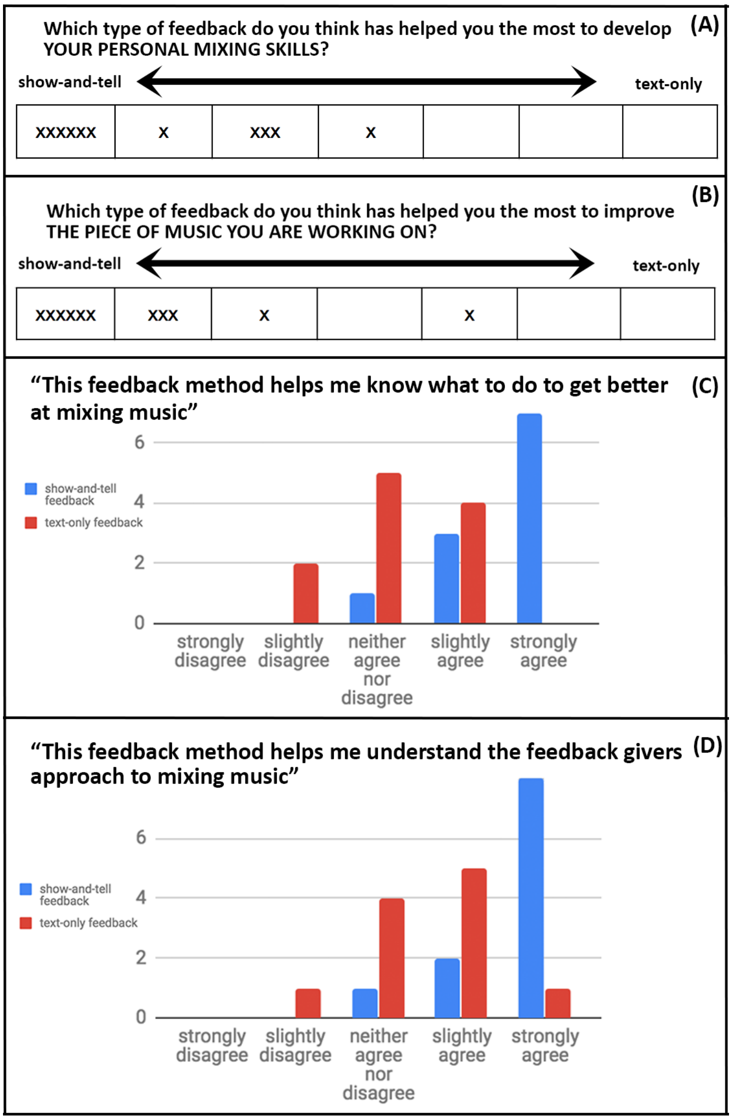

Figure 5.6 Survey responses from feedback recipients

also expressed by feedback givers e.g. "*It can be hard to put what you think into words to then comment about*" (P2), or "*It was harder to explain without showing*" (P14). Such text-only feedback requires interpretation by the person receiving, which may be particularly challenging for novices: "*[Text-only feedback] can be slightly vague in that you have to second-guess what they mean... [It's] useful if you already have an idea of what is being suggested. Probably better for more advanced mixers.*" (P5). Some participants appeared to be unable to interpret the feedback at all. For example, when asked what he didn't like about text-only feedback (P11) stated "*It doesn't show you [the feedback giver's] thought on the piece*".

In contrast there was a strong sense that text comments can be made clear when a feedback receiver is able to actually experience the proposed changes to the artefact, as show-and-tell allows: "*This method is very helpful because you're not only getting text feedback but an actual demonstration of what others would do to the mix from their perspective*" (P13).

Some comments referenced show-and-tell feedback's ability to let recipients see or hear the proposed changes to the artefact, whilst some comments referenced both: "*This is much better. You can see and hear what they mean*" (P12), or "*I like how you're able to hear and see how the person has changed the settings. It's really helpful.*" (P7). In using the terms 'hear' and 'see' these participants are showing appreciation for this feedback method's ability to allow them to perceive the change in the artefact, as well as its ability to make visible how tools on the interface have been used to implement this change. One participant described this feedback method as providing... "*a nice map of how you could remix it yourself*" (P9).

5.9.2. Level of detail

Participants described show-and-tell as being more detailed and precise. Feedback givers described being able to 'do more' and one lecturer described how show-and-tell opened up a new level of subtlety to them. Another lecturer suggested that the precision comes from being able to try out and refine the feedback using the interface tools before submitting it to the recipient, a process which conventional text-only feedback does not support: "*lecturers often pretend that they know exactly what needs to happen to fix things but they can't know that - not everyone knows that instantly - you need to test what you think, and it's an experimental process*" (Lecturer 2)

Whilst our student participants were given exactly 15 minutes to leave each piece of feedback, lecturers were given a little more free reign. I noted that most of the lecturers appeared to demonstrate a higher level of immersion when giving show-and-tell feedback, and it frequently required my prompting for them to bring these pieces of feedback to a close. One lecturer explained how the process of creating show-and-tell feedback made him lose focus on his role as an educator, and instead step back into his former role as a music producer and mix engineer:

> "I noticed that with the text-only feedback I'll say the most immediate thing in the mix whereas with the [show-and-tell] feedback I didn't really know when to stop, and that's maybe my fault, so maybe I should have just made one or two obvious changes because I couldn't really stop myself just continuing to mix it and mix it

> [laughs] and so perhaps the students wouldn't be able to take on board all those changes at the one time. Maybe I was thinking more as a mix engineer rather than as a lecturer now I look back, because I was trying to make the best mix I could rather than help someone improve their mixing." (Lecturer 3)

Some of our participants appeared to find the more expansive show-and-tell feedback left for them somewhat hard to digest: "*Too many changes can be confusing and overwhelming*" (P5). Others suggested a tendency for the explanatory text component of show-and-tell to be somewhat overlooked: "*Some people changed things in the controls but did not explain why*" (P3), and "*It would help if they had more text written as well*" (P11). To explore this I computed the mean average word counts for the text components of both types of feedback, and found them to be of very similar length 25.8 words for show-and-tell feedback and 25.2 for text-only feedback. This suggests that either participants were referring to specific examples or that show-and-tell feedback may necessitate the inclusion of a greater quantity of text than for text-only feedback, perhaps because more is communicated through the 'show' component and therefore more tell is required to contextualise this information.

Several lecturers appeared to pre-empt the issues described above and developed personal strategies to try and make their show-and-tell easier for the recipients to comprehend, which often involved splitting feedback over several entries so that each interface change and piece of explanatory text related to a single concept or tool within the interface:

> "You need to layout your explanatory text well using numbers or bullet points and making it quite concise so people know what they are looking at when they see the interface change. They'll be like, "there's the pan comment… oh now I see what you've done with the pan"" (Lecturer 1)

Other lecturers appeared to start formulating a strategy upon reflection:

> "Maybe when using show-and-tell feedback I need to write more and do less. Maybe the balance isn't quite right because I only wrote one sentence, two sentences at the most. So I was really just writing about [obvious] levelling changes and not about the subtleties of the mix. The show-and-tell maybe explored more subtleties of the mix." (Lecturer 3)

5.9.3. The role of artistic vision

Most of the feedback givers, whether novice students, senior students or lecturers reported leaving feedback that represented their own interpretation of the how the artefact should be shaped, as opposed to considering the feedback recipient's vision for the artefact and trying to help them achieve their aim: "*It allows you to tell the artist how you think it should sound*" (P1) or "*you've got to listen to the song and the song will tell you what has to be done to it*" (Lecturer 3)

The feedback givers' artistic vision was more clearly transmitted though show-and-tell rather than text-only feedback, and some participants were happy to try out any show-and-tell feedback left for them, sighting its potential to give them new ideas: "*You can see how others think and maybe take their opinions*" (P4), and "*I can hear how other people prefer to mix certain sounds with others, affecting new ideas*" (P3). The majority of recipients however expressed some concern around feedback they received which did not align with their own artistic vision for the artefact: "*Some suggestions were too different from my ideas*" (P6). One of our lecturers proposed that aligning feedback to the recipients artistic vision becomes more important the more advanced the recipient:

> "Maybe it depends what level, because, let's say it's an NC [novice] student, if you aren't involved in lots of genres and your aesthetic awareness isn't that good and your stylistic sympathies aren't great you could still probably help out with the basic stuff couldn't you? Like balance and panning. You could make a lot of helpful comments I think. But perhaps as you get up the levels and peoples' mixes are becoming a bit less amateur or beginner then I think it does help to have someone who is within your niche, to make those comments that can push you forward in your craft." (Lecturer 1)

5.9.4. Who is in control?

An issue that emerged with show-and-tell feedback was that the feedback giver can take over the artefact. One of our senior student feedback givers reported being uncomfortable with this: "*It's sometimes hard to give feedback as it makes me feel bad when changing someone's mix if they've worked on it*" (Senior student 2). Many of the feedback recipients expressed similar concerns e.g. "*I wouldn't want some random guy being like 'You should change this thing' because it's like 'bruv I don't know you', you know what I mean?*" (P3).

In contrast, the ambiguity inherent in text-only feedback allowed the feedback recipient to feel like they retained ownership, with the feedback serving as a jumping off point for experimentation and self-reflection: "*since [text-only feedback's] not always exact, it can be fun to play around with*" (P9). One of the downsides of text-only feedback's ambiguity is that it does not make-visible the competence of the feedback giver, which emerged when asking participant 15 what they didn't like about text-only feedback: "*You are unsure of how musically advanced the person leaving the comments is*".

5.10. Discussion

The goal of this work was to gain insights into the impact upon user experience of a system designed to support the transmission tacit knowledge within learning feedback. Many participants specifically referenced the demonstrations (showing) that show-and-tell feedback facilitated. My findings, within the themes of clarity and level of detail, evidence the quality of those demonstrations. The quantitative data even more directly demonstrates that modelling could be facilitated through show-and-tell feedback via its ability to make visible the feedback givers' working methods. Given the assumption I drew from the literature; that effective modelling and coaching can lead to tacit knowledge transfer, and requires both demonstration (show) and explanation (tell), I believe this work offers preliminary evidence that show-and-tell feedback could support tacit knowledge transfer. However, this should be tested in future work employing a different set of methods which are more oriented towards measuring knowledge transfer as opposed to a focus on gaining insights into user experience.

The fact that participants judged the feedback they received through the show-and-tell method to offer clearer feedback was encouraging but not unexpected based on what we know from the Multiple Representations literature, which reports the inherent ambiguity in descriptive information representations such as text information, and how this can be resolved through the inclusion of depictive representations - in our case these were the auditory information (the sound of the music) and tool use information (the state of the interface controls) which together provide the 'show'. That participants deemed show-and-tell to also offer a greater level of detail can be put down to a number of factors. Firstly, consider that some feedback givers (the lecturers) were observed and self-reported being more immersed during show-and-tell feedback provision than during text-only feedback provision. We might infer that the engaging nature of the feedback leaving process produced the immersion which led to this greater level of detail. Secondly, consider that the auditory and tool information communicated through the 'show' inherently allows for a level of subtlety which a descriptive representation cannot meet due to its inherent inaccuracy. Finally, consider that each type of information makes a slightly different but complementary contribution. Auditory information (in the form of hearing the music) targets critical listening skill development, the tool information targets tool application skills, and descriptive representations can convey strategic information necessary for participants to develop a conceptual model of the task as a whole, and also help recipients develop their domain-specific vocabulary.

The results also demonstrate that text-only feedback cannot convey sufficient clarity and detail to adequately support coaching and modelling. This is to be expected given the tacit nature of the music mixing activity where we can "*know more than we can tell*" (Polanyi, 2009), or as one participant put it "*It was harder to explain without showing*" (P14), coupled with the inherent ambiguity of descriptive (text-based) information representations (Ainsworth, 2006). In our case, ambiguous musical terms contained within the feedback text (such as 'bright', 'harsh' or 'boomy') cannot be made clear without the support of the auditory, non-verbal representation, to provide a tangible example.

Whilst the results demonstrate the potential of the show-and-tell feedback concept, they also indicate areas where this first iteration of the music mixing-oriented show-and-tell feedback system could be improved upon. A common issue raised by participants was that feedback givers did not always provide sufficient text-based explanations to accompany their demonstrations i.e. not enough *tell* accompanying the *show*; e.g. "*Some people changed things in the controls but did not explain why*" (P3). Similarly, feedback givers reflected that they should perhaps have left more explanatory text. This can be attributed to an over reliance on the show element. As explanations of experts' actions are an important part of modelling, consideration should be given to how best to address this issue. One approach would be to scaffold feedback givers to leave more comprehensive text explanations by, for example, triggering a pop-up text-entry box each time a control is changed, with a dialogue asking the feedback giver to enter text to explain the control's use. Less invasive and less likely to detract from the feedback giver's flow would be to append a text prompt to the comments box for each control changed, along the lines of "*I changed control X because...*". Scaffolding feedback, particularly when it comes from non-experts, is a common technique used by those creating distributed feedback and critique systems (Kou and Gray, 2017). Previous work highlights the need to support learning interactions, especially when these interactions involve non-expert educators (e.g. peers) (King, 1997), and suggests that such sentence openers could be effective in helping feedback givers produce on-task, and therefore helpful text comments (Baker and Lund, 1997), and Lazonder et al. (2003) postulates that their application may be best suited to a-synchronous communication contexts like this. It may also be the case that encouraging the feedback givers to reflect upon and explain their proposed changes triggers the detection and repair of any misconceptions and knowledge gaps they posses – thus enhancing the benefits to both feedback givers and receivers (Webb and Palincsar, 1996).

Although not directly addressed by the participants, modelling could be further enhanced by clarifying the steps the feedback giver went through, as opposed having our system simply present the totality of their changes and relying on the feedback giver to convey process information within the text component (as is currently the case). The visual imagery mockup show-and-tell feedback interface presented earlier in this chapter accommodated this through a feedback history list. Such a list could relatively easily be implemented within Remix Portal, or some variation on this theme like a set of 'step through' buttons. This latter approach would also address an issue that was raised by the participants, in that "*Too many changes can be confusing and overwhelming*" (P5) coupled with the fact that there was a tendency for some expert feedback givers to do just this (i.e. provide too much feedback). If left unaddressed this may hinder the development of the feedback recipient's conceptual model as a key component within this domain is an understanding of the relationship between tools (interface controls) and their impact upon the artefact. Changing one interface control at a time and experiencing the result upon the artefact obviously makes this relationship clearer (as the step-through process would allow). This may be particularly important when changes are subtle and thus more difficult to detect perceptually.

A related issue concerns exactly which interface controls are suitable candidates for inclusion within the feedback. Within this Remix Portal iteration I chose to only record changes to interface controls that produce a tangible change in the creative artefact. The advantages of this approach are that it helps keep the feedback simple and reduces the chance of a recipient expending effort searching for a change in another representation state which may not be there — a situation which could prove demotivating. For example, should a feedback recipient spend time and effort listening with great attention to try and discern the auditory impact related to the interface change, only to realise the interface change has not impacted the audio, they may be less inclined to expend as much effort in future. However, an argument could also be made that all interface control changes should be recorded, even those that don't impact the artefact, such as controls used to zoom in and out and to start and stop playback, as they would give a more detailed picture of the feedback giver's process and thus might help enhance the recipient's developing cognitive model. I therefore acknowledge that further work is be required here to understand how best to approach these design subtleties.

The themes of artistic vision and control reflect not only of the challenge of putting show-and-tell feedback into practice, but of inducting students into critique processes generally. For example, it is known that feedback which recipients deem as controlling or critical can thwart efforts to improve performance (Baron, 1993). They serve as a reminder that novices may find it hard to accept criticism, and may benefit from support as they learn how to take advantage of feedback from critique sessions (Tinapple et al., 2013). Instructors should therefore give thought as to how best to support learners as they begin participating in show-and-tell feedback processes. Designers might be able to mitigate this problem to some extent by creating mechanisms to help feedback seekers reflect upon and communicate where they would like feedback givers' input — perhaps asking for help with a specific aspect of the artefact manipulation. This could enable the feedback recipient to maintain control of their artistic work as it should reduce the likelihood that feedback givers will creatively reimagine the work at times when it would be inappropriate, such as when the recipient is in the latter stages of their work and interested in help with refining their own artistic interpretation.

The results exposed a particular issue which occurred when feedback revealed a mismatch between the artistic visions of the feedback giver and feedback seeker. Most feedback givers reported creating feedback that aligned with their own interpretation of the artefact as opposed to trying to see things from the feedback seeker's perspective and aligning their feedback to this. However, this only appeared to pose a problem when the feedback was broad, with many controls on the interface changed, because such broad feedback could reveal the feedback givers' creative vision, whilst it typically remained hidden when feedback only involved a small number of controls on the interface. I therefore offer two potential suggestions for design to mitigate this specific issue:

- Pair feedback seekers with feedback givers who share aesthetic sensibilities i.e. who are likely to have complimentary artistic visions for the artefact. This is perhaps better suited to a wide network context such as an online community with lots of active participants. Implementing such a system could involve feedback seekers rating each piece of feedback they receive. Then when they submit artefacts for review in the future any feedback left could be sorted based on the scores previously assigned by this feedback seeker to these feedback givers, making feedback from appreciated feedback givers more prominent. A simpler approach would be for feedback givers to request feedback from people they 'follow'.

- Restrict the number of controls feedback givers can modify thus limiting the potential for their artistic vision to be made visible to the feedback seeker. This may be more applicable in an environment like a class of students where the number of potential feedback givers are

> small and therefore people who do not share aesthetic sensibilities will still be involved in feeding back to one another. In tandem with restricting the number of modifiable controls, precomposed sentence starters (Lazonder et al., 2003) could again play an important role in focusing the attention of the feedback givers so as to dissuade them from leaving broad feedback, possibly encouraging them to focus on specific tools or concepts instead.

Whilst I anticipated that the text-only feedback would be viewed as more ambiguous, I thought resolving this ambiguity through the other representations would be seen as a universally positive, when in fact at times this ambiguity was preferred as it made the feedback seem less prescriptive and helped the recipient retain a feeling of control over their creative work. At other times however, particularly the later stages in the production process when the recipient wants to refine their artefact, this ambiguity will not be as welcome. I have organised the types of issues participants said feedback helped with into three categories, which I believe may be applicable across other creative contexts: i) Help developing their creative vision for the artefact i.e. getting ideas ii) Help using the interface tools to implement their existing creative vision successfully iii) Help identifying any inadequacies within the artefact which they may have been unable to perceive. Designers could create mechanisms to help feedback seekers reflect upon where they would like feedback givers to focus and then communicate this to the feedback givers. An example implementation could involve feedback seekers choosing from a range of exemplar questions related to the three focuses for feedback listed above, perhaps filling in blanks or otherwise modifying the text to suit their own needs, then this question, or set of questions, would be made visible to help guide feedback givers.

As I stated in the opening sections of this chapter, I believe the show-and-tell feedback concept could be applicable to other creative digital media domains, beyond digital music mixing. For example, those learning digital photography face similar challenges around ambiguous language when receiving feedback from an expert: a photograph may be described as ‘washed out’ but such descriptions provide no clues as to what tools correct this issue, how to use them to do so and how to recognise when the issue has been successfully resolved. Secondly, there are similar challenges around perceiving changes in artefacts, particularly when they are subtle. A useful point for future work would be to implement the visual imagery-oriented show-and-tell feedback interface presented in 5.4, and conduct a similar exploration of its impact upon user experience. A visual imagery-oriented show-and-tell feedback interface would function very similarly whether the creative artefacts are photographs, graphic illustrations, static cartoons etc., however implementation would get a bit more complicated when applying this concepts to dynamic visual arts like movies and animations. Yet, the same fundamental design criteria could still be applied. It would just require feedback and changes are time-stamped and time-ranged, if they apply to a spatial region of the artefact and not the artefact as a whole, and presented accordingly to the user. Time-stamped comments were in fact implemented within the music remixing application but were not utilised in the reported deployments for the sake of simplicity. Similar issues around control and artistic vision are likely to exist in such creative domains too. For example, there is no absolute correct way of processing an image - it is a matter of personal aesthetics, and therefore any feedback suggestions which deviate too far from a feedback seeker's personal aesthetic sensibilities may well be viewed negatively. Accordingly, these design suggestions (such as facilitating feedback seeker questions to maintain control, and step-through demonstration lists to enhance clarity) may help designers produce effective show-and-tell feedback systems for a broader range of contexts beyond music mixing.

5.11. Conclusions

In this chapter I presented the show-and-tell feedback concept, which is an attempt to facilitate tacit knowledge transfer via feedback. I described a Remix Portal iteration which encompassed a show-and-tell feedback interface. It was used to support teaching on two music production courses. The study at these two 'in-the-wild' settings provided insight into how show-and-tell feedback can impact the experience of feedback givers and receivers, in comparison with conventional text-only feedback.

My findings revealed that show-and-tell feedback can offer clearer and more detailed feedback than text-only feedback, and is broadly favoured by feedback givers (both experts and novice peers alike) and feedback receivers. However, the study revealed issues around artistic vision and control which may hinder the potential benefits of the show-and-tell feedback approach. Accordingly, the work presented in this chapter culminated in presenting suggestions for how these issues might be mitigated through design. I believe these suggestions could make interesting areas for future work.

Whilst the work presented in Chapter 4 revealed the motivational benefits that can come from having musicians provide feedback to novice music mixers, I acknowledged that further work was required to investigate how to optimises the knowledge transfer that may occur through this process. My response is the show-and-tell feedback interface as presented here, and the results of deployments in two further education settings show strong evidence that it should lead to better learning gains than would occur with conventional text-only feedback.

Chapter 6. Designing to support Knowledge Transfer via Worked Examples

6.1. Introduction

The study presented in this chapter addresses the research question: *How can we capture and use expert knowledge in the form of music mixing-oriented worked examples to support music mixing skills acquisition?* This research question and the work it reflects was born from the realisation that Remix Portal, in its show-and-tell feedback configuration, is capable of serving other pedagogical functions. Specifically, I realised that it is capable of delivering music mixing *worked examples* to students at the beginning of a learning cycle. I reasoned that this pedagogical approach is worth exploring as, firstly, it differs significantly from the feedback scenario in terms of the placement of the artefact manipulation demonstrations. Therefore, this scenario may represent a good way of harnessing and using expert knowledge for situations where experts are unable to participate as feedback givers. These demonstrations were provided after (and in response to) learner activity in Chapter 5's show-and-tell feedback scenario. In this study however, they would precede learner activity i.e. participants would be presented with the artefact manipulation demonstrations to explore before working on their own music mixes. This study could therefore contribute to expanding our understanding of how we should design technology to support the learning of music mixing skills and creative digital media skills more broadly. Furthermore, this study could potentially contribute to the body of knowledge around worked examples, as a gap exists around using worked examples to support craft-based skill development. The final factor which motivated this study was the realisation that no additional software development would be required, as Chapter 5's Remix Portal iteration could simply be redeployed here. Therefore I could conduct this study with very little labour expenditure, in comparison with the other studies presented in this thesis.

Within the literature review I presented a framework for understanding fundamental differences in approach and performance between novice and expert music mixers. From this I derived a set of four key music mixing competencies: possession of a clear vision for the music, a process centred around holistic judgements, highly developed critical listening skills, and an actionable understanding of the link between tools and musical attributes. These competencies will be used to help evaluate music mixing worked examples' impact upon learning.

The aim of this study is to explore whether worked examples delivered via the Remix Portal interface, constitute a useful music mixing learning and teaching aid. The study objectives are:

i To explore participant perceptions around the usefulness of worked examples.

ii To look for evidence of the worked examples supporting the development of the four key music mixing competencies.

iii To gain insights for the design of music mixing worked examples and the systems that host them.

6.2. Study design

Given the exploratory nature and breadth of my three stated aims, I opted to employ a qualitative method, probing participants perceptions of the worked examples during short, semi-structured interviews. This fitted well with the contextual constraints imposed by study environment. The study took place at a further education college. This was, in fact, the same further education college where one of the show-and-tell feedback deployments had occurred the previous year (as reported in Chapter 5), however with the exception of one lecturer, none of our new participants had been involved in our previous work. The study constituted a single, two-hour class where the worked example units were used to support the teaching of music mixing skills. These student participants were at a busy point in the academic year, and with the study taking place during class time a method had to be employed that would have minimal impact upon their main class activities whilst providing data that would allow us to address our research objectives, and short interviews were deemed most appropriate in this respect. All student participants were given the opportunity to opt out of participating in the interviews (and thus bypass data collection) but nobody took up this offer.

6.2.1. Participants

Participants consisted of one lecturer plus 14 students. Of these students four were female, ten were male, and all were around 20 years of age. They were all in their third and final year of an Audio Engineering degree course and thus, having reached this stage in the course, it could be assumed that all possessed a reasonable level of competency with music mixing techniques and technologies. As mentioned, they were recruited by their lecturer and whilst participation in the class was mandatory (as it was a regular college class) all students were given the option to decline participating in the data collection element of the study.

6.2.2. Procedures

During the co-design sessions with the lecturer I focused our attention on how the worked examples would be incorporated into his teaching practice and used during the class session. We decided that each participant would sit at a computer workstation and would be given around five minutes to explore a specified worked example before the lecturer would ask the participants what they noticed, then he would play the example over loudspeakers and demonstrate the before and after processing, and explain his thought process which underpinned the mixing presented in the worked example. The first hour of the session was dedicated to this purpose, so a number of worked examples to be explored in this way.

During the second hour of the class, the students were asked to choose and then mix a song from Remix Portal's library, applying any relevant knowledge or techniques they had acquired from the worked examples. During this time, I interrupted pairs of students from their mixing task in order to conduct semi-structured interviews. I had opted to interview them in pairs due to the advantages of paired interviews (peer support helps produce more open and articulate responses, as described in 3.3.2) as well as to accommodate time constraints. The questions I asked each pair were loosely based on the following set:

- What do you like about the examples?
- What do you not like about the examples?
- Did you learn anything specific from these examples?
- Do you think these examples convey any kind of strategy you could use in the future?
- When you got to do your own mix, did you do anything based on what you learned from the examples?
- Does [the lecturer's] mixing process differ from your own mixing process? If so, how?
- How has your mixing process changed over time?
- How did this lesson using the examples differ from a normal lesson?

The session ran slightly over the allocated two hours. Later in the day I conducted a 20-minute semi-structured interview with the lecturer to probe his reflections on using worked examples within his teaching practice. I asked the lecturer what he liked and disliked about the worked example units, whether he thought there were any aspects of learning they were particularly good at supporting, and in what ways the lesson in which they were used deviated from a normal lesson. The class session along with all the interviews were audio recorded then analysed, and content that related to our research aims was extracted and transcribed.

6.3. Creating the worked examples

As the study was to revolve around the use of a set of worked examples, I had to give consideration for how to produce these worked examples. Given the contextual difference between the domain of music mixing and the domains within which worked examples are typically employed (STEM), I decided that the design suggestions from the worked example literature would not be the best place to start. Instead, I engaged the class lecturer (a former professional recording engineer and mixer, and an experienced educator) in a co-design process to create an initial set of worked examples based on his experience of best practice teaching within this domain.

The class lecturer and I spent two, two-hour sessions on this co-design task. During the first session I explained the background to worked examples and the worked-example effect. We then discussed the prospect of the before/after processing of a whole mix constituting a worked

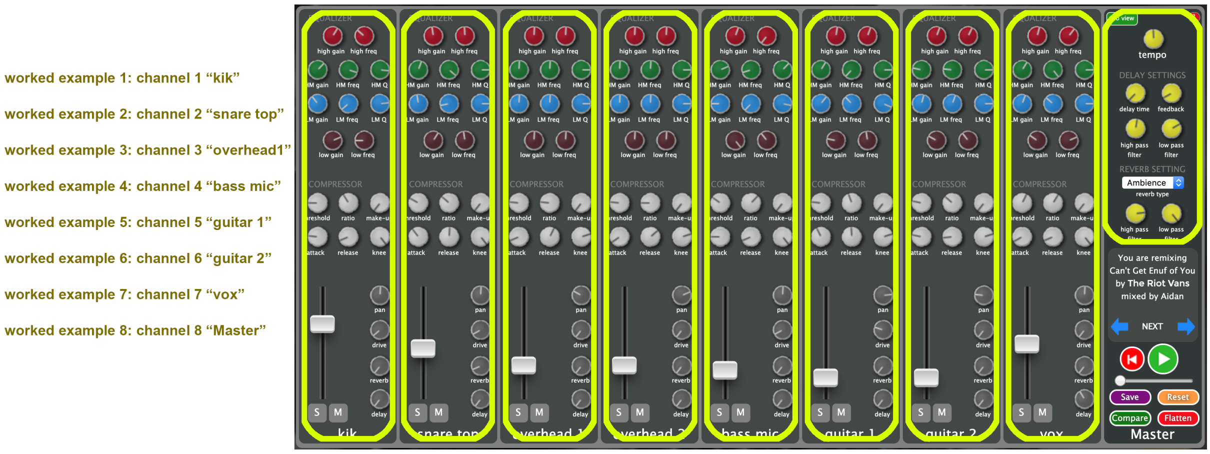

Figure 6.1 The processing applied to each mixer channel can constitute a worked example unit

example i.e. the idea that a worked example would provide information on every interface control that was changed from its default position to produce the polished mix. We reasoned that this may present an overwhelming quantity of information, given that an expert music mixer may change hundreds of dials or sliders on the interface whilst creating their mix. This quantity of information may be too hard for participants to unpack and make sense of. For example, it would be hard for participants to understand the relationship between one changed dial and its impact upon the sonic change induced in the artefact in the presence of hundreds of simultaneously presented dial changes. We therefore decided that mix processing should be segmented into more manageable processing chunks – I refer to these from here on in as *worked example units*.

We then focused on how to manage this segmentation, and considered two potential types of worked example unit: either those where the processing is applied on a single channel (depicted in figure 6.1), or those where the processing is applied to impact a musical dimension (such as tonality, dynamic, sense of width, sense of depth etc.). This latter approach is depicted in figure 6.2. In the end, we decided to concentrate on the former, *worked example unit by channel* approach as the lecturer was used to isolating channels when demonstrating mixes, and therefore felt more comfortable with this as it more closely matches his normal teaching method. However, we included one *worked example unit by musical dimension* as we wanted to get some feedback from participants around the segmentation strategies.

We settled on the idea of the lecturer mixing one song within Remix Portal, from which we would generate a set of worked example units. The lecturer considered that this would create a suitable amount of material for the participants (his students) to engage with over the course of a two-hour class.

The second co-design session was dedicated to creating the worked example units. This involved the lecturer uploading raw audio files for a song he had recorded, then creating and saving a mix within Remix Portal. I then segmented the processing applied within this mix by manipulating the data stored in the database, in order to create processing *chunks* which matched what we had agreed would constitute the worked example units. I then added each of these chunks as a show-and-tell comment, as well as using one comment to represent the mix as a whole. I entered basic text descriptors within these comments, such as "*Here is Dave’s treatment*

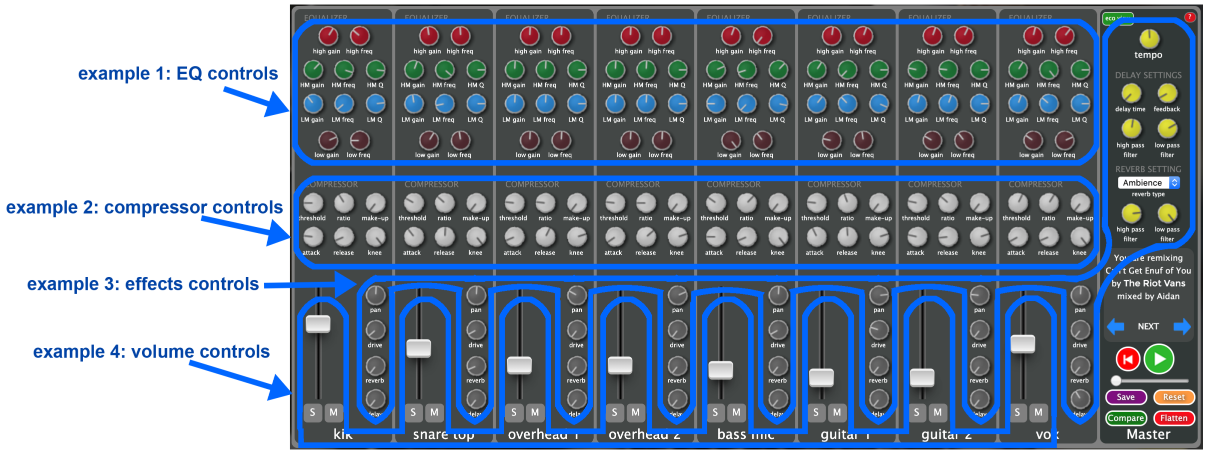

Figure 6.2 The processing applied by each control type can constitute a worked example unit

of the 'kik' channel". I did not enter text explaining the lecturer's processing here as he wanted to convey this information directly whilst teaching the class. Finally, I reset the default mix to an unprocessed state. It should be noted that the worked examples could have been created without such a convoluted method. Specifically, the lecturer could have created them directly within Remix Portal without me having to perform any database manipulations, however, due to time constraints and the lecturer's unfamiliarity with Remix Portal, I considered our approach to be the most reliable for this situation.

In total, eight worked example units were created to represent an effective music mixing process for the demonstration song. Participants would access these worked example units by opening the comments panel within Remix Portal, and clicking on an *audition suggestion* button. The examples as they would appear to the students are depicted in figure 6.3 – the salient information is the yellow control-set outlines as they indicate what controls have changed and therefore what processing is demonstrated within each worked example unit.

6.4. Results

This section includes the results from the worked examples deployment sessions. These results are then discussed in the subsequent section and then returned to in the concluding chapter of this thesis where they are integrated with the results of the other deployments.

6.4.1. Session observations

During our class session, after participants had explored each worked example unit, the lecturer talked for around five minutes, explaining the thinking which underpinned the processing he had applied. These explanations usually referenced four things:

1. The subject of the worked example unit itself, as evidenced in the following example where he discusses the tonal properties of the subject: "*I scooped out around about 300-400Hz on the kick drum where there is a kind of boxiness*"

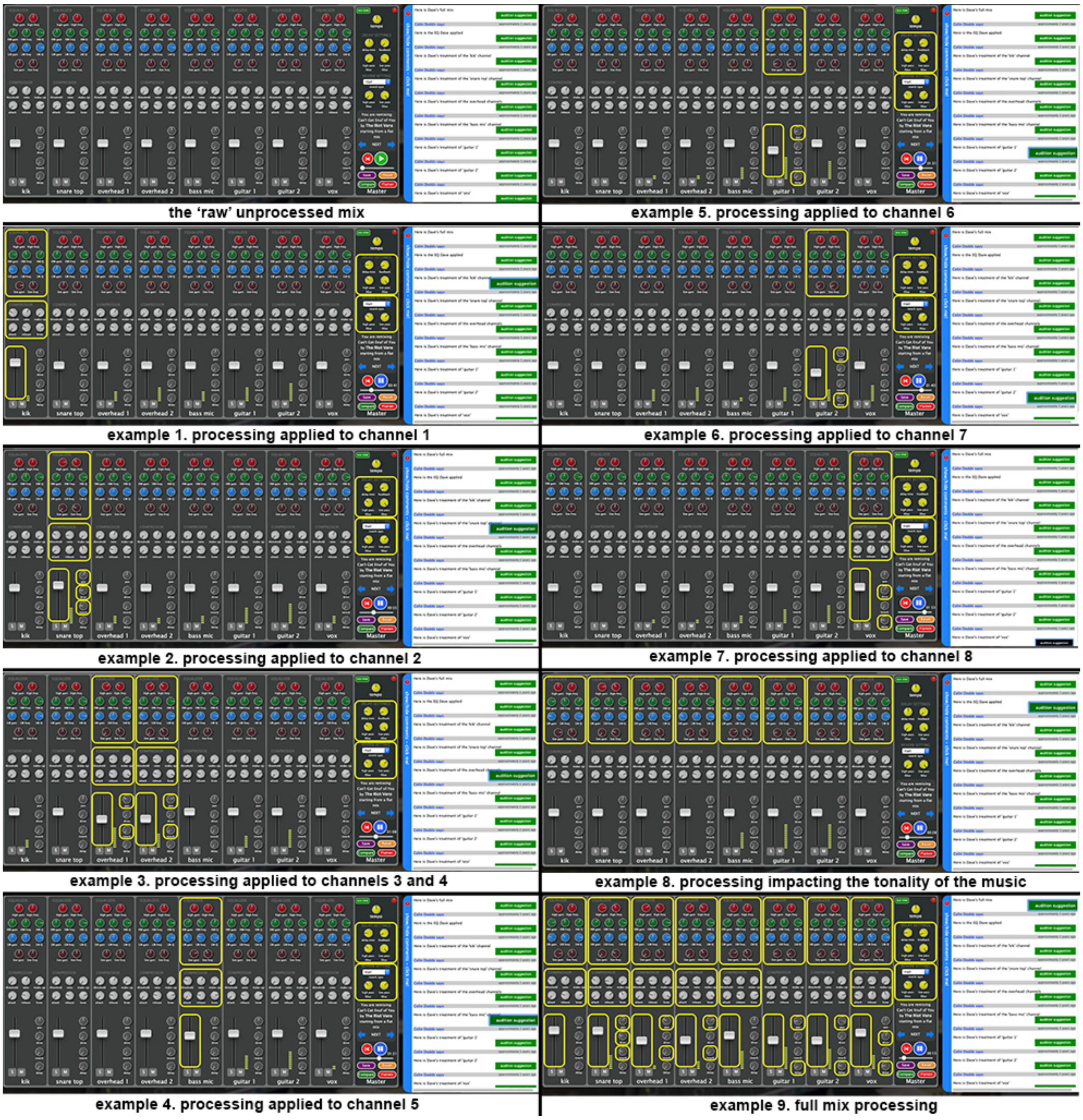

Figure 6.3 Interfaces depicting the processing associated with each worked example unit

2. The impact of the processing on other elements of the music besides the subject of the worked example unit. In the following example the kick drum is the subject yet he references the bass guitar: "*I've scooped out the middle [frequencies] of the kick drum so that the bass [guitar] can fit in between it*", and in this second example he references the drum kit as a whole: "*It sounds a bit top heavy when you solo it but remember I mixed it to blend in with the other elements of the drum kit*"

3. The dimension of the music he was considering when applying his processing: e.g. "*So with the kick drum I basically split it tone-wise into two halves*"

4. A general underlying principle. For example, he segued from talking about a worked example unit and how he had removed low frequencies from the snare drum, to talking about his approach to low frequencies generally in rock and pop music "*...and as you'll see in the other examples I tend to remove the low frequencies from everything except the kick and the bass, which gives a window for those instruments' frequencies to work in without any other instruments frequencies conflicting with that, which is how you get a tight bottom end which is what I always want*"

Once the lecturer had the attention of the students following their engagement with a worked example unit, he would ask them what they had noticed. This brought up issues which guided the lecturer's explanation. For example, one participant commented on noticing the sense of width created for the cymbals by the pan control settings: "*I notice you didn't pan the overheads [cymbals] all the way*". This may indicate the participant's preconception about the conventional way to process these channels. The lecturer was able to offer a justification for his decision which was aimed at helping the students develop their strategic thinking:

> "That's because you want the guitars wider than the drums, because if you think about trying to create an illusion about watching a band you would have the guitarists further to the side of the stage than the drums, the drums would be quite narrow really. If you listen to the mix it actually becomes really big by focusing the drums down the middle."

He also attempted to address potential preconceptions by not just explaining what he had done, but also what he didn't do: "*I haven't boosted the top end on this one because the guitar is quite distorted sounding already and so if you turn up the high end it just becomes really fizzy sounding*".

He would usually frame his processing explanations as questions:

> "Have you ever noticed in your own mixes how overhead cymbal hits are just there and gone? So you need to add compression to increase their sustain to match all the other heavily compressed instruments which will have long sustains. That's why I added compression here. It's a rock thing that lots of engineers do."

His explanations would often incorporate sonic descriptors, but he would normally pair these with technical descriptions which could help participants understand how to use tools to control these features:

> “There’s two frequencies I tend to balance on electric guitars, one’s around 700Hz which gives you a kind of honky sound, and and one is around 2.5kHz which is for the brightness.”

Much of his processing choice explanations were generalised to genre norms: "*This style of music is all about delay on the vocals, not reverb or anything else*", or:

> “In rock music, drum kits don’t actually sound like real drum kits... I mean if you were to solo a recording of a rock drum kit it wouldn’t really sound like someone playing drums in a room, whereas jazz does. With a jazz record you should be able to put on your hi-fi or headphones and see the musicians playing there in front of you. It’s a really natural kind of sound. Whereas with rock and pop it’s all about the voice and the rhythm with the kick and the snare playing off one another and then the melody will sit somewhere underneath it, so it’s a kind of different way of mixing completely.”

He also discussed technical considerations:

> “When you’re recording vocals you’ll often get a lot of that proximity effect which makes the vocal sound really close. In this style of music we need the vocal to sit back a bit so that’s why we cut a lot of the bottom end off of it.”

Some of his advice was aimed at helping the learners avoid the potential strategic errors:

> “When mixing try not to use the solo button too much. The danger is that if you solo things you’ll get the perfect kick drum, perfect snare drum etc., but when you put them all together they’re all fighting for frequencies and space in the mix, so you want to mix the song as a whole.”

Other comments were aimed at promoting desired processes. For example, on several occasions he stated the importance of considering the depth dimension, and how his processing of a particular worked example unit was, in part, to try and give the impression of a certain depth quality i.e. how near or far it should appear to the listener.

In summary, the worked example units were supplemented by a significant amount of input from the lecturer. This input spanned a large breadth, from high level considerations about aspects like genre, to low level technical considerations. The input would often cover the subject of the worked example unit, the impact on neighbouring musical elements, and its relationship to the mix as a whole.

6.4.2. The student participants' experience

Listening, looking, thinking

A participant from pair 5 explained how they engaged with the worked example units:

> "You first listen to hear the change then you look to see how much the controls have been changed by, and maybe it's not as big a change as you thought or maybe it is... I am curious as to how he does it."

This demonstrates how the worked example units that Remix Portal delivered were able to exercise this participant's critical listening skills (when they were listening to try and identify a change), and then enabled them to see how tools were used to enact this change. The process clearly caused this participant to try and integrate the information presented through the worked example unit with their prior knowledge, as evidenced when they said "*maybe it's not as big a change as you thought or maybe it is*". A participant from pair 8 also indicated that they were trying to integrate the information they were gaining from the worked example units, and they used experimentation to support this endeavour:

> "I was like, "why does the delay sound like that?", and then I looked and I saw the high-pass filter and that made me question why he had he done that. And then that would make me try other things that I had not tried before."

Participants reported that the worked examples presented on Remix Portal helped them understand their lecturer's mixing process, and represented an improvement upon conventional lecture-based teaching practices. For example, a participant from pair 1 stated: "*For sure, just being able to see it and have him explain why he did things was a lot better than just having him say "I did this"* ". This participant went on to explain how the session is likely to influence their own music mixing process going forward: "*I'll be mixing as a whole and not soloing as much, and I'll be more particular with the frequencies when EQing, giving everything its place*".

A participant from pair 4 expressed a similar sentiment:

> "That's how I learn, if someone, like, shows me something then I'm more likely to remember it and know how to use it myself, so I found [the worked example units] really useful."

Other participants reported how the session would positively impact their use of music mixing tools, for example:

> "I learned about the frequencies and which ones to boost and which ones to take away, because I've always struggled with that so it's good to hear [the lecturer's] perspective on that." (Participant from pair 3)

Remix Portal's ability to let users compare pre/post processing for each worked example unit was an important aid in this regard, as it helped them identify auditory artefact and tool changes, and this in turn helped them derive knowledge that they might use in their own mixes going forward. A pair 8 participant expressed this as follows:

> “I think being able to flick between the two [unmixed and mixed] really quickly and seeing the controls change was really helpful. It might just be little things that you can see went on or you go "*why does that sound different?*" and without it becoming too complicated you can see where the adjustments have been made...you listen to it [the processing associated with a worked example unit] to begin with and hear the impact of it and then you think "*right, well that’s happened to the mids [frequencies] or that’s happened to the top - what’s he done there?*" And then you look [at the controls] and then that would probably make me try things that I’ve not tried before.”

Learning from an expert

This participant’s engagement was likely enhanced by knowing that the examples were created by an expert:

> “I liked this type of teaching method - it was good listening and then thinking about how he does things because he really thinks differently about things, so I was curious to see because obviously he’s been in that line of work so it’s interesting to see what he makes of it.”

The above quote also indicates how the process expressed through the worked example units differs from this participant’s current process ("*he really thinks differently about things*"). However, it was also clear that whilst participants appreciated gaining knowledge of the lecturer’s expert process, they did not view it as prescriptive or representing the only way to process this music: "*He obviously knows more [about mixing music] than we all do but at the same time it’s creative so you can try new things*" (Participant from pair 5). A participant from pair 2 put it as follows:

> “[Our lecturer] is more experienced so he knows the proper way to do certain things but I don’t think there is one proper way to do a mix. So it’s more tips and advice rather than "*this is how it’s done*", it’s "*this is how you could do this*" or "*this could make this sound better in a particular mix*". Well it could, not it will [sic].”

A pair 7 participant made a similar point:

> “I would agree that [the lecturer] was showing us the correct way to mix music but it is a subjective thing. I mean, what he did was make each piece fit within its place [in the mix] but there are multiple routes you could take to achieve that goal.”

Many participants’ current process could be characterised as containing a large portion of trial and error. For example a participant from pair 1 explained: "*I just experiment and see if I like the sound of it*". This approach perhaps belies their lack of vision for the music, and indicates that many of these students have not attained what I described as expert status pertaining to the competency of visioning.

Participants specifically appreciated hearing the processing the lecturer had applied to the music e.g. participant 6 stated "*It’s good to hear how someone else mixes*". This participant then went on express that Remix Portal's design makes it "*...easier to hear the little changes*". This participant cited the ability to *solo* channels (effectively reducing the volume of all other content to zero) which made it easier to examine the subject of the worked example unit.

Some participants specifically referenced the benefit of seeing how tools were used to enact the processing. For example, a pair 5 participant stated: "*It's helpful seeing how the controls change*", and a pair 8 participant indicated how our design supported this:

> "It's good to see a highlight around where things have been changed but it's also good where things haven't changed to not see a highlight at all, so like, if you hear something with your ears but you're not really sure where to follow, the highlighting helps you see those wee bits."

Self-paced learning

This pair 8 participant went on to offer a fairly detailed critique of the worked-examples-through-Remix-Portal concept, appreciating the persistence offered by the platform: "*It's also good to have the finished mix which you can go through in your own time so if there is something you want to check more or listen to more you can*", and also expressing appreciation for the fact the example mix was segmented into worked example units:

> "It's good to be able to solo each section and see what's been done at each stage rather than just having "*right that's what I've done to it all and this is the way it was before*". It's good having it in stages so you can just focus in on one bit so if you really like what they've done with the guitars and you're like "*why is that like that?*" you can zero in on that stage more simply than if you had to pick apart a full mix. So as a teaching tool that's good I would say, that you can do it in steps."

This participant also pointed out the importance of pairing the worked example units with suitable explanatory information, with the ability to ask questions of the worked example's author particularly appreciated:

> "It's good being able to ask questions, because even if you can see what was done you might still not know why it was done, so it's good to have someone you can ask questions of, to explain something you just don't understand... you might come to your own conclusion in your head about why he's done something but then he tells you the way he's done something is for a completely different reason."

When asked if they thought they had learned anything new from engaging with the worked example units a pair 1 participant responded:

> "I'd say compared to what we've been learning [over the course of the semester], processes like panning and EQ, the Remix Portal helps you visualise it. So what I've learned from the examples is slight things that just made it better, things that make it make more sense."

6.4.3. The lecturer’s experience

Vulnerability

The lecturer explained that using the worked example units he had helped create represented a significant change to his teaching practice:

> “It’s actually been different from how we deliver the module because the module, how we used to run it, had more of a lecturer feel where I would speak or talk to the class... when you become a lecturer you tend to forget to talk about yourself, you tend to leave your [domain practitioner] expertise at the door and you tend to talk about other people’s expertise in much grander settings.”

And so making his own artistic practice the subject of the lesson was quite challenging for him: "*I was almost feeling quite embarrassed about it*" but he came around to appreciating this new approach:

> “It’s actually a good feeling that those years of experience that you’ve built up are actually being absorbed by students and valued... I’ve got to remember that that’s what the students are there for. That’s what they see on the front page of the website. That they get to come and work with experts in the field and pick up the hints and tips from them.”

And he believed this approach could enhance learning in a way that his normal teaching practice could not: "*With this it felt like I was imparting expertise onto them that I would not normally do*".

Lightening the load

He explained that his typical teaching would often involve him demonstrating mixing techniques to the class, but he believed this method was sub-optimal for the following reasons:

> “I’m probably working too fast for them to absorb the knowledge. I could actually sit and explain each knob turn, say “I’m thinking about doing this because of this” but it would become really repetitive and boring and because it’s a long sequence of instructions I think they would tend to forget what I was saying after the first couple of instructions.”

In contrast, he believed the worked example units represent more digestible chunks of information:

> “So Remix Portal, because you can isolate, say, the kick drum and say ‘*this is how I processed it*’ and then talk them through each stage of compression, EQ, panning, stuff like that, that makes much more sense than saying: "*right I’m going to move that there, and then I’m going to move that there*" and so on. So that style of teaching has become obsolete and I think Remix Portal has been really useful in terms of the students gaining an understanding of all the processes.”

He related this to a concern around the complexity of existing music mixing hardware and software: "*Mixing desks are so complex and [industry standard mixing software] Pro Tools has got a very steep learning curve*". The lecturer believes this creates a situation where learners have to spend so much time and effort getting to grips with the mechanics of these tools that they have insufficient capacity remaining to give the consideration required to develop an effective overarching mixing process encompassing a vision for the music:

> “What I think tends to happen is that students tend to concentrate far too much on the mechanics of making a mix...It’s almost as if they’ve got to break down the barriers to understanding the mixing desk before they can understand the techniques.”

But he clearly thought Remix Portal reduced this load, as he went on to say:

> “...whereas Remix Portal removes all of those. It was much more immediate in terms of them being able to see what I did in terms of mixing. And easier for them to absorb that and maybe use that in their own mixes in the future. So I think that was really useful.”

Remix Portal not only used visual cues to highlight controls that have been used when creating a worked example unit, and also enabled the worked example unit to be soloed (which effectively silences all other musical content) and thus makes scrutiny of this auditory output much easier. The lecturer noted this aspect of the design too:

> “And it was great that you could isolate all the changes I made to, say, the kick drum, in terms of reverbs and EQ’s and stuff like that. So they can actually see what I was trying to achieve within the instruments within the context of a mix rather than just the mix as a whole, so that was really really good.”

I pointed out how one participant noticed and commented on an advanced mixing technique contained within the worked example units. I asked if this kind of advanced technique would normally be picked up by the students, to which the lecturer responded: "*No, they wouldn’t normally pick that up because when a student looks at a [traditional mixing] desk or software they just see a mass of buttons*". And he reflected his own observations:

> “When I was going around [checking the students’ work] the students, they were trying out the band pass and the reverb techniques and stuff like that. Stuff that I would mention in class but I’d never see implemented [in their mixes] in previous years. I suspect that when I go back I will probably see it quite a lot now. That and the EQ settings and the panning. I think we’ll probably see better mixes coming through in future.”

Scaffolding a mixing process

However, whilst supporting scrutiny at the micro level is good, as it help with the development of critical listening skills and understanding of tool use, it was also deemed important to help the participants think about the mix as a whole: "*One of the things we are pushing in class is to mix the song as a whole*". This means helping the students develop an effective mix process, where processing is not only considered in regards to the item being processed, but also in terms of the knock-on effect upon other musical elements. He believed the design of Remix Portal could support the development of an effective process because it allowed participants to: "*see the whole mix, all the channels at once and so they could jump between one channel and another and make adjustments that way rather than soloing each channel and doing it that kind of way*".

Perhaps at a higher level than thinking about the mix as a whole i.e. paying attention to knock-on effects of processing, is conceptualising a vision for the mix which would guide processing choices. The lecturer reflected this when describing his own mix process:

> “I’m using a lot of evaluation on the songs, the age of the players, what stage they are in their careers, the genre of the song. All of these things are considerations when you do a mix. A lot of people, particularly students, tend not to think about that. But what makes your mixes sound better is your evaluation of all these different influences on how a mix should sound. Taking them into consideration and then making a mix from there. It’s not the mechanics of a mix, it’s the thinking behind it that makes a mix.”

And he explained how such considerations filter through into processing choices:

> “So what you tend to do is you build up a bank of judgement calls - previous judgement calls that were successful, and you evaluate which judgement call would be most appropriate to the genre or style of music you are working on.”

The lecturer reflected upon how he might integrate worked examples into his teaching going forward:

> “I can imagine that if I prepared half a dozen mixes and used Remix Portal it could be really really useful for myself, it would save me lots of time, be a much more efficient way of teaching students.”

Therefore, whilst this study used one worked example, segmented into many worked example units, our lecturer might be happy with a portfolio for half a dozen such worked examples, likely covering a range of styles or genres, each segmented into sets of worked example units.

6.5. Discussion

The results I presented above reveal participant perceptions around the usefulness of worked examples, and clearly demonstrate that both participants and the lecturer perceived the worked example units to be extremely useful. Participants particularly liked that verbal information was supported by clear, comprehensible demonstrations which not only helped them understand but also encouraged them to experiment, whilst the lecturer believed this approach made better use of his expertise as a practitioner than conventional teaching methods. I therefore believe that worked examples delivered through an interface adhering to Remix Portal's show and tell interface design criteria, may be of benefit to all those teaching or learning music mixing skills.

In the remainder of this discussion I consider how worked examples can facilitate music mixing skills development, implications for the design of worked examples and the systems that deliver them, and what my work contributes to the worked example literature.

6.5.1. How worked examples support the development of key music mixing competencies

Our findings indicated worked examples can help music mixers develop three key competencies relating to listening skills, tool use, and mix process. Considering listening skills and tool use: I saw evidence from multiple sources that the worked example units prompted the participants to actively listen to try and identify changes in the audio brought about by the processing, and then to explore how tools were used to create these sonic changes. Participants were asking themselves questions which guided their exploration and followed up exploration with experimentation e.g. "*why does the delay sound like that?...and then that would make me try things I had not tried before*" (pair 8 participants). Such active exploration and experimentation are thought to be precursors to knowledge acquisition and are an objective of many pedagogical approaches (De Jong and Lazonder, 2014).

I saw evidence that the worked example units, together with the lecturer's instruction, can help participants develop better music mixing processes, with one participant stating "*I'll be mixing as a whole and not soloing as much, and I'll be more particular with the frequencies when EQing, giving everything its place*" (pair 1 participant), which was exactly the process the lecturer was trying to cultivate. This contrasts with the former process they described: "*I just experiment and see if I like the sound of it*".

Another key competency is for music mixers to develop a clear vision for the music they are working on. I saw no direct evidence that the worked example units could help people develop effective visions to guide their mixing activities, however I did see evidence that the worked example units are unlikely to contribute negatively to this as participants expressed an understanding that examples represent just one way of tackling the mix and other approaches can be equally valid. They viewed the examples more as templates for how you could mix sound, or a way to get things into a good place before you would put your own artistic spin on the mix.

It might be the case that the worked example units will lead to the development of effective 'mix visions' over time. Consider the lecturer's statement: "*you build up a bank of judgement calls, previous judgement calls that were successful, and you evaluate which judgement call would be most appropriate to the genre or style of music you are working on*". This describes how his vision for a mix emerges; by reflecting upon the suitability of potential processing options in light of characteristics of the music. I would infer that as one gains music mixing experience, one will build up their *bank of judgement calls* and with this knowledge will come the potential to form a suitably detailed vision for the mix. Therefore, as the worked example units help users gain experience of music processing, they will contribute to users knowledge bank of 'judgement calls', and therefore they may in time help users develop their own mix visions. This will ultimately help users develop their own personal style, and/or the ability to mimic particular styles. Music producers will typically consider it important to have a personal style, as bands and artists will hire them in order to try and impart some of this style on their recording, whilst recording engineers may find it particularly advantageous to be able replicate a range of styles to help the musicians they are working with shape their music into a specified direction.

Whilst I did not see evidence that the worked examples, in isolation, helped people with visioning, I would argue that the changes the worked example units brought to the lecturers teaching practice make visioning a more likely learning outcome for the students. For example, as my observations document, how he used the worked examples as cues to discuss higher level concepts including his vision for the mix and his thought process which led to this vision emerging.

6.5.2. Lessons for the design and delivery of music mixing worked examples

On the face of it, worked examples might not seem all that different to many teaching styles involving demonstration. However, consider that they bring benefits associated with digital, and these benefits were appreciated by participants. For example, the persistent nature of the examples was appreciated: "*It's also good to have the finished mix which you can go through in your own time so if there is something you want to check more or listen to more you can*" (pair 8 participant). The fact that they allow quick switching between pre/post artefact manipulation states was appreciated too: "*I think being able to flick between the two [unmixed and mixed] really quickly and seeing the controls change was really helpful*" (pair 8 participant).

Mwangi and Sweller asserted that "*the structure of worked examples may substantially compromise the benefits derived from studying them*" (1998, p. 174). During the design phase, the lecturer and I decided to segment worked examples into worked example units. This appears to have been a good design decision with a pair 6 participant stating that in contrast to comparing the before/after processing of a whole mix, the worked example units made it "*easier to hear little changes*". Two approaches to worked example segmentation were explored: worked-example-units-by-channel and worked-example-units-by-musical-dimension - these approaches were depicted in 6.1 and 6.2. The lecturer praised the worked-example-by-channel approach due to the ability to isolate the content of these examples via the solo button. For our example song, this effectively reduced the amount of changes to the auditory information that a participant must try and disentangle by 7/8ths, and the lecturer believed this would better help participants focus on and comprehend the content of each worked example unit. It is worth noting however, that other systematic music mixing processes have been proposed which could have been used as a structure for segmenting the worked examples. For example, Moylan (2014, p. 37-38) proposed five potential systems:

- a serial approach: mixing tracks one by one and gradually bringing more tracks into the mix until all are present and integrated – this matches our worked-example-units-by-channel approach,

- mixing rhythmic tracks first, followed by harmony tracks then finally integrating the melodic components,
- mixing tracks starting with the most important (usually the lead vocal) and finishing with the least important,
- a parallel approach where channels are mixed in the presence of all the musical components – this matches the holistic mixing process the lecturer was advising the participants to adopt,
- a front to back approach where items intended to be perceived as closest to the listener are mixed first, and those which are intended to be perceived as distant are mixed last.

Further work would be required to establish whether our worked examples could be segmented along these lines, and how such approaches might be experienced by learners.

Whilst the lecturer appreciated Remix Portal's ability to help participants scrutinise elements in isolation, he also expressed a desire to encourage his students to not to mix elements in isolation. This may seem contradictory, and in some regards it is, but it represents a key challenge for music mixing instruction. Scrutinising elements in isolation is an appealing tactic commonly employed by novices. It is useful because novices will possess rudimentary critical listening skills and find it hard to tune into specific elements within a mix (for example the tone of a voice) when other auditory elements are presented concurrently (like the rest of the instruments in the composition). This is a matter of selective attention and relates to the well known cocktail party effect which reports our ability to *tune into* a conversation in a noisy room. It is thought that our sensory memory parses all stimuli discarding unwanted information whilst passing wanted information onward to working memory (Arons, 1992). However, novice reliance on the solo button suggests that the parsing involved in a music mixing task may well be more challenging than parsing involved in distinguishing speech at a cocktail party. In using the solo button, a novice is able to isolate the wanted auditory feature and silence the rest of the audio which effectively lowers the load placed upon their sensory memory. Expert music mixers, in contrast, commonly mix music as a whole, i.e. mix an element whilst the other elements are audible. This is the process the lecturer was advocating and it is useful because processing one musical element usually has a knock-on effect upon other musical elements within the mix, so having all musical elements present enables the mixer to monitor both the wanted effect and the side effects whilst processing. However, this practice will require highly developed selective attention. So the question for music mixing instructors is not just how to communicate effective mix processes (such as mixing the song as a whole), but how to help students develop the critical listening skills (i.e. the selective attention) to be ready to engage with such processes effectively.

The optimal delivery of music mixing-oriented worked examples may require deviation from conventional music mixing software interface paradigms. All music mixing software faces a challenge around screen real estate, in that there is always a tension between the number of processing options available and the amount of related controls that can be presented on screen at any one time. Most digital audio workstation software works on a paradigm of processing plugins, with each sound processing component featuring its own interface which can be collapsed and expanded as necessary. Remix Portal in contrast, employs the traditional mixing desk layout paradigm, where every processing interface control is presented on screen simultaneously. This has a particular advantage when providing learners with worked examples because it means all of the interface control changes belonging to a worked example unit will be visible on screen, making it easy for the learner to comprehend what controls have been altered. This feature is further enhanced via the drawing of yellow boxes around altered controls, highlighting for the learner which controls have been altered. In a conventional digital audio workstation it is not possible to draw a learner's attention to interface controls that have been changed by the demonstrator, as not all controls can be presented on screen simultaneously, and highlighting of changes is not supported.

6.5.3. Intersection with worked example literature

The worked example concept is based on the idea of providing novices with experts' problem solutions to study. The hope is that studying these solutions will impart effective strategic information which reduces the need for novices to resort to trial and error tactics when faced with a similar problem, and thus suffer the associated heavy cognitive load which can hinder task performance. Our worked examples helped the lecturer advocate for an effective music mixing strategy (mixing a song as a whole) and helped him demonstrate his application of this strategy. However, I identified that in a music mixing domain, novices face a major obstacle when trying to use this strategy, due to underdeveloped critical listening skills preventing them from being able to effectively selectively attend to the elements of interest in the audio whilst other elements are audible. So, whereas worked examples were originally conceived to deal with bottlenecks in working memory, for novices learning music mixing a key bottleneck may occur at the earlier sensory memory information processing phase.

It is generally accepted that worked examples offer the greatest benefit to novices, helping them assimilate information into their emerging schemas (Ward and Sweller, 1990). It is, however, worth noting Atkinson et al.'s (2000) assertion that worked examples may prove useful to experts, allowing them to *"study complex performance by other experts in order to learn stylistic techniques or fine-tune their own complex performances"*. Given the lecturer's description of his own process as reliant upon a "*bank of judgement calls*", it is likely that the worked examples will help our music mixing participants build up their own banks of judgement calls, not by *doing* themselves but by studying the lecturer's mix processing. However, I cannot indicate whether our participants would find such worked example units any less engaging and beneficial as they gain experience. What is worth mentioning, it that the worked examples helped our lecturer to structure his verbal presentation to the class, with each worked example unit serving as a cue to help him cover a wide range information from technical to conceptual.

6.6. Conclusions

Within the worked examples study my aim was to understand whether worked examples constitute a useful music mixing learning and teaching aid. My objectives were to explore participant perceptions around the usefulness of worked examples, to look for evidence of the worked examples supporting the development of the four key music mixing competencies, and to gain insights for the design of music mixing worked examples and their supporting interfaces.

I proposed *worked example units* which represent the outputs of a process whereby a complex worked example is segmented into manageable information chunks. The lecturer and the participants all indicated that our approach to worked examples can prove educationally beneficial within a music mixing context. The key benefits I saw are as follows.

Firstly, the worked examples inspired engagement and fostered active learning as evidenced by the fact participants were asking themselves questions, exploring and experimenting in response to the worked example information.

Secondly, our digital worked example units enabled participants to return to the examples many times and work through them at their own pace in order to make sense of the information they contained. This constituted an improvement from the lecturer's current practice of providing a lecture encompassing a live mixing demonstration, because this traditional approach affords no way for participants to return return to the demonstration, and to explore and compare the information it contains.

Third, the worked example units helped participants make sense of the links between changes they could perceive in the artefact (i.e. sonic changes) and interface control changes. This is because the worked example units presented a limited amount of change the users, effectively reducing the amount of auditory information they had to disentangle and associate with interface controls.

I saw evidence that indicate the worked example units could help people develop three of the four key music mixing competencies: an effective process centred around holistic judgements, highly developed critical listening skills, and an actionable understanding of the link between tools and musical attributes. Whilst I saw no direct evidence that the fourth competency - the possession of a clear vision for the music - could be fostered through the worked example units, I argued that the examples should not hinder the acquisition of this competency based on my finding that participants understood that worked example units represent just one way of approaching a mix and other approaches would be just as valid. Furthermore, I reasoned that this fourth competency may emerge as the other competencies develop.

Whilst the worked example units were appreciated, it is unclear how this approach may fair in other instructional contexts, such as a scenario where the community contribute the worked example units. I identified contextual features which I believe contributed to the positive experience participants reported; features which may not be present in other contexts. For example, it appeared to be important to many participants that they knew that the worked example units were created by a domain expert. Furthermore, we can't separate the worked examples from their accompanying instruction, and in this case the instruction was delivered by an expert teacher with a good prior knowledge of the participants, and he was able to teach in a responsive manner by using participant's questions to guide his instruction. So whilst the text facilities within Remix Portal could be used to present accompanying instruction, and whilst the results of the study appear to show much potential in using worked example units to support music mixing tuition, further work would be required in order to understand how they might be used in informal, remote, or asynchronous learning contexts.

Chapter 7. Designing to Support Novice to Expert Transitions

7.1. Introduction

Whilst my previous work has demonstrated the potential motivational benefits of using Remix Portal to connect students with local musicians (Chapter 4), and the learning potential when it delivers show-and-tell feedback (Chapter 5) or worked examples (Chapter 6), an under-explored area of Remix Portal's design concerned the question of how to determine the optimum number of interface controls to present to users. Remix Portal had undergone a series of design iterations, not only to add new features (such as the show-and-tell feedback mechanism), but also to try and match the interface to the participants I would be working with in a forthcoming deployment context. The consideration I was trying to balance was as follows: on the one hand, I wanted to avoid placing too many controls on the interface as this might confuse users, whilst on the other hand I wanted to avoid placing too few controls on the interface to reduce the risk of users becoming frustrated by the limitations. This design work was largely intuitive, and although I did not scrutinise the outcome of these design decisions closely, I believe I struck a reasonable balance in the deployments thus far, based on the participant feedback I did receive. However, these were all short deployments, with users engaging for no more than half-a-dozen sessions. I considered that the interface layouts may not fair so well with longer term use, as users may come to outgrow the interface once they had overcome its complexity, and as their skills developed they may come to desire more control over the music, hence a more complex interface may be appropriate. I pre-emted this to some extent with the interface presented in Chapter 4, which featured *pro* buttons that controlled the revealing and hiding of additional sets of interface controls, thus should a participant be happy to trade an increase in complexity for more control over the music, they could do so with these *pro* buttons. This was, however, very much a first draft of this type of interface. I decided to explore the design of such interfaces in future work; work that I now come to address. The question which guides the work presented in this chapter is: *How can we design multi-layered interfaces to support novice to expert transitions within the context of music mixing skills acquisition?*

I came to learn of the work of Ben Shneiderman who has made significant initial progress around the design of multi-layered interfaces (Shneiderman, 2002). However, whilst various formats of multi-layered interface have been proposed, there is a gap in the literature concerning how designers should decide what items are appropriate for any given layer, and what role users could play in this design process. I explored this problem in the context of creating a music mixing interface through a design process involving three design activities.

What follows in this chapter is the description of a design process which incorporated several design activities undertaken at a primary school. The intention of these design activities was to explore methods which aimed to inform the segmentation of a complex interface into a number of interface layers. A music-mixing multi-layered interface is then presented, with the design influenced by the findings from the design activities. Finally, an exploratory study where the multi-layered interface was used at an after school music club for secondary school students is described, and findings presented.

7.2. The design process

Shneiderman (2002) proposed three multi-layered interface formats. These comprise a basic format where each layer within the interface features a different set of controls, an *expanding* format where each consecutive layer adds more controls, and a *mushrooming* format which offers a modular design with users able to add different interface component clusters to a basic, initial set. The *pro* buttons I had developed aligned with the mushrooming concept and whilst I liked this interface, I decided to review which multi-layered format would best suit my aim.

My decision regarding which of these types of multi-layered interface to pursue was informed by cognitive load theory (Sweller, 1994). As discussed in the literature review, cognitive load theory posits that our limited working memory capacity imposes a key bottleneck to learning, and when the intrinsic and extraneous cognitive loads that a task places upon us combine to exceed our working memory's capacity, learning or making sense of the task information may become impossible and we may loose track of our task goals (Whitenton, 2013).

I reasoned that a typical single-layer music mixing interface might impose high extraneous load upon novice users because they will have to expend a significant amount of mental effort trying to understand (and retain) the association between the various controls presented on the interface and the way each impacts sonic qualities of the music. Expert users will already understand the relationships between interface components and sonic qualities (unless some very novel interface is used) and, therefore, additional cognitive resources will not be required for this task, which means they can focus more effort on scrutinising the various elements within the audio and sculpting them to fit together pleasingly. Cognitive load theory offers *chunking* (Tuovinen, 2000) as an explanation for how the experts are less burdened by the interface. Essentially, over time the experts will have learned the associations between interface components and sonic qualities, and this learning is easy to recall such that the mapping between sonic features and interface controls no longer places much load upon an expert's working memory.

A sensible design goal would be to reduce the intrinsic cognitive load experienced by novice users, and as the difficulty of pairing interface components to sonic artefacts contributes to this load, then reducing the number of interface components may offer a good solution. However, as the data from Chapter 4 demonstrated, this might prove frustrating to more capable users. The answer is to present the interface with less controls to the novices, whilst offering an interface with more controls to more advanced users who will possess sufficient domain ability for their working memory to have capacity to handle the intrinsic and germane cognitive loads associated with a more complex music mixing interface. An *expanding* multi-layered interface will accommodate such a range of abilities: Novices could use a basic layer, whilst experts could use a layer which encompasses these basic controls and adds additional controls to provide more creative options. From a cognitive load theory perspective, a basic layer will reduce the space a novice user has to search during the previously described process of mapping interface controls to the sonic qualities they impart, and therefore will not burden their working memory as much as an interface with a greater number of controls. Furthermore, as a novice learns these associations, chunking will occur such that these controls place less burden upon their working memory going forward. They may then have capacity to handle new interface controls, and this is accommodated by the next layer on the multi-layered interface which will add a number of new controls to the interface. Should the user move to the next layer of the multi-layered interface, then the process will begin again, with the user learning to associate the new controls with their impact upon the audio, with the working memory demand being reduced as the learning solidifies. A user may continue moving up the layers in this way until they reach the highest layer of the interface which features the greatest number of interface controls and therefore possesses the most complexity.

Whilst there is good theoretical justification for pursuing an expanding multi-layered interface as a means of accommodating a range of abilities, there is little research which can inform the design decisions which such an approach necessitates, concerning how to segment a complex interface into a number of layers. The goal of this design work was, therefore, to establish a basis for making decisions about which controls should be presented on any given layer of the multi-layered interface. I was already of the opinion that the interface would feature a very limited set of controls at the lowest layer, and controls would be added at each new layer to create a gradual increase in complexity until full complexity is reached at the highest layer. A key question then concerned which controls to exclude from the lower layers. I considered that there may be a number of approaches a designer might explore in this regard:

- Frequency of use: Present only the most commonly used controls on the lower layers.
- Difficulty of use: Present only the easier to use controls on lower layers.
- Teacher led: The teacher may have a specific method or process they want to impart upon the novices. Controls/layers could be arranged to support this pedagogy with all non-essential controls saved for a higher layer.
- Student led: Ensure lower levels retain the controls participants find most useful, with the less useful controls saved for higher layers.

Time constraints meant that I could not explore each of these design strategies. I oped to explore the *difficulty of use* approach because I judged it to be complementary to the cognitive load criteria. That is to say, difficult to use controls may exert a greater cognitive load than easier to use controls, and therefore users may benefit from lower interface layers being composed of both fewer and simpler controls. I also opted to pursue a *student led* approach based on the criteria of a desire to limit user frustration, and I thought the autonomy inherent in a student led approach might support this. I developed two methods to explore the student led approach, both involved asking the participants to make a judgement about how useful they found each interface control type to be. These methods are presented in sections 7.3.2 and 7.3.3. The method I developed to explore difficulty of use did not involve asking students to provide ratings based on their perception, but instead involved trying to derive information automatically, based on the participants' performance whilst using a representative interface. I explored this work via the listening game activity which is presented in section 7.3.1.

7.3. Design Rationale

A number of constraints were placed upon the design space which limited the options for how to produce low complexity, basic interface layers. Firstly, as Remix Portal follows a mixing desk metaphor design (in common with much contemporary DAW software such as Pro Tools, Cubase and Logic Pro as explained in Section 3.5.6), each musical stem loaded into the mixer is given a *channel strip* of interface controls. Therefore, the more stems a song has, the more interface controls are presented on screen. Whilst the number of interface controls presented to a user could be reduced by limiting the number of musical stems playing, this was deemed an unsuitable solution towards the aim of reducing cognitive load, as it should be possible to hear all stems regardless of the interface layer chosen, in order for the music to be properly presented to listeners.

Secondly, there were controls on the Remix Portal interface that I deemed necessary for all layers, these included:

1. The song management controls including the play, pause, skip to start, save and reset/flatten buttons, as well as the playback position slider, and change mix arrows.
2. The layer selector radio buttons on the left hand side of the interface.
3. Feedback facilities consisting of the pop-out feedback panel on the right hand side of the interface.
4. The main Remix Portal site menus (located at the top and bottom of the interface).

I therefore decided to limit the interface controls that would be considered for exclusion from layers, to controls within the virtual mixing desk that can modify the sonic qualities of the musical output. My reasoning is that these controls will require focused attention to match them to their impact upon the music, and therefore might impose a relatively high cognitive load. This narrowing of the design space resulted in a set of approximately 12 types of control that could be considered for exclusion, many of which where composed of several individual dials. Therefore, decisions could be made regarding whether a layer should possess no controls of a specific type, all the controls belonging to a specific type, or some subset of controls belonging to this type.

The criteria against which the potential options were evaluated were: (i) accommodate cognitive load, (ii) limit frustration, and (iii) limit confusion. The cognitive load criteria was derived form the literature review, whilst the criteria of limiting frustration and confusion were derived from earlier study findings.

A key decision in any multi-layered interface design concerns the number of layers to provide, and this was one such decision where I felt my data was of limited help. I opted for five layers because as I started sketching out various interface layer configurations, five layers offered what I considered to be a reasonable step up in complexity at each subsequent layer. Fewer layers would have meant introducing more interface controls at each additional layer – a quantity which I felt might negatively impact criteria one and three. More layers may have been better, but I judged five layers to be sufficient.

The interface controls within a mixer channel represent the design options for each layer of the multi-layered interface. The criteria by which they were evaluated include a desire to accommodate cognitive load, limit frustration, and limit confusion. However, further information was required to inform this evaluation. To this extent, design work was conducted during Chapter 4's primary school deployment. For background information on participants and context, please refer to section 4.3. This current chapter focuses on key activities from this deployment which informed the multi-layered interface design, including the listening game activity which occurred during week 2 of the deployment, and the two control rating activities which occurred during week 4.

7.3.1. The listening game activity

The listening game activity constitutes an attempt to automatically derive difficulty ratings for each interface control. I basically applied the classic *spot the difference* game concept to a music mixing context. Here, I take difficulty to mean the trouble participants have in perceiving the link between an interface control change and its impact upon the audio output through the headphones or loudspeakers. I chose this interpretation of difficulty as it links closely to one of the four key music mixing competencies developed in chapter 2.4: *an actionable understanding of the link between tools and musical attributes*. Difficulty was considered important because earlier findings suggested that difficult interface controls might cause participants frustration or confusion, and therefore it may offer a better user experience if they were to be omitted them from lower layers. Furthermore, difficult controls might impose a greater cognitive load.

The listening game relies upon an adapted Remix Portal interface which is depicted in 7.1. A key interface modification added to facilitate this game is the large *check secret mix* button visible on the right of the interface in figure 7.1. This toggles the audio to change between the secret mix and the participant's mix. When in *checking secret mix* mode, the interface is greyed out to indicate its deactivation, furthermore the interface controls are locked in position and cannot be adjusted by a user. Pressing the *check secret mix* button again will toggle this mode off, with the grey overlay being removed and the interface controls becoming accessible again with changes to them being reflected in changes to the audio output. Users are tasked with trying

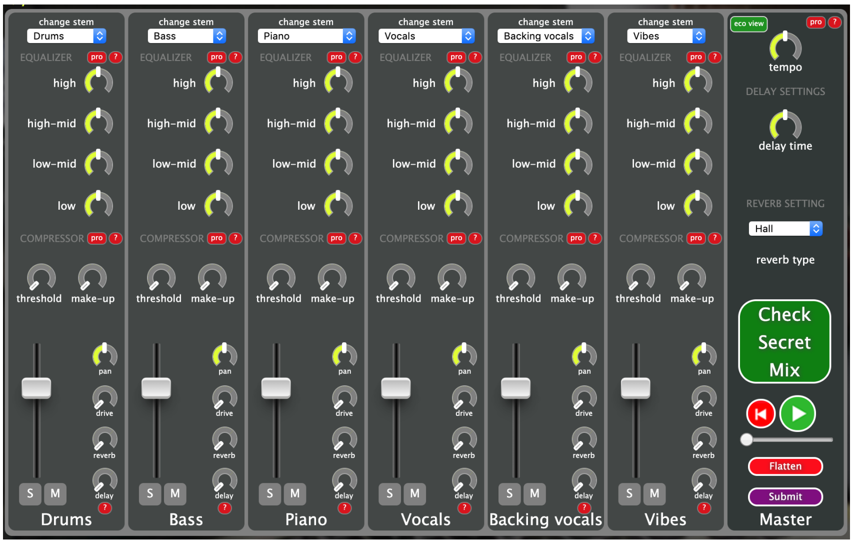

Figure 7.1 Listening game interface: note the "check secret mix" button

to adjust the interface controls until their mix matches the secret mix as closely as possible. As the users cannot see the interface control positions that generate the secret mix, they are forced to pay close attention to the audio to try and ascertain differences between the two mixes, and then once they have identified a differing feature within the audio, they must work to try and understand which interface control manipulates this feature, then they must continued paying attention whilst they adjust this control until they can no longer identify a distinction for this feature between the two mixes. To help clarify this further, I now present a description of the game from a fictional user's perspective:

> "I sit at the computer and begin the game by pressing the play button. As I start to hear music I press the *check secret mix* button and instantly notice that the music changes. I also notice that the interface controls have turned grey so I know that I am currently listening to the secret mix. I now concentrate on listening to the music as I switch between the two modes. I realise that the piano is significantly quieter in the secret mix. I recall that the volume fader (slider) controls the loudness so I find the piano fader and adjust it down. I switch between the mixes several times whilst I fine tune the fader position until I can't tell the difference between the piano volume within the two mixes anymore. I then turn my attention to trying to identify another difference between the two mixes. I notice that the tone of the vocal differs, with it having more low frequencies in my mix than the secret mix. After some experimentation I find the interface control that alters the *bassiness* of the vocal and I begin to adjust and compare. Once I am satisfied, I continue to identify, adjust and match other features within the audio until I can no longer distinguish differences between the two mixes, or until I cannot work out how to reduce the remaining differences via the interface controls, or until I run out of time."

Prior to using the listening game with the participants I had to source a secret mix. I could have pursued a number of approaches such as using a randomising function to determine control positions for the secret mix. However, for practical reasons I decided to simply create one secret mix myself. I gave myself the rule whilst mixing, of making three changes for each control type; a large change, a medium change, and a small change. The intention was for the large change to be fairly obvious to participants, the medium change to be somewhat apparent, whilst the subtle change might take a lot of scrutiny to identify. I considered that this strategy would create a level playing field, meaning that the deviation scores should reflect the difficulty participants have in using a control type, as opposed to them having difficulty because a control type was used more or less liberally than another control type within the secret mix. This strategy was possible for the repeating channels (e.g. channel one's fader could have a large change, channel 2's fader a medium change, and channel 3's fader a small change), however it was not possible for the controls on the master channel which could only be set once. These master channel interface controls consisted of the tempo and delay time dials, and reverb type selector. It should also be noted that no solo or mute buttons were set to *on* in the secret mix to avoid confusion.

I primed the participants to use the game by briefly showing them how to switch between the secret mix and their own mix, and how to use the submit button at the end of the game. I also notified them that the game would last 5 minutes, and I added a competitive element by informing them that I would be reading out which pair achieved the highest score at the end. Then I set a countdown timer and the participants began playing the game working in their usual pairs.

A couple of groups finished early (after around 3 minutes of play time) and there were a couple of technical issues: one group got stuck soloing a backing vocal when there was no singing present in that part of the song, so I helped them to understand what had occurred and to return the interface to a suitable state. Another group - a girl on her own as her classmate was off ill - could not get any sound out of the computer. She had to refresh the page after around 3 minutes and so her work up to this point was lost and she did not have sufficient time to fully recover.

When a user presses the *submit* button a calculation occurs based on the difference in control positions between the user's mix and the controls modified to create the secret mix. A score is output, and I used this score to reveal the winners of the game to the class. The control positions are also recorded to our database for further processing, which is described in section 7.3.4.

7.3.2. Control usefulness rating activity

Whilst the listening game was an attempt to gain information around the difficulty participants had in using each interface control type, the control scoring activity was an attempt to focus on the perceived usefulness of each control type.

Each participant pair was given a sheet of paper depicting the Remix Portal interface and asked to rate how useful they found each control type on a scale of 0 to 10. They completed these forms during the fourth session, and therefore had three sessions of remixing experience to draw upon. The forms were filled out whilst they were remixing the music of the local musicians, and therefore they could experiment with the interface controls on the computer if they needed

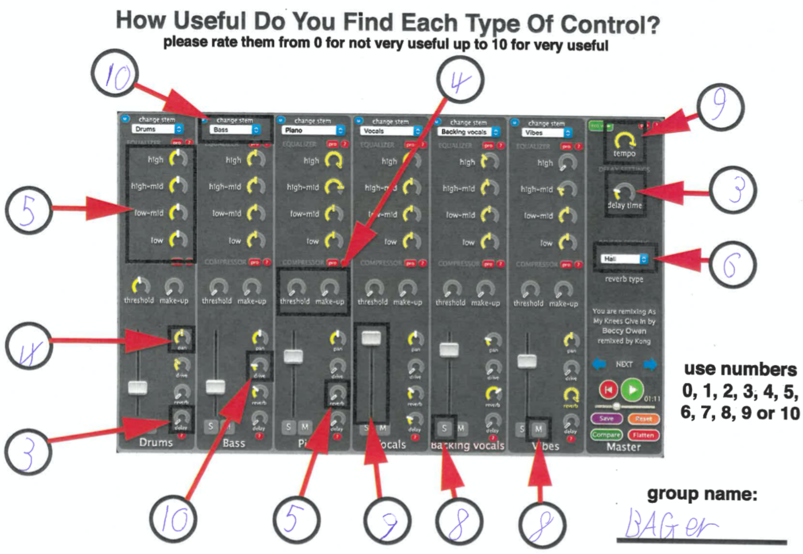

Figure 7.2 A completed control usefulness rating form.

to remind themselves what a control type did. They were given a 15 minute window within the remixing task to complete the control usefulness rating forms. A completed rating sheet is depicted in Figure 7.2.

7.3.3. Rank ordering activity

The rank ordering activity had the same aims as the control ranking activity, in that the focus was on gaining information about perceived interface control usefulness. However, I deemed it advantageous to explore a slightly different configuration of information collection, to try and gain insights around what methods are preferred by our user group, and also to provide an element of data triangulation. The activity was undertaken towards the end of session 4, once the main remixing activity had been completed. I merged the student pairs into groups of 4, and I gave each group a sheet of blue card which had a series of 13 labels stating *most useful control*, *2nd most useful control* and so on, and a set of 13 corresponding boxes, each with a velcro loops patch. I also gave the groups a set of yellow cards, each featuring the name of an interface control and with a velcro hooks backing. The participants were tasked with working in their groups to rank order the controls. They were given 15 minutes to complete this task. A completed set is depicted in Figure 7.3.

The main differences between this activity and the previous control rating activity were as follows:

- In the control rating activity participants could use the Remix Portal interface to check a control's function, whilst in the rank ordering activity they had no computer access and thus had to recall what each control type did (i.e. they had to associate a control name to its behaviour).

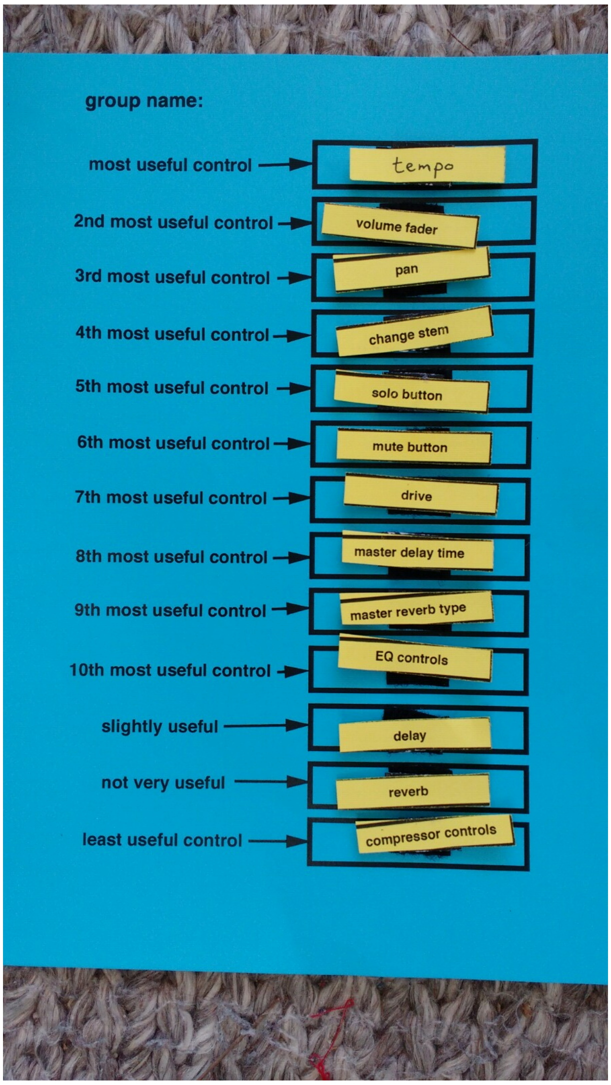

Figure 7.3 A completed control usefulness rank ordering form.

- With the control rating activity participants could give controls the same score, whereas this is obviously not possible in the rank ordering task.
- The rank ordering activity used larger groups (of four participants), which brought people together who had not interacted much during the previous study sessions. The hope was that this would stimulate discussion.

7.3.4. Findings

The findings which informed the design of the multi-layered interface are based on data comprising interface control difficulty ratings (derived from the listening game), and usefulness ratings (derived from both the control rating activity and the rank ordering activity), as well as observations made during the control rating and rank ordering activities.

Listening game findings

As described previously, at the end of the listening game a user will press the *submit* button which triggers a calculation. This calculation provides the average distance between the positions of *secret mix* and *user mix* interface control pairs. I decided to only apply this to controls modified to create the secret mix, i.e. controls in their non-default positions, to avoid the risk of participants scoring highly without doing any matching work. For example, any pan controls used in the secret mix would have their numerical values compared against those in the user mix and the mean difference would be recorded as the pan control's difficulty rating for this user. A second process was then run to take the mean of the control rating scores across all users. The scores are given as a percentage, with 100% representing a perfect match, from which we would infer that the participant has no difficulty using this control. A low percentage score reflecting a poor match which we can infer is due to difficulty using that control. Table 7.1 presents these control ease of use ratings:

From the above, we can see that all participant pairs managed to select the correct set of musical stems. They did a good job of matching the tempo and volume faders, however at the other end of the spectrum participants performed poorly when it came to matching the master reverb type and setting the compressor dials. We can therefore infer that stem change selection box, tempo dials, and volume faders are easier for novice music mixers to get to grips with compared with the lower scoring interface controls including master reverb selection box and compressor dials. With other interface controls falling somewhere in between.

If we were working with this information alone, and were interested in building a three layered interface for this user group based on *difficulty of use* criteria, we might ensure stem change, tempo dials and volume faders are included on layer 1. We might also ensure master reverb selection box and compressor dials are omitted until layer 3. However, this data was just one of the sets of data that informed the multi-layered interface, and therefore whilst this information is evident in the design choices I went on to make, other considerations influenced the design too.

	Ease of use score
change stem	100%
tempo	91%
fader	83%
solo	n/a
mute	n/a
drive	65%
EQ	37%
master reverb	19%
pan	70%
reverb	47%
delay	41%
compressor	32%
master delay time	53%

Table 7.1 Ease of use scores. The higher the percentage, the more closely matched the controls were, therefore the easier participants found them

During the game I observed that all participants appeared to be well engaged in the task. After the game all participants reported enjoying the activity (with the exception of the participant who suffered a technical glitch). I asked the participant pairs to think back to the game and to recall which controls they found the easiest to hear and which they found the hardest. Interestingly, several pairs said that they found the volume the hardest control type to match (whereas an expert may say this is the easiest), and no participant pairs had a clear idea of which control types were the easiest.

Control rating findings

The participant control usefulness rating scores are presented in table 7.2. It should be noted that when some groups could not agree on a control rating score, they decided to just write each participants' score on the sheet. In such cases, I took the average. Looking at the aggregated scores, the three highest rated interface controls are stem change, tempo dial, and volume fader, with solo and mute buttons just behind this. The interface controls rated least useful were the master channel's delay time dial, the compressor dials, and the delay and reverb dials.

I observed that participants would sometimes question what a control did, and would then use their computer to experiment with Remix Portal to find out (or to remind themselves). Participants did not always agree on control ratings and sometimes they were unable to resolve their differences and so they just wrote both scores on their sheet.

Rank ordering findings

Combining our participant pairs for this activity resulted in six rank order sheets being produced. To integrate them, I decided to score each control based on ranking, with the control judged least useful (i.e. lowest ranked) scoring 0, the second lowest ranked scoring 1, and so on, with the

	stem	tempo	fader	solo	mute	drive	EQ	reverb type	pan	reverb	delay	compressor	delay time
group 1	10	0	4	2	3	8	9	1	6	7	5	0	0
group 2	6	10	10	5	6.5	10	6	2.5	10	10	10	10	5
group 3	10	10	4	8	5	10	4	9	3	6	2	3	1
group 4	10	9	10	8	7	7	7	7	3	6	4	6	3
group 5	7	10	8	10	10	8	8	9	6	7.5	6	5	8
group 6	10	9	10	6	5	3	5	8	4	2	7	9	7
group 7	5	10	10	9	10	3.5	1.5	6	9.5	5	6	8	5
group 8	10	9	9	10	8	6	7	9	6	5	7	8	4
group 9	8	10	9	4	4	7	9	5	7	2	5	2	7
group 10	10	9	9	8	8	10	5	6	4	5	3	4	3
group 11	10	10	2	9	7	5	4	6	1	6	7	0	0
group 12	9	10	10	9	7	0	4	0	8	2	1	2	3
Average	**8.8**	**8.8**	**7.9**	**7.3**	**6.7**	**6.5**	**5.8**	**5.7**	**5.6**	**5.3**	**5.3**	**4.8**	**3.8**

Table 7.2 Control ratings

most useful control scoring 12. I was then able to calculate the mean average for each control. These scores are presented in table 7.3.

The tempo control was deemed the most useful, followed by solo and mute buttons, and volume fader. The least useful controls were the delay, compressor and reverb dials.

I observed that participants enjoyed engaging with the velcro materials and that this activity stimulated discussion between the participants. This may have been, in part, because of the larger groups, and also because the nature of the rank ordering activity forces a comparison between controls, which was not the case for the rating activity. The top ranked controls appeared to be well understood by the participants and they meaningfully discussed its use, however the controls which were placed lower on the ranking list were questioned more in the discussion, such as "*what does this one do again?*".

Reflections on these methods

Table 7.4 shows the scores each Remix Portal interface control type achieved across the three methods. It should be noted that higher scores are considered better, indicating that interface controls are more useful or less difficult to use. Employing these three methods allows for data triangulation, and the data shows a good amount of similarity between the scores produced by these methods, thus evidencing that the data is reliable. Controls including the stem change selector and the tempo dial scoring highly in each method, and controls including the compressor dials, reverb, delay and master delay dials scoring poorly. As these results are largely complimentary, it is not necessary to choose whether to design the multi-layered interface along *difficulty of use* or *student led* criteria, as the resulting interface would look very similar.

Reflecting upon the rating and rank ordering activities, I believe the computer access which students had during the rating activity helped them gain clarity about what a control did. This clarity may have been lacking during the rank ordering activity. The rank ordering activity was advantageous in that the students enjoyed engaging with the materials and the nature of rank ordering forced discussion and direct comparison between control types, in order to decide which would be placed higher and which lower. If I was to take these methods forward I would use the rank ordering activity but would provide access to a computer with Remix Portal so groups could check the function of interface controls.

Reflecting upon the listening game activity, participants appeared to enjoy using it, and it had useful learning outcomes due to participants exercising and developing their listening skills. However, it took a significant amount of my labour to create, and because the results align closely with the results we got using the other (significantly less labour intensive) methods, it might not be my first choice if I was working in an environment with a tight timeline or budget. It was however, nice to collect and compare automatically derived and participant submitted scores, and seeing how complimentary they are adds a level of security to the design decisions that follow.

	tempo	**solo**	**mute**	**fader**	**pan**	**stem**	**drive**	**M reverb**	**EQ**	**delay time**	**reverb**	**compressor**	**delay**
group 1	12	11	9	8	10	5	0	7	4	3	1	2	6
group 2	11	10	6	7	5	8	12	9	4	1	2	3	0
group 3	12	7	11	3	10	1	4	9	2	6	8	0	5
group 4	9	10	12	7	2	11	6	1	4	5	3	8	0
group 5	12	9	5	11	8	10	6	4	7	3	2	1	0
group 6	12	8	7	11	10	9	6	4	3	5	1	0	2
average	**11.3**	**9.2**	**8.3**	**7.8**	**7.5**	**7.3**	**5.7**	**5.7**	**4.0**	**3.8**	**2.8**	**2.3**	**2.2**

Table 7.3 rank ordering derived usefulness scores

	usefulness rating	usefulness ranking	difficulty score
change stem	8.8	7.3	100%
tempo	8.8	11.3	91%
fader	7.9	7.8	83%
solo	7.3	9.2	n/a
mute	6.7	8.3	n/a
drive	6.5	5.7	65%
EQ	5.8	4.0	37%
master reverb	5.7	5.7	19%
pan	5.6	7.5	70%
reverb	5.3	2.8	47%
delay	5.3	2.2	41%
compressor	4.8	2.3	32%
master delay time	4.6	3.8	53%

Table 7.4 comparison between usefulness scores and difficulty score

7.4. A Music-mixing multi-layered interface

The multi-layered interface is an attempt to create set of interfaces to suit a spectrum of music mixing competencies, from novice to expert. It is largely based upon the findings presented in section 7.3.4. I also drew upon findings and observations from other Remix Portal deployments. However, the data could not meaningfully speak to all aspects of the design, and in these instances I drew upon my background of over ten years of experience teaching music production skills to make the necessary design decisions.

An interface design rule derived from cognitive load theory suggests the use of familiar patterns and symbols (Whitenton, 2013). Accordingly, each layer follows the layout of the previous layer, with controls retaining their positions from the previous layer, and with new controls added around them.

Layer 1

As the first layer is aimed squarely at users who are just getting started with music mixing, I restricted the virtual mixing desk on the first layer to four types of interface control. I chose the stem change selector, tempo dial, volume fader and solo button, as these were the best performing interface controls in both the usefulness rating and difficulty score metrics. Layer 1 is depicted in Figure 7.4.

Layer 2

For layer 2's virtual mixing desk, I opted to introduce the mute, drive, pan, reverb, and delay controls. All these interface controls had moderate or good usefulness and difficulty scores. This interface is depicted in Figure 7.5.

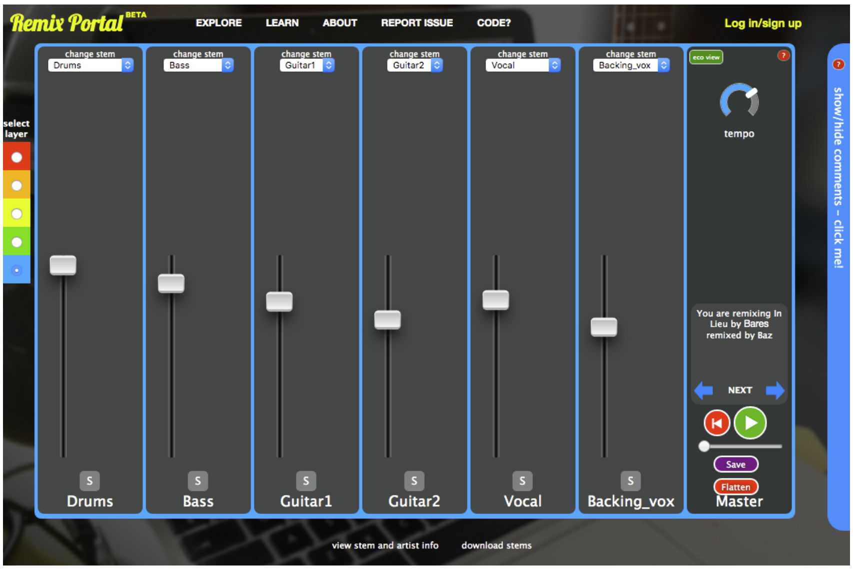

Figure 7.4 Layer 1 of the multi-layered interface

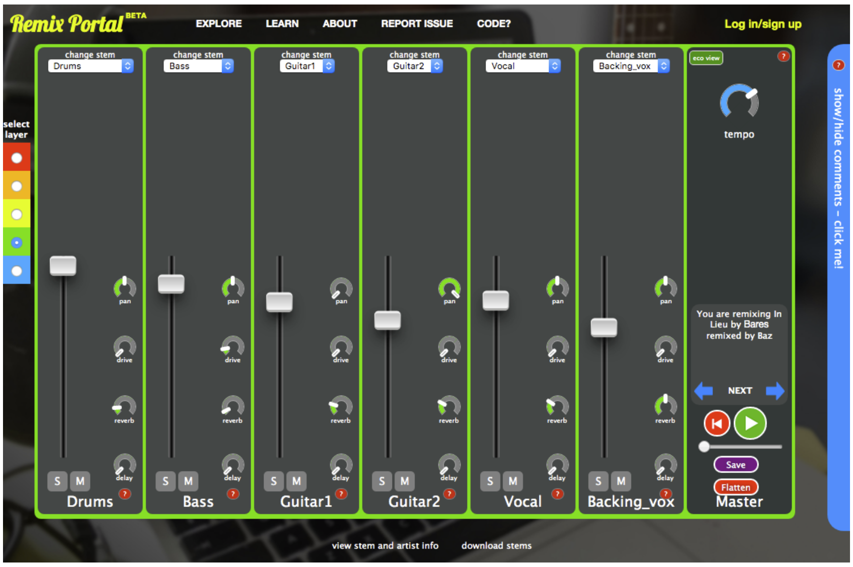

Figure 7.5 Layer 2 of the multi-layered interface

Figure 7.6 Layer 3's volume blocks interface

Layer 3

For layer 3's virtual mixing desk, I began introducing interface controls that scored poorly in the usefulness and difficulty assessments, including EQ, compressor controls. These are both mixing tools with a number of parameters and I decided to not provide users with control over all parameters at this layer, in order to keep the complexity low. I also introduced basic master channel controls including a delay time dial and reverb type selector.

An issue I reported in section 4.2.3 was that some participants wanted more control over the music, and there was a specific recommendation to allow participants to create changes over the music's duration. I decided to facilitate this in layer 3 by replacing the standard, fixed position volume faders with a volume blocks interface. These volume blocks allow the volume to be controlled on a per section basis. For example, a user may choose to set the volume of the drums fairly low in the first verse, then raise it for the chorus, and so on. The volume blocks interface is presented in Figure: 7.6. Each block represents a section of the song, and the block can be dragged up or down to raise or lower the volume. Blocks are coloured blue by default, but when the playback position intersects with the song section a block covers, it turns orange to inform the user that should they with to change the channel's volume for the currently playing section of the song, this orange block is the one they should manipulate. When the volume blocks interface is closed, the original volume fader remains visible and it gets repositioned up or down as the song plays, to match the settings dictated by the volume blocks. Clicking the volume fader serves to open the volume blocks interface.

Another alteration at this layer concerns the 'u' symbols beside the stem change selector. This enables participants to upload their own audio stem as an alternative to selecting from a channel's given set of stems. The layer 3 interface is depicted in Figure 7.7.

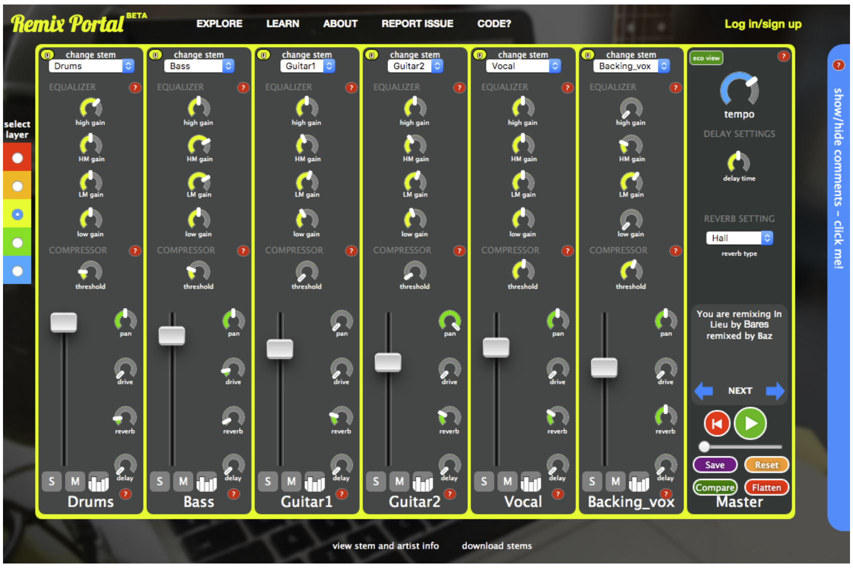

Figure 7.7 Layer 3 of the multi-layered interface

Layer 4

Whilst I provided very basic EQ and compressor interfaces in layer 3's virtual mixing desk, in layer 4 I added more complexity to give users control over previously restricted parameters. This resulted in four additional dials for each EQ interface and four more dials for each compressor interface. I also added an 'R' button beside the stem selector, to facilitate participants recording audio directly into Remix Portal, however this feature was never successfully implemented. Furthermore, I added a small button beside the drive dials so users could switch between three different distortion algorithms to give different sonic textures.

Perhaps the most significant change at this layer is switching the volume blocks interface for a line graph-style interface that I called *volume envelopes*. This is depicted in Figure 7.8. This removed the support participants had for creating volume changes on a per song section basis, and instead gave them the ability to create volume changes at any points they wished within the song. Furthermore, they could now create volume ramps to smoothly raise or lower the volume over a period of time, which contrasts with the sharp volume step changes associated with the volume blocks.

Layer 5

Layer 5's virtual mixing desk adds more complexity to the EQ and compressor interfaces by providing control over yet more parameters. The resulting interfaces offer a level of control that would suit professional music mixers. Basic EQ controls are also added to the master channel's delay and reverb sections. This fifth layer of the multi-layered interface affords a level of sonic shaping that many professional music mixers would demand, and therefore this represents a tool suitable for expert users.

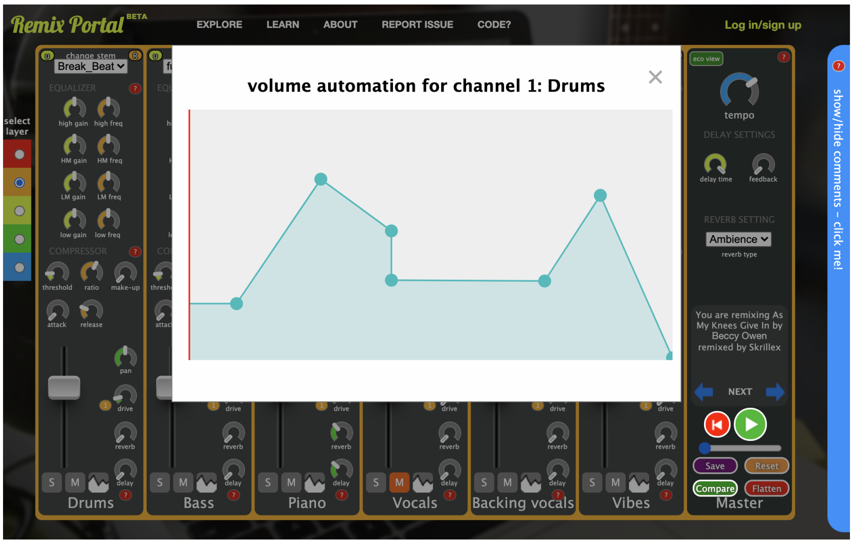

Figure 7.8 The volume envelopes used in layers 4 and 5

Figure 7.9 Layer 4 of the multi-layered interface

Figure 7.10 Layer 5 of the multi-layered interface

7.5. Evaluation Sessions - Introduction

The research question guiding the work presented in this chapter is: *How can we design multi-layered interfaces to support novice to expert transitions within the context of music mixing skills acquisition?* A multi-layered design approach was pursued as a potential solution to the challenge of supporting novice to expert transitions, and the first half of this chapter details the creation of a music mixing multi-layered interface, informed by three novel design methods. The latter half of this chapter details an exploratory deployment at an after school music club. From this setting I attempted to evaluate whether the interface is well suited to supporting music mixing skill development. This evaluation was inspired by Csikszentmihalyi's flow theory (Nakamura and Csikszentmihalyi, 2014). Whilst I detail this theory in the literature review, an important concept worth recalling is that, according to flow theory, an activity which is too challenging for a person's skill level might induce anxiety, and an activity which is too easy might induce boredom. However, when a person's skill level is well matched to an activities difficulty, an optimal flow state might be induced. Based on this, I wanted to explore whether allowing users to self-select an interface layer would allow them to set an appropriate level of challenge for their current skill level, and avoid feeling of anxiety or boredom.

During the deployment presented in Chapter 4, I learned that musicians can find it difficult to compose feedback for students they don't know, particularly with regards making specific suggestions for alterations to a mix, and students can have difficulty interpreting this feedback. I reported this as a potential obstacle to the successful formulation of a local learning ecology involving students and local musicians participating remotely. In this chapter I return to this issue as I reasoned that a multi-layered interface might impart information about the skill level of the user (inferred from seeing which layer they chose to work with), and therefore influence the musician's feedback creation process. I therefore decided to explore how multi-layered interfaces impact the feedback giving process.

In summary, I had two objectives for these evaluation sessions:

1. To explore how the multi-layered interface's were experienced by music mixing student participants.

2. To explore how multi-layered interface are experienced by feedback givers.

7.5.1. Deployment setting

These sessions took place at a secondary school in the North East of England. An after school club was formed which offered students the opportunity to learn music remixing. The club ran for six sessions over the space of two weeks, with each session lasting 1.5 hours. Participants were recruited through the school's music teacher, who was present for the majority of the sessions although the course was delivered by myself. Participants and their parents/guardians were given an information sheet explaining that the course doubled as academic research and were all given the option to opt out of the study entirely, or just the data collection element of the research. All participants were happy to contribute their data to the research.

	Male	*Female*	*Total*
Session 1	7	3	10
Session 2	6	1	7
Session 3	4	2	6
Session 4	4	0	4
Session 5	3	2	5
Session 6	3	0	3

Table 7.5 Number of student participants by week

Participants

In total, eleven students from school years 10 and 12 (15-17 years of age) participated. Three were female and eight were male. However, due to the informal nature of the after school club not all participants attended each session. Table 7.5 shows the attendance by week. All participants reported an interest in music and music making, however none reported any prior experience of music mixing.

Additionally, two expert music educators evaluated how the multi-layered interface can impact feedback provision.

Sessions overview

During the first session, the participants were introduced to Remix Portal and explored a conventional (non multi-layered) music mixing interface whilst creating a first remix. At the end of the session an informal group interview was held to capture information about participants' understanding of the various mixing desk control types.

The second session began with the participants using the same non multi-layered interface. They were then introduced to the multi-layered interface and were asked to explore the layers whilst creating a remix that would make the music sound different. Each participant was then asked to write down which layer they preferred using, and to write a description for each layer. Finally, a group interview was conducted to capture participants' initial experience using the multi-layered interface.

Participants practised remixing using the multi-layered interface during the third session. They each picked a card stating one of three musical contexts - nighclub, relaxing radio station, experimental radio station - and were given a piece of music to try and remix into this style. At the end of the session the participants listened to each others remixes and tried to identify which card the remixer had picked, and were asked to explain their judgement in relation to musical features of the remix.

The fourth session was dedicated to a music remixing project where each participant chose a song from the Remix Portal library and remixed it as they saw fit, using their preferred interface layer. One-to-one interviews were conducted with the participants who attended this session.

Between the fourth and fifth sessions feedback on these remixes was created by an expert music educator from my research group. During this session I questioned their thought process to try and establish how the multi-layered interface might impact their feedback provision.

The participants received feedback during the fifth session and were given time to refine their remix in light of this feedback.

The sixth session was devoted to more remixing practice. Participants chose another song and remixed it as they saw fit.

During these sessions, I spent time with each participant, asking them if there were any things they didn't understand or wanted help with. The instruction they received was therefore individualised and responsive.

After these sessions with the student participants, I had a session with a second expert music educator where I presented the students mixes though Remix Portal's multi-layered interface, and asked them discuss how they would approach the task of creating feedback for these participants. This music educator was one of the lecturers at a further education college where I did a previous deployment.

7.6. Findings

During the second session, participants were introduced to the multi-layered interface and were tasked with using it to create a basic remix, ensuring they tried each layer in the process. At the end of this task, the participants were given a piece of paper and asked to write down what layer they preferred using. Two participants indicated that they preferred using layer 4, three indicated they preferred layer 3, one participant reported that they alternated between layers 4 and 5, and one reported that they alternated between layers 3 and 4. They were also tasked with writing a description for each layer. These descriptions are presented in Table 7.6. This second session concluded with a group interview that probed participants' initial experiences with the multi-layered interface. There was a general sense that the multi-layered interface offered an accessible entry point, with one participant commenting: *"I found it good and easy and it's an easy thing that's good for beginners and learning"*, and another adding: *"Yeh, much better than the other [single layer] one"*. However, the higher layers with the more complex control sets appeared to offer a substantial challenge, as when asked what they found most challenging one group interviewee responded: *"Looking at the red level - phwar!"*. This was a sentiment shared by the other three group members and evidences that they found this layer overwhelmingly complex upon first acquaintance.

Interface comprehension

Participants reported specific challenges with the terminology on the interface during this group interview: *"Some of the words - I didn't know what they meant"*. They also found understanding the function of interface components challenging: *"Figuring out what things do and mean"*. However, they understood that they just need time to get used to the software, and nobody during

Layer 5	scary; intimidating and complex; too much; hard but I can understand most; advanced; complicated; very in your face and way too confusing
Layer 4	fine for me; just right but still complex; ok; good; harder; advanced; alright but slightly confusing
Layer 3	simple; perfect; suitable; bit easier; developing your skills; requires some understanding; great - perfect settings
Layer 2	easy; simple; nice; easy; a little harder but still okay; simple; pretty simple
Layer 1	very easy; too easy; easy; simpler; simple and easy to use; easy; too simple

Table 7.6 Participants' descriptions of each layer

this early group interview could think of any changes that would improve the software for them. Instead, they complemented its design: *"it's pretty easy to use"*, and they particularly appreciated the layers approach: *"I like the layout of things for different understanding levels"*, and: *"Yes, the layers are really, really helpful"*. This indicates that the challenge of learning to use the music mixing software – a challenge associated with understanding the function of interface controls and the terminology used to label them – can be mitigated to some extent by this multi-layered interface design.

Moving on up

By the end of the fourth session, participants were significantly more experienced with the multi-layered interface. I conducted individual interviews with the four participants who attended this session, to probe their experiences after using the multi-layered interface for three sessions. Participants described initially exploring the layers (as I had instructed them to do), then choosing a relatively low layer (either the first or second layer), before progressing up one or more layers over the three sessions which followed. I asked each participant to describe their thought process at the point they decided to move up a layer. Participant 2 moved up to access a greater range of functionality: *"I thought I could get more out of the music by moving up"*, as did participant 4: *"There's just more options"*. Participant 1 expressed a similar sentiment but added that they wanted the greater challenge that this enhanced functionality could bring: *"Because I wanted to give myself a bit more of a challenge as there's more things to change on the music"*. Participant 3's decisions to move layers was born more out of curiosity: *"I just wanted to experiment and see what the differences were"*. Interestingly, decisions to move up appeared to be preceded by participants' gaining confidence (and presumably competency) with their current layer: *"I'm feeling pretty confident now so I'm probably going to have a go with the higher, harder ones"* (P2), and: *"Once I'm happy I'll move on"* (P4). Participant 1 stated: *"I'm trying the yellow one but really I'm more at the green one"*. This demonstrates their confidence at layer 2 (the green layer), yet their desire to challenge themselves by using the yellow layer (layer 3). After moving up to a new layer and gaining familiarity, participant 3 expressed a feeling of contentment: *"I'm quite content at the moment because this new one [the orange layer] has just the right amount* *of controls, not too much, not too little".* This indicates that the change between these layers represented an appropriate step-up in difficulty for this participant, and this sentiment was echoed by the remaining participants who agreed that after moving up a level, the new layer provided a suitable amount of challenge for them, and that it was not too hard to make the transition to a higher layer.

The sweet spot between boredom and stress

Each participant was asked to consider how they would feel if they were restricted to working on a lower, more basic layer. Whilst no one welcomed the idea, participants were split on how they anticipated being impacted. Participants 2 and 4 viewed this in a negative light, with participant 4 stating:

> “It would be a bit boring. I’d adjust the volume on a few things and then that would be me done. But I might be frustrated because I wouldn’t have the things to boost the bass or cut the mids or whatever.”

Participant 2 asserted:

> “I’d be really limited. It would be quick and easy, like you could do things with it but it would be really limited in what you can accomplish compared to yellow (middle) layer.”

Participant 3, in contrast, stated: *"I wouldn’t be that bothered because it does the job"*, and participant 1 said they would feel:

> “Alright because although the blue one [level 1] is very basic I think the green one [level 2] would be...not as challenging as the yellow one [level 3] but it would be where I’m at at the minute.”

These contrasting responses possibly indicate that participants 1 and 2 were not quite as competent and/or confident as participants 3 and 4, hence why they would be less dissatisfied using a basic layer than participants 3 and 4 who would find such a layer restrictive and therefore boring.

Each participant was also asked to consider how they would feel if they were restricted to only working with the highest layer i.e. the most complex interface configuration. Participants 1 and 3 thought this would be too much for them: *"I’d struggle a lot. I like to work up one thing at a time rather than going straight to the top, otherwise I’d have no idea what I’m doing with it"* (P1), and: *"A little bit stressed. It seems like really overwhelming, but I’m sure I could pick it up because it’s basically the same only with more buttons"* (P3). Whereas participants 2 was not as daunted by the prospect stating that they would feel: *"Okay, because you can still do the same thing. It would just be nowhere near as quick because you’ve got a lot more options"*. Participant 4 was similarly undaunted: *"Excited. I like a challenge"*, however, they didn’t anticipate a time penalty for using a higher layer like participant 2 had done, stating that they thought creating a mix with the highest level would take: *"Probably around the same time because I'd know what I want and I wouldn't mess around"* (P4).

I probed how using the multi-layered interface impacted participants' concentration whilst remixing, as deep concentration can indicate a state of flow. All four participants reported that they felt they were able to concentrate well when remixing using their self-selected layer. Participant 1 indicated that they found the multi-layered design better than the conventional, single layer interface in this regard, due to the staged introduction of interface controls: *"Rather than everything being there at once it's easier to have things added one at a time, and then once you know what you're doing with one thing you can move onto the next"* (P1). Participants considered that their concentration would be negatively impacted if they had to use a higher level than they would have chosen themselves e.g.: *"Yes [my concentration would be impacted], on layers when there are more things, you don't understand what they do and so it's confusing"* (P3), and: *"I like a challenge but if it's too much I might get frustrated and then I'd probably just stop"* (P2).

They also thought their concentration would be negatively impacted if they had to use a lower layer: *"...because there's not enough things going on to absorb you in"* (P4). Participant 3's response was similar: *"You wouldn't have to concentrate as much but it would get kind of boring after a while. Like if you knew what everything did on the orange then going back to the blue wouldn't be a good idea"*. Interestingly, this is a more negative response than participant 3 gave when asked to consider how using a lower level would make them feel, to which they had responded: *"I wouldn't be that bothered"*. Participant 2 explained that they liked to challenge themselves in order to maintain concentration: *"I focus more on a harder level because there's a lot more information to take in. It's the opposite with the blue one. Because it's way less complicated it's way more relaxed"*.

Volume interactions

A key distinction between the layers was differing volume adjustment paradigms. On layers 1 and 2, track volumes could be adjusted using volume faders. These are undoubtedly simple to use but can't be automated so the volume for each track will remain consistent for the duration of a song. Layer 3 features the volume blocks interface which enables a channel's volume to be set for each section of a song, meaning users can configure it to change over time. However, volume ramps (i.e. gradual volume increases or decreases) are not possible using the blocks interface. Layers 4 and 5 replace the volume blocks interface with a line graph-style interface which we refer to as volume envelopes. This enables a user to change a channel's volume at any point in the song and to create volume ramps. Whilst this offers the most flexibility, I considered it the most complex to use so I was keen to understand how participants experienced these various volume change approaches. Participant 2 preferred the volume blocks on layer 3 to the more simplistic volume faders approach:

> "I think rather than changing it for the whole thing, I think it's better for changing it for different sections. I think the blocks are a good way of changing it for the

> different sections...but the envelopes on the higher levels look really interesting. I think I'll have a go with them next session."

Participants 1 and 4 also favoured the blocks approach with participant 4 commenting:

> "The envelopes are confusing. The blocks are easier to understand. You can make each song's section louder or quieter. Like in the choruses you might want some things louder. So it gives you good control but it's not too hard. With the envelopes it's hard to pinpoint where sections are."

Participant 3, in contrast, preferred the envelopes: *"It just makes it easier. With the blocks you've only got so many blocks but with the envelopes you can have as many changes as you want and you can make a more gradual build-up"*.

Layer layouts

I asked each participant to consider the controls presented on each layer, and if they thought it would be better to introduce any controls at a lower layer, or leave any until a higher layer. No participants had any suggestions for improvements and participant 1 commented: *"I think it's spot on. Each one is a nice step from the last one."*

7.6.1. The view of the expert music educators

Two expert music educators reviewed the mixes within the multi-layered interface context. One provided feedback to the students and answered my questions as they worked; the other did not provide feedback but went through a process of considering how they would approach a feedback giving task.

Both experts were of the opinion that the layer a participant had chosen would have an influence on the contents of the feedback they would provide. Reflecting upon the feedback they had created, expert 1 asserted: *"I think I did give more detailed feedback to those students using the higher levels"*, and they followed up with the following explanation: *"...with the [higher layers] there's a lot more controls so there's more options for me to comment on"*. Similarly, expert 2 explained: *"If someone's chosen, say, layer 1, it's like they're saying "this is what I can handle" so I would stick to those controls... It helps you know where to start especially if, like you say, you don't know the students."*

However, these experts also looked to information *within* a layer when determining how to pitch their feedback. Expert 1, for example, would make a judgement on the participant's ability based on how many controls remained unused upon the interface: *"the last one I did, they had used the red level [layer 5] but hadn't touched many of the control so I thought they're not at that level"*.

This would change how they approached the feedback giving task. Expert 1 again:

> "Those that chose the orange or red [layers 4 or 5], there were a lot of controls that appeared to be left at their default positions. So there were lots of things they hadn't

> messed around and played with...I had been suggesting refining what they had done, mainly because that was what they had tried out, so I found it easier to concentrate on controls they had tried as opposed to focussing on things they hadn't."

Expert 2 informed me that they would assess how well the controls had been applied within a layer. This would influence where they would focus their attention when providing feedback. Interestingly, this might involve suggesting a participant moves up to a higher layer:

> "I suppose if everything was great with what they had done you might try and push them on a bit. Like saying "look what you could achieve if you just took the next step". So here I'd be saying "I think you'd benefit from these other controls [on a higher layer]", and I would try and show them how to get started with them."

Expert 1 did raise a concern around the challenge of distinguishing purposeful artistic choice for the types of unsubtle control use or lack of control use that we might expect from novices. As when asked whether they got a sense of participants' ability from the layer they had chosen and how they had used it, expert 1 responded:

> "Yes, but whether it was right or not, or whether it was prejudged I don't know....There was one [mix] where there was an awful lot of distortion on one of the stems and it seemed like they had rammed the controls up pretty high. Whether or not that was an artistic choice or whether it was because they have less nuanced ability with the controls, I don't know for sure."

She reported that having more background information on each participant could be helpful to feedback givers. However, there remained a sense that the multi-layered interface was superior to a conventional, single-layer interface for feedback provision to students they did not know. For example, expert 2 commented: *"You do get a lot from the layers information, I think it's definitely an improvement"*.

7.7. Discussion

The participants in our evaluation sessions had no prior music remixing experience, yet they all reported finding a suitable Remix Portal layer that allowed them to begin their music remixing journey. The multi-layered interface therefore appears suitable for newcomers to the activity. Latterly, all participants reported opting to move up one or more layers over the course of the deployment sessions, and experienced no trouble in transitioning between the layers. This provides good evidence that the multi-layered interface will continue to suit users as they move on from novice towards an intermediate level of ability. Given that the final layer of the Remix Portal interface contained a range of interface controls comparable to professional equipment, the multi-layered interface should continue to be relevant as participants progress towards an expert level of ability. Data from two expert evaluators also demonstrate that multi-layered interfaces can convey useful supplementary information to feedback givers, about the user's ability level and where they should focus their feedback giving efforts to produce effective feedback. Taking this evidence together, a strong case can be made that multi-layered interfaces offer an improvement over conventional, single-layer interfaces and can play a useful role in supporting novice to expert transitions.

These findings have parallels with Csikszentmihalyi's flow theory (Nakamura and Csikszentmihalyi, 2014). A central idea of flow theory is that flow becomes attainable when the challenge associated with an activity is well matched to the skill level of the person doing the activity. Activities which are too challenging might induce anxiety, whilst activities which are too easy might induce boredom. This clearly correlates with the paper-based layer descriptions participants provided, and also their responses when asked to explain how they would feel if they were restricted to using a higher or lower layer than they had self-selected. For example, participant 4 volunteered the word *"boring"* when I asked how they would feel if restricted to a lower layer, whilst a higher layer would make participant 3 feel *"A little bit stressed"*. When asked to write descriptions for the layers at the end of their first session, as Table 7.6 documents, participants volunteered the words *scary*, *intimidating*, and *confusing*) to described the most complex layers (layers 4 and 5) – words that are related to anxiety. There were no words related to anxiety used to describe the lowest layers. Similarly, the phrases *too easy* and *too simple* were used to describe the most basic layers (layers 1 and 2); descriptions that reflect the potential for participants to experience boredom if restricted to these layers. No words or phrases relating to boredom were used to describe the higher layers. Taking these layer descriptions together with the observation that the participants demonstrated deep concentration when remixing with a self-selected layer, this provides good evidence that multi-layered interfaces may help users obtain an optimal flow state.

Interestingly, whilst flow theory draws attention to the challenge associated with doing an activity, we should not consider the activity in isolation from the tools used to engage with it, and the skill level of the person doing it. Specifically, the activity of music remixing changed depending upon what layer a participant was engaging with, and what skill level the participant possessed in terms of their ability to scrutinise the audio and perceive subtleties within it. For example, the novice music mixers were only observed using basic layers and only engaged with a relatively small number of musical dimensions. As the participants gained in skill and experience, they would move to a higher layer where they could experiment with new controls, and over time they would learn how to use them to impact more features within the music. Therefore, the task of music remixing can be considered a task of manipulating a number of musical dimensions, and with an increase in skill level and interface layer, comes the desire and opportunity to impact more musical features.

Reflecting upon our findings in relation to cognitive load theory, we might surmise that one of the factors which caused our novices to gain enough confidence to decide to move up a layer was that chunking (Tuovinen, 2000) was occurring which caused them to learn the associations between interface controls and the sonic properties of the music. Learning these associations means less cognitive resources need to be expended here in the future, which may result in the users feeling like they have sufficient cognitive capacity to take on the challenge imposed by the next layer up.

It is worth considering whether each interface control upon a layer imposes the same amount of cognitive load. Based upon the logic presented in the previous paragraph, it is reasonable to assume that if a user gained familiarity with a previous layer, then the controls inherited from the familiar layer will impose less cognitive load than the new controls. Secondly, the data from the design activities suggests which controls may be the most burdensome, and which the least. The listening game activity found that some controls were more challenging for users, which suggests they might impose a higher cognitive load. Furthermore, from the participant-provided usefulness ratings we might infer that controls rated as the most useful were the ones they have been using the most, and therefore the ones where the most chunking will have occurred. This could mean that these controls don't inherently impose less cognitive load than other interface controls, it's just that users engage with them more, or sooner, and so the cognitive load they impose goes down more quickly than for other controls.

Whilst a common design recommendation is to minimise the cognitive load an interface imposes, e.g. (Whitenton, 2013), the approach we pursued involved allowing users to control the interface composition and therefore the amount of cognitive load they would experience. Our findings suggest that complex interfaces can be appropriate and even advantageous, but should be provided to users who have sufficient cognitive resources to cope with them. Allowing users to self-select a layer on a multi-layered interface may be an appropriate way to achieve this.

Reflecting upon the design activities that informed the creation of the multi-layered interface, although the students who participated in the design activity were significantly younger than those involved in the evaluation sessions, the resulting design appeared appropriate as none of the evaluation group could suggest interface improvements in terms of moving controls to different layers. The information obtained from the young and novice participants involved in the design activity was best suited to informing the layout of the lower layers, and influenced the design decision to provide limited access to more difficult/less useful controls until the final layer. However, these participants were not advanced enough to help with the development of the volume blocks or volume envelopes interface. Perhaps doing the design activity with two groups; one group of novices (as we had) and one group of experts (which we did not have), would provide evidence which could then be integrated and might better inform the design of all the layers in the multi-layered interface.

7.8. Chapter conclusions and limitation

My initial Remix Portal interfaces featured single-layer designs and deciding which controls to place on the interface involved balancing the risk of participants becoming bored by lack of options, against the risk of participants being overwhelmed and cognitively overloaded by too many options. These single-layer interface designs did not perfectly suit all participants. I attempted to remedy this with an *expandable* interface, and this work evolved into the multi-layered interface design presented here, which is an attempt to provide an interface that users can self-adjust, to find the sweet spot between simplicity and complexity, and to stay within this sweet spot during their progression from novice to expert.

The work presented in this chapter also addressed an issue I had identified around feedback provision; specifically, how both feedback givers and receivers can find it challenging when they don't know each other well, as was the case in Chapter 4's deployments. The experts can find it hard to pitch their feedback if they don't know the capabilities of the students, and the students can find it hard to interpret this feedback if they can't get a sense of the feedback giver's character.

The focus of the work presented in this chapter is on exploring multi-layered interface design as a potential solution to the two issues outlined above; issues of participant/interface fit, and of feedback provision in an environment with limited background information on each party. I began by exploring how to design a multi-layered interface. I considered a range of approaches to the challenge of how to segment a complex interface into a set of layers. I proposed segmentation based on one of the following criteria: frequency of use, difficulty of use, teacher led, or student led. I then explored three novel design methods for gathering information based on the *difficulty of use* and *student led* approaches. Following this, I presented a five-layered music mixing multi-layered interface and deployed it at an after school music club in order to conduct a basic evaluation.

Despite the fact that I was only able to use the multi-layered interface for a short time with a small number of participants, I did see indications that it might help users avoid the anxiety that could be encountered with an interface that is too complex, or the boredom encountered if an interface is too simplistic. I also observed that it can help users find an interface that suits their current level of ability, can aid good concentration, and can maintain their interest as their skills develop. Similarly, whilst only two expert music educators evaluated the interface from a feedback giving perspective, I did see indications that the layer information embedded within the remix, would influence the feedback provided. Our experts reported that they would provide simpler feedback to users who had opted to use a more basic layer, and indicated that they thought the multi-layered approach was an improvement over conventional, single-layer interfaces for feedback provision to students they don't know.

In summary, whilst I think further work is required to strengthen this evaluation, the data I have is consistent with the idea that multi-layered interfaces could play a useful role in supporting novice to expert transitions, and the design methods I developed could help with the production of multi-layered interface.

Chapter 8. Discussion and Conclusions

8.1. Introduction

This final chapter demonstrates how the research aim and guiding questions set out in the introduction have been addressed within the thesis. The chapter then presents a reflection upon the contributions made within this thesis. The limitations of this research are then discussed along with directions for future work.

8.2. Reflections upon research questions

The project aim was **to perform a design-based exploration of social music mixing; its tools and its impact upon learners**. Four research questions were devised to support this exploration, and these questions are presented again here, along with explanations of how these questions were answered, descriptions of the findings which emerged, and comments upon their generalisability.

8.2.1. Research Question 1: Can music remixing activities support the formation of a local learning ecology involving young people and established local musicians, and if so, what factors are important in the design of the tools and social configuration?

This question was primarily addressed in Chapter 4, where two local learning ecologies were constructed and studied. These local learning ecologies involved students participating during their school music lessons, remixing the work of established local musicians, and then receiving feedback upon these remixes. When the activity was viewed through the analytical lens of Activity Theory, the local learning ecologies were understood to be organised around two activities; the production and consumption of music remixes, and the production and consumption of learning feedback. The students were producing the music remixes which were consumed by the musicians as well as their classmates, whilst the feedback was produced by the musicians and consumed by the students. Linking to wider literature, the work completed here using local learning ecologies produced multiple versions of the music, which was then also consumed by many people. This contributes to the realisation of Benkler's many-to-many new information economy (Benkler, 2006). This is distinct from the traditional one-to-many media distribution model, where, in the case of music, a definitive version of a recording is created and distributed. This might be an interesting avenue to explore in further research.

The results of these field studies were very encouraging, with the key stakeholders responding positively when reflecting upon their participation in the enacted local learning ecologies. The students' reflections revealed similar motivations to participate as had been identified in young people participating within successful, online music remixing communities (Cheliotis and Yew, 2009; Jenkins, 2009; Prior, 2010). This included a desire to share remixes for recognition and support, and an appreciation of the activity's engaging nature. The musicians were encouraged by the creative ideas the young people returned within the remixes, and were initially motivated by the opportunity to 'giving something back'. The teachers were motivated to participate in order to give their students the chance to try something new and different around a contemporary music making style which the teachers did not feel confident to teach by themselves.

Two significant issues were identified following these field studies however. These related to the social configuration and consisted of a communication gap and a labour gap. The communication gap resulted from strict school rules preventing young people communicating with the musicians via the channels typically used by participants in informal music remixing communities. This issue was addressed during work presented in the latter half of this chapter, by incorporating basic text-feedback tools into Remix Portal, and then taken further within the work presented later in this thesis, by embedding novel communication tools directly into Remix Portal. For example, the show-and-tell feedback interface which helps feedback givers communicate demonstrations of changes they make to a remix, and the multi-layered interface which attempted to help feedback givers understand how to structure and pitch their feedback. The labour gap problem concerned the brokerage required by the researcher to set-up the local learning ecologies, and the expertise required to teach the music mixing skills and to demonstrate Remix Portal. This should not be considered an insurmountable problem because I reported evidence that teachers' confidence grows quickly, and initiatives like *teacher champions* have proven successful in other domains where new technology is being rolled out, with the teacher champions being those teachers with some experience who can then support their colleagues in their initial use of the new technology (Sinnayah et al., 2021).

A third issue concerned an accessibility gap, and this issue was identified from the outset when considering that it is an older demographic who typically use music (re)mixing applications. The first iteration of Remix Portal was therefore created with a very simple interface to provide sufficient accessibility, however the field study revealed that some students can quickly outgrow this simplistic interface and therefore to help these more capable students avoid frustration, an *expandable interface* was created which enabled users to reveal (or hide) more interface controls by pressing 'pro' buttons. This work laid the foundations for the multi-layered interface work presented in Chapter 7.

The enacted local learning ecology did possess some contextual differences when compared with the remixing communities observed in the wild. For example, whilst Benkler (2006) observed remixing communities to be composed of *"loosely connected, widely distributed individuals who work cooperatively, openly sharing resources without managerial commands"*, some amount of 'managerial commands' were required to establish and maintain the local learning ecology, and to ensure the remixing activities match school requirement (e.g. ensuring each child has suitable feedback on their remix by a certain point in time). Such managerial commands were provided by the researcher during the study, but it is hoped that the teacher would eventually take on this role in future project deployments. Similarly, the actors could not be said to be widely distributed, indeed the theory behind local learning ecologies says that all actors within a local learning ecology should be within a single locale (Hodgson and Spours, 2013). However, the increased top-down structure and shrinking of participants' geographic distribution did not appear to diminish or alter the motivation of participants, as our participants' experiences closely matched those reported by young people operating within informal music remixing environments (see e.g. (Cheliotis and Yew, 2009; Jenkins, 2009; Prior, 2010)). Therefore, we can assert that some of these contextual factors may be unimportant.

Given the enthusiastic response of all stakeholders within the constructed local learning ecologies, and the fact that solutions were found to the core issues that arose from these initial deployments, this thesis proposes that there is significant potential for local learning ecologies to be formed around music remixing activities with young people participating in formal music education environments and established local musicians. In turn, we argue that this configuration of social music mixing could have a significant, positive educational impact. It would serve as a way to realise calls to incorporate expert musicians within music education (See and Kokotsaki, 2015), and would reduce the reported skew towards western classical music (Hess, 2014; Rogers, 2002; Spruce, 1999). And by basing the activities around remixing i.e. building upon the work of others, the young people should, according to Jenkins (2009), develop media literacy skills, self-confidence, and ethical frameworks which will help prepare them for the workplaces of the future.

Two key lessons were learned concerning the design of systems to support such local learning ecologies. It is considered that these lessons could be generalised beyond the context of music education, to all subject areas, as the input of local expertise could be advantageous across the curriculum. Firstly, communication with actors beyond school must occur through a trusted platform, and these communications should be vetted by a trusted party before they are passed to the young people. Secondly, the clearer the visibility between the young people and the local experts, the greater the benefits are likely to be for both parties. Younger students can particularly appreciate the visibility afforded by video feedback in comparison with text-modality feedback, as it enables them to gauge the experts' facial expressions which can aid interpretation of their words.

8.2.2. Research Question 2: How can we design technology to support tacit knowledge transfer through feedback within the context of music mixing skill acquisition?

This question was intended to explore how the feedback provided to students participating in the local learning ecologies could maximise learning gains. Following the field deployments it was considered that whilst participating in the local learning ecologies enhanced the students' engagement with their music education, the information returned in the feedback was relatively poor from a learning perspective. Surveying the literature led to the understanding that music mixing expertise constitutes a type of tacit knowledge, and tacit knowledge is usually passed on through apprenticeship learning configurations involving demonstration and feedback within face-to-face learning environments (Agyemang and Boateng, 2019; Collins et al., 1991; Collins, 2010; Owsinski, 2013; Polanyi, 2009). The ambition embodied within this research question was to gain insights into how to design technology to make these types of processes available to people outside the typical face-to-face learning environments described in the literature. Such insights would have the potential to support tacit knowledge transfer between feedback givers and receivers even when they are geographically or temporally separated, as would occur in the local learning ecologies we were interested in.

The work undertaken to address this research question resulted in the following design criteria which encapsulates the concept of show-and-tell feedback:

- Design Criteria 1 (DC1): Facilitate modelling and the corrective component of coaching (Collins et al., 1988) by providing a mechanism via which the feedback giver can make and store changes to the artefact.
- Design Criteria 2 (DC2): Provide a mechanism that enables the feedback giver to communicate the thinking behind their artefact processing, as *process level* information helps the novice develop a conceptual model (Collins et al., 1988) and aids learning (Hattie and Timperley, 2007).
- Design Criteria 3 (DC3): Enable the feedback recipient to experience the feedback giver's proposed changes to the artefact i.e., to *play* their demonstration, which may draw the feedback recipient's attention to unnoticed and sub-optimal aspects of their work (Collins et al., 1988), and overcome comprehension issues related to written descriptions (Ainsworth, 2006; Carless, 2006; Goldman, 2003).
- Design Criteria 4 (DC4): Enable the feedback recipient to see how the feedback giver used tools to accomplish their proposed change, as *modelling* of working methods aids learning (Collins et al., 1991, 1988).
- Design Criteria 5 (DC5): Ensure the feedback recipient can easily switch to the pre-feedback state to a) facilitate close comparison between the two which can help the novice notice what may otherwise only be evident to an expert (Cambre et al., 2018; Schwartz et al., 2016), and thus develop their sensory, perceptual tacit competency (Dahlbom and Mathiassen, 1993; Schindler, 2015), and to b) remove unhelpful feedback.
- Design Criteria 6 (DC6): Support feedback provision from multiple feedback givers, making it possible for recipients to benefit from a range of perspectives, opinions and recommendations (Cho and Schunn, 2007), and increasing the likelihood of receiving feedback matching their aesthetic sensibility (Bergmann, 1994; Tinapple et al., 2013).

User testing was conducted with a system that embodied these design criteria. It was judged to provide clearer and more detailed feedback than the conventional, alternative text-based feedback method. Participants expressed a clear opinion that this feedback method would help them develop their music mixing skills. Despite issues of control and artistic vision also emerging, it is argued that this show-and-tell feedback method is better suited to supporting tacit knowledge transfer through feedback in remote or asynchronous settings than the dominant, contemporary text-based form of feedback.

The design criteria documents key features which other researchers looking to explore technology-facilitated tacit knowledge transfer could use as a starting point for their own work. In addressing this research question I have developed an understanding of how to produce tools to better support social music mixing. However, the findings could have value beyond a music mixing context, as I attempted to demonstrate through the visual imagery-oriented show-and-tell feedback interface presented in Chapter 5.4. It is argued that the findings of this work could have value in any remote and/or asynchronous learning settings where the subject involves the use of graphical user interfaces to manipulate non-text-based artefacts.

8.2.3. Research Question 3: How can we capture and use expert knowledge in the form of music mixing-oriented worked examples to support music mixing skills acquisition?

This research question was intended to explore alternative configurations of a local learning ecology, beyond the musicians serving as feedback givers. To this end, music mixing *worked examples* were explored. In contrast to the feedback configuration, a worked examples configuration necessitates the input of the musicians upfront, as they must create example mixes for the students to study before they engage with their own music mixing activities.

The design work conducted whilst exploring this research question led to the development of worked example units, which are intended to segment complex worked examples into manageable information chunks. These were validated during the associated field deployment and participants deemed them to be a necessity for effective learning.

The results of the field study presented in Chapter 6 demonstrate that the worked examples can support the acquisition of music mixing skills through the active learning they promote, and the self-paced learning they facilitate. Furthermore, the worked examples delivered through Remix Portal's show-and-tell feedback interface helped learners understand the connections between interface tool changes and the sonic changes imparted within the music. Developing this understanding is a key part of music mixing skills development, as discussed in Chapter 2.4. The worked examples therefore, offer significant advantages over conventional lecture-style teaching methods. Accordingly, it is argued that this alternative configuration of social music mixing – social music mixing via worked examples – can serve as an effective teaching tool and should be considered by those involved in teaching music mixing skills.

These findings could be generalisation to the teaching of other creative, artistic subjects, as they will all share essential characteristics in that the creative challenge can be thought of as an ill-defined problem (Greeno, 1976) with no clear goal, solution path or expected solution. Therefore, in all creative, artistic contexts, I expect novices to find value in seeing an expert's working method and being informed of the reasoning behind their actions.

8.2.4. *Research Question 4: How can we design multi-layered interfaces to support novice to expert transitions within the context of music mixing skills acquisition?*

This research question touches upon a central issue for learning technology designers, which is how to support a learner's progression. It also takes into account the fact that much professional-grade music mixing software is rather complex, and therefore may impose a high barrier to entry. Attempting to support students' transition beyond school into music making communities necessitates helping students learn to use the types of tools commonly used by the community members. This entails finding ways to combat their complexity, especially when students are new to the activity.

The literature review informed our understanding of how complex interfaces can hinder learning, be that due to the extraneous cognitive load described by cognitive load theory (Sweller, 2005), or by the anxiety that can be induced when the student has insufficient skill to handle a complex interface and the associated challenge, as described by flow theory (Csikszentmihalyi et al., 2021). The literature review also revealed a potential solution in the form of the multi-layered interface (Shneiderman, 2002). One configuration of a multi-layered interface is to provide a number of layers, increasing in complexity with each successive layer, and to enable the user to control which interface layer is active. This lets them balance the interface's affordances against their ability to handle complexity. This was the type of multi-layered interface configuration that was tested within the work presented in Chapter 7.

An emergent design challenge addressed whilst answering this research question concerned how to decide what interface controls should be placed on any given layer. Three novel design techniques were developed in response to this, and they drew upon user input to sort the interface controls by perceived usefulness and difficulty of use. The idea being that interface controls that are deemed less useful or more difficult to use should be reserved for higher layers, whilst highly useful and easy to use controls should be encountered sooner. Two of these design techniques involved the participants self-rating usefulness and difficulty via rank ordering or discrete rating activities. The third design technique involved deriving difficulty scores from a gamified music mixing test. These design techniques were considered complimentary and produced similar results thus increasing confidence in their utility.

The evaluation of the music-mixing multi-layered interface revealed the advantages of the multi-layered interface for teaching music mixing skills and for supporting skills progression. Specifically, it helped participants avoid the negative emotions that might occur should they be restricted to an interface which is too simplistic or too complex for their current level of ability. It also provided feedback givers with implicit information about the participants' level of ability or confidence, which should enable more effective, targeted feedback. The interface evaluation also served to validate the design activities used to arrange the multi-layered interface's configuration due to the fact that the participants could not suggest improvements to these interface layouts and considered the layouts optimal. Given that the multi-layered interface appeared able to help students maintain an optimal state of flow, and navigate the challenge posed by potential extraneous cognitive load, it is argued that the multi-layered interface can make an excellent tool for teaching music mixing skills and for helping people progress from novice to expert music mixer. Furthermore, it is argued that the findings could be generalised to other areas where novices are intended learn to use complex graphical user interfaces to produce creative artefacts.

8.3. Contributions

This section reflects upon the contributions made within this thesis, and the discussion is organised around the following four categories of contribution: *artefact*, *empirical*, *conceptual*, and *methodological*.

8.3.1. Artefact contribution

Artefact contributions are well recognised within the field of Human-Computer Interaction (Bowers, 2012; Remy et al., 2018; Wobbrock, 2016) and beyond (Hevner et al., 2004; Johannesson and Perjons, 2014). The designed artefact – Remix Portal – represents a contribution in that it was systematically refined through the application of findings from field deployments. It is now offered to the research community as an open source music (re)mixing tool with four distinct interfaces, described in Chapter 3.5:

1. A basic music mixing and mix playback interface which was utilised in the field deployment described in Chapter 4.2.

2. A music mixing and mix playback interface featuring an integrated text feedback mechanism. The use of this interface was described in Chapter 4.3.

3. A music mixing and playback interface featuring a novel *show-and-tell* feedback mechanism. The exploration of this was described in Chapter 5.

4. A multi-layered music mixing and playback interface featuring five interface layers of increasing complexity. The deployment of this interface was described in Chapter 7.

Others can benefit from this contribution by using Remix Portal's open source code as the starting point for their own research, or by replicating the ideas embodied within the design elsewhere. Whilst the implemented interfaces are very much focused upon music remixing, the show-and-tell interface iteration and the multi-layered interface iteration could be adapted and applied beyond the music mixing context. For example, chapter 5.4 presented a show-and-tell interface mockup aimed at supporting the acquisition of digital imagery skills. I would argue that a significant proportion of Remix Portal's source code could be recycled to implement such an interface. Similarly, the source code that pertains to the multi-layered interface's layer views and switching mechanism could be recycled should someone wish to create a multi-layered interface for another context of use.

This artefact contribution is tied closely to the empirical contribution described subsequently, which accommodates the description of the design process as well as insights gained following deployment of the designed artifact into the field. It is also tied closely to the conceptual contribution as this influenced the design. It is hoped that when the reader views the artefact alongside the conceptual and empirical contributions, they should be satisfied of sufficient novelty and utility in the artefact for it to merit a worthy contribution in its own right.

Returning to one of the motivations set out in the introduction of this thesis, namely the erosion of the arts within formal education, the artefact created (Remix Portal), along with the accompanying teaching materials, could play a role in supporting music learning in a context of budgetary, time and staffing cuts. This is because the input of experienced musicians helps mitigate the reduced music expertise within the school staff, the online nature of the tool gives learners access in their own time so they can continue learning at home even if school lessons are short, and the fact that the tool is available at zero cost to schools lowers monetary barriers to musical activities. Having said this, I believe that Remix Portal (in common with other technological solutions) cannot fully make up for the damage done to arts education via deprioritisation and budget cuts over recent years. Therefore, I will continue to argue for strong arts education funding, and I believe Remix Portal, like other technologies, will function best alongside a strong teaching team in a well-funded environment.

8.3.2. Empirical contribution

The field studies where the designed artefact was used produced data that revealed insights into participants' experience with both the artefact and with the surrounding social configuration. These insights support the validation of the artefact's design, and in the case of the work presented in Chapter 4 especially, validation of the social configuration mediated by the artefact.

Qualitative data collected during this thesis revealed the potential for the sustainability of the enacted local learning ecology, and evidenced the positive benefits of this local learning ecology. These benefits included enhancing student participants' engagement with formal music education, and enhancing their desire to participate in music making activities beyond school. However, the data also revealed challenges to the local learning ecology's potential sustainability, with a particular issue being the strong school rules and norms which served as an obstacle to the close coupling of students and established local musicians – something that the students reported as being desirable. This key issue was then addressed in subsequent field studies, partly through careful brokerage work with the school leaders to enable the rules to be relaxed slightly, and partly through design iterations consisting of a move to provide text-based feedback, then show-and-tell feedback, and then feedback within a multi-layered interface environment. These successive iterations offered enhanced transfer of information through the designed artefact between musicians and students (and vice versa), and thus improved the potential for learning to occur through these interactions, as the findings from these field deployments evidences.

Evaluating the show-and-tell feedback interface revealed the superiority of this new method over text-based feedback which is likely the dominant feedback paradigm for remote or asynchronous learning. Specifically, show-and-tell feedback was found to provide feedback with enhanced clarity and detail in comparison with text-only feedback. Similar advantages were found when this interface was used to provide teaching demonstrations via *worked examples*.

Of particular note was the benefit participants derived from being able to work through the demonstrations at their own pace, and *step in* to take over the audio processing and experiment, and thus engage in active learning which should produce the type of educational benefits described by the *goal free effect* (Tuovinen, 2000). However, an emergent issue related to some participants complaining that the feedback they received did not align with their artistic vision for the artefact. Issues of artistic vision could largely be addressed by the inclusion of multiple feedback givers, so whilst a some feedback givers may not correctly interpret the intention behind the remix, others most likely will, and the feedback receiver is free to choose which, if any, feedback suggestions to follow. Based on the empirical evidence, it is argued that this interface, whether used to provide show-and-tell feedback or worked example teaching demonstrations, enhances the potential for effective teaching and learning of music mixing skills. The advantages of this interface may be particularly useful to those learning within remote and/or asynchronous learning contexts, where face-to-face and hands-on demonstrations are not possible.

Exploring the multi-layered interface in use produced data which revealed the potential for the interface to help students attain, and stay in, the *flow channel* (Csikszentmihalyi, 1990). This contrasts with conventional, single-layer interfaces which risk being either too simple or too complex for a learner's level of skill and goals. This type of mismatch may cause frustration or anxiety which can hinder learning (Shernoff et al., 2014). Accordingly, it is argued that multi-layered interfaces represent an improvement over the dominant single-layer interface paradigm within learning contexts. Furthermore, findings revealed that multi-layered interfaces may help feedback givers produce effective feedback in situations where they have little knowledge of the learner, as presenting the learner's work through their self-selected interface layer conveys information about their skill level or confidence, and helps constrain the features fed back upon. As feedback is one of the most important influences upon learning and achievement (Hattie and Timperley, 2007), such insights into how feedback can be improved could offer significant benefits to learners and those who support them.

Further empirical contributions are provided by descriptions of the design process that accompanied each interface iteration. Within these descriptions, designers should find generalisable information which could support the use of these designs within other contexts, or could support the creation of design variants. For example, within Chapter 5, design criteria and discussion is included to explore how the show-and-tell feedback interface concept may be applied within anther creative domain.

8.3.3. Conceptual

This thesis offers a number of conceptual contributions, as detailed within this subsection. Firstly, the literature review led to a framework for understanding music mixing skills acquisition, as presented in 2.4. Whilst each piece of literature from which this framework is derived points to one or more traits that competent music mixers possess, no literature was found which pulled these traits together into a holistic framework. The claim is that a novice must develop four music mixing competencies to progress towards expert. These consist of: (i) *possession of a clear* *vision for the music*, (ii) *a process centred around holistic judgements*, (iii) *highly developed critical listening skills*, and (iv) *an actionable understanding of the link between tools and musical attributes*. Future work could explore the predictive power of this framework to provide further validation. For example, would music mixes produced by someone who possesses all of these competencies be judged as more competent in a blind listening test than equivalent mixes produced by someone lacking in one or more of these competencies? As it was within this thesis, the framework was used solely to aid the design and evaluation of the Remix Portal. This framework should also have value beyond this immediate project, and should serve researchers or educators working within a music mixing learning context.

Another contribution was to extend the concept of local learning ecologies to include helping young people transition into participating in community activities. Up until this point local learning ecologies (Hodgson and Spours, 2013) had been restricted to the idea of helping young people make successful transitions beyond school into further education or employment. This thesis cites the benefits of participating in local music communities – for the individuals, the other musicians involved, and society at large, and this together with the findings from the enacted local learning ecologies (as described in 4) makes a case as to why community participation should be included within the local learning ecology concept.

A significant contribution of this thesis is the conception of the show-and-tell feedback interface, as described in 5. This concept was born out of reflecting upon the literature around apprenticeship learning and its underpinning tacit knowledge (Collins et al., 1991; Collins, 2010; Polanyi, 2009), and considering how the processes involved might be supported by digital tools and made accessible to people in non-face-to-face learning environments. This led to the design of a feedback tool oriented around demonstrations of interface changes. A key aspects of the concept is that a piece of show-and-tell feedback should provide three things: (i) a revised version of the artefact so the learner can experience the feedback giver's idea of a correction or improvement, (ii) a depiction of how tools were used to enact this change, (iii) an explanation of the feedback givers thinking in relation to this proposed change.

The work around multi-layered interfaces makes a conceptual contribution as formative work around multi-layered interfaces was conducted with domain experts as the intended users. These experts required support to transition to new computer-based tools, but they had a fundamentally solid understanding of the overarching task activity. The context within which multi-layered interfaces are used within this thesis differs because the intended users are not domain experts, nor are they familiar with the technology. Therefore, a goal of the multi-layered interface within this thesis, in contrast to previous work around multi-layered interfaces – e.g. by Carroll and Carrithers (1984) – is to help people to learn to use the tools *and* to gain an understanding of the overarching task activity.

A further conceptual contribution emerging from the work around multi-layered interfaces involved integrating flow theory with cognitive load theory to support the design of the learning tool. Flow theory posits that anxiety may be induced when a challenge exceeds a learner's capability (Csikszentmihalyi, 1990; Nakamura and Csikszentmihalyi, 2014). Viewing this through the lens of cognitive load theory, we might posit that anxiety can be induced when the intrinsic, germane and extraneous loads related to a task exceed the learner's capacity. Whilst it is common for interface designs drawing from cognitive load theory to keep interfaces simple so as to reduce extraneous cognitive load (Oviatt, 2006), in the context of education, complexity may need to be introduced if learners are to develop the competency to handle an interface with more affordances. This may be the case if the learning goal is to teach the students how to use professional-grade tools. The challenge facing designers is about how to scaffold learners towards using a fully-featured, complex interface without them being overburdened along the way, by the extraneous cognitive load such an interface could induce. The thesis proposes multi-layered interfaces as a solution to this problem because they can allow complexity to be added gradually, as described in Chapter 7. Each subsequent layer should add a manageable amount of extra extraneous cognitive load, and if the learner takes their time to learn these new controls before advancing, the extraneous cognitive load will have been reduced to leave capacity for the load imposed by the new controls on the subsequent layer. So long as the learner steps through the layers gradually, they should be capable of learning to use a highly complex interface. Such a learning pathway should maximise the time a learner spends in an optimal flow state, not overburdened by an overly complex interface, nor bored by an overly simplistic interface.

8.3.4. Methodological

A methodological contribution is made via the descriptions of the design activities which were used to inform the layout of the multi-layered interface. This is believed to be the first work that explores how to incorporate user input into the design of multi-layered interfaces, or deals with the micro-level issue of how to decide what interface controls should be positioned on each layer. The three design activities offer a potential solution to these challenges. To recap, these design activities consisted of a rank ordering exercises where participants were asked to evaluate interface control usefulness, a discrete scoring exercise where participants were asked to rate interface control difficulty, and a gamified listening test that attempted to implicitly collect interface control difficulty ratings.

8.4. Limitations and reflections upon methodology

I discovered during the course of this work that school contexts are challenging spaces to do applied research. The first significant issue I encountered concerned the limited flexibility allowed by the national curriculum, which meant that there was only a very few weeks that could be devoted to 'risky' activities like research where the outcome must be uncertain to some extent given the desire to explore something new. This meant that I could only access schools for a relatively short amount of time each year, which limited the data I could collect and the constrained the time between design cycles to a much longer period than I would have liked. Furthermore, I would have liked to conduct a longitudinal study in order to assess behaviour change over time, to see if the local learning ecology could really foster participation in music making communities beyond school, and whether remixing serves as a low-barrier gateway into music making from which point participants would be motivated to go on and develop instrumental or vocal proficiency. Whilst schools did come to see the benefits of participation and became open to the idea of a longer-term study, unfortunately insufficient time remained within the PhD to make this a reality. I was therefore constrained to working with data around attitudes and opinions, from which I infer how behaviour is likely to be impacted. Whilst I draw upon theoretical backing to support these assertions, observing behaviour change over a long time period would have been preferable.

At the outset of this research project the aim was *to perform a design-based exploration of social music mixing; its tools and its impact upon learners*. Had I removed the 'design-based' element of the project aim, the number of potential methodologies I could have used to guide the exploration of this topic would have increased, and I could have commenced work exploring social music mixing in learning settings with pre-existing commercial or non-commercial music mixing tools. However, I believe I would have soon run into difficulties due to the necessity for communication between students and musicians. The teachers I worked with judged regular face-to-face communication between school students and community music experts to be impractical, given school safeguarding concerns, budget limitations, and musicians' work schedules. Therefore, technology must be used to mediate the communication. However, findings from the first field deployment, as presented in Chapter 4.2.3, revealed the school-wide ban on social media which rendered it unsuitable for facilitating such communication, which was to involve the sharing of music remixes between students and musicians, and the gathering of feedback. Furthermore, I am unaware of any available music (re)mixing tools that have adequate communication facilities built-in. Therefore, I am convinced that the design component of the methodology was necessary to get past this issue, as it allowed me to create a tool with integrated communication facilities, and furthermore, the communications could be withheld until screened and approved by the teacher or researcher, which gave the school gatekeepers (the teacher and their management) sufficient confidence to allow the research to proceed.

Of course, one does not need to subscribe to design-based research (DBR) to included design within their methodology, but given DBR is not too prescriptive of the methods it encapsulates – e.g. qualitative or quantitative takes on DBR are okay (Easterday et al., 2014; Kelly, 2006) – it can be a good fit for much education-oriented design research. One of the tenets of DBR is a commitment to solving real-world problems (Barab and Squire, 2004), and the problem which motivated this work, as described in the introductory chapter, is the underperformance of much contemporary music education which led to a government commissioned report stating that many children in England receive a sub-standard music education (Henley, 2011), and its disconnect with the lives of the students it serves due to a prevailing Western Classical music bias (Hess, 2014; Rogers, 2002; Spruce, 1999). My application of DBR seemed to address this issue, given the positive reports of the students post-participation concerning how it impacted their engagement with their music education and their desires to participate in music activities in the future. Over the course of the iterative design cycles conducted during this research, the designed artefact was refined to make it better fit the goals of facilitating communication around the critique of music mixing skills, and to better fit the desires and capabilities of the participants to help them maintain interest as they gained expertise. However, the other central tenet of DBR is its commitment to advancing theory (Barab and Squire, 2004), and upon reflection I think I found it challenging to balance these two aims. Whilst my work resulted design principles around show-and-tell interfaces and multi-layered interfaces, which DBR proponents would classify as types of *"theories that work"* which are of particular interest to DBR, and stand in contrast to *grand theories* (Tiberghien et al., 2009), I still feel like my focus was on exploring an alternative approach to music education as a solution to the issues of students' disengagement, as opposed to, for example, spending as much effort exploring the generalisability of the design principles into other contexts. I therefore think the dual concerns of DBR (to advance theory and solve practical problems) could well pose a challenge to other researchers.

8.5. Directions for future work

An issue I encountered within the schools context concerned the strict safeguarding procedures in place, which made establishing the local learning ecologies difficult, as reported in Chapter 4. A success of the project was developing a pathway to understand how trust could be gained, positive impacts upon the students demonstrated, and then rules relaxed to better support the process that has delivered positive results. An interesting next step would be to try and learn where this trust building process has to start from at each successive institution, and how far reports of positive experiences from elsewhere can move this process forward when planning studies with new partners.

Perhaps a more significant issue within this context concerns how to create a sustainable economic model for the local learning ecologies. Essentially, the labour of the researcher must be withdrawn at some point, and therefore how can this labour gap be filled? For example, it was found that teachers can lack the confidence to teach music remixing skills and therefore it was essential that I did this teaching in the early stages of the project. However, the teachers quickly grew in confidence and indicated that they would be willing to teach the remixing sessions themselves in subsequent project cycles. This indicates that sustainability may be possible, however the onboarding of new teachers could be tricky. Creating a network of experienced teachers to help onboard new teachers into the remixing pedagogy may offer an effective solution, but this cannot be stated with certainty at this point. And in relation to the musicians, all the musicians contributed to the project free of charge and were happy to do so citing positive benefits of participation (e.g. a sense of 'giving back', and being creatively inspired by the remixes), and due to music not being their main income. I believe not paying the musicians was justified during this project because it helped clarify their intrinsic motivation for participation. However, I acknowledge that should the project be sustained beyond the research phase, musicians should be paid fairly for their contributions. Otherwise, their participation risks contributing to the de-professionalisation of musicians. It is therefore an important topic for further research to explore how this could be achieved. So, whilst this thesis demonstrates that social music mixing-oriented local learning ecologies can be successful, further work is required to understand how to make this a sustainable and ethical endevour.

Whilst a music mixing show-and-tell feedback interface was developed, deployed and evaluated in Chapter 5, the digital imagery-oriented show-and-tell interface also presented in this chapter never made it past the design stage. A good direction for future work would be to develop this interface and evaluate it in a similar fashion to the music-oriented show-and-tell feedback interface deployment. Such a study would be a significant help to understanding the generalisability of the concept.

In chapter 7, I describe how multi-layered interfaces can implicitly communicate a learners' level of ability or confidence, which may help a feedback giver compose more helpful feedback. I believe this idea has significant potential and deserves to be studied in greater detail, beyond the small-scale study presented in this thesis. Researchers could, for example, probe in greater depth how the complexity of the interface a creative artefact is presented upon impacts feedback composition.

8.6. Conclusion

This thesis set out to perform a design-based exploration of social music mixing, its tools and its impact upon learners. Social music mixing was explored within the context of local learning ecologies, where the activity involved school students and expert local musicians: the local musicians would provide music, the students would remix the music, and the musicians would then provide feedback upon these remixes. Interactions between the two groups were mediated by Remix Portal, a bespoke music remixing and communication tool developed for the project and iteratively refined over the course of this work. Field deployments and qualitative data collection methods revealed that the students and teachers experienced positive learning outcomes, whilst the musicians reported feeling good about being able to contribute positively to the lives of young people and were creatively inspired by the musical ideas the students returned. This thesis identified three key challenges for the successful creation of music remixing-oriented local learning ecologies: a communication gap; a labour gap; and an accessibility gap.

The communication gap concerned the need for clear communication between the students and the musicians in order for either group to realise the positive benefits of participation. Clear communication requires the support of the gatekeepers – the teachers and their managers – which is often difficult due to school safeguarding policies and procedures. However, the evidence gathered in this thesis provides a case study which demonstrates the positive benefits that can come from allowing communication which enables local learning ecologies. More importantly, a solution enabling messages to be withheld pending the approval of the teacher (or trusted third party), was integrated into Remix Portal, so no additional tools are required to support the communication process and perceived safeguarding risks were reduced. The clarity and detail of the communication between musicians and students was also enhanced through the development of the show-and-tell feedback interface, which couples text-based descriptive information with depictive information demonstrating interface control changes and their impact upon the music.

By making Remix Portal available online as a running application, as open source code, and by reporting the guiding design criteria, other people can use the remixing and communication tools developed during this project to establish their own social music mixing-oriented local learning ecology, or with some thought and adaptation, a local learning ecology based around a related creative subject such as digital imagery.

The second key challenge concerned the labour gap. I found that teachers initially lacked the confidence to teach music remixing skills and the resources to source musicians to participate in local learning ecologies. However, with the right tools and resources the field studies proved that teachers can quickly grow in confidence and should become happy to lead music remixing sessions once familiar with the pedagogy. Whilst sourcing musicians may remain challenging, I found that, given the positive outcomes reported by participating musicians combined with the small time commitment required, retaining musicians within the local learning ecology should not pose a significant problem. Furthermore, the thesis also explores an alternative scenario where musicians contribute worked examples of music mixes for students to study prior undertaking their own music mixing activities. This scenario does not rely on the musicians being available to create learning feedback at a specific point in time, yet the worked example configuration was still able to positively impact learning. It is acknowledged that should this project be sustained beyond the research phase, an economic model where the musicians are paid fairly for their contributions should be explored, so as not to contribute to the de-professionalisation of musicians.

The final challenge concerned the accessibility of music remixing tools. Firstly, most existing music remixing applications require purchase and installation, which can lead to budgetary and I.T. obstacles. Remix Portal solves these issues as a free-to-use, online music remixing application which can be accessed by any computing device with a web browser. Furthermore, many music remixing interfaces are inaccessible due to their complexity, providing a barrier to entry, particularly for young or less able students. This thesis argued that whilst accessibility is important, design has to also enable the learners' progression and thus the ability to move on to greater levels of complexity. Remix Portal was therefore intended from the outset to be as accessible as possible, whilst maintaining deep functionality. Using an iterative design process culminated in a multi-layered interface, which enables users to select a level of complexity that matches their current level of ability and/or confidence. Furthermore, the multi-layered interface supports feedback provision by implicitly communicating information about the users' ability and/or confidence to feedback givers, which helps them compose appropriate feedback.

Given the positive impact of the social music mixing activities upon learners and other stakeholders within local learning ecologies, coupled with the knowledge that the identified challenges can be overcome, I conclude that it is possible to form successful local learning ecologies between learners and musicians based around social music mixing activities. And given the under-performing status of formal school music education (Henley, 2011; See and Kokotsaki, 2015), I believe the time is right for policy makers to look for ways to improve the learner experience and generate more positive outcomes within music education. This thesis has shown that social music mixing within local learning ecologies is an approach which could offer significant benefits to young people, schools, and communities.

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Appendix A. Giving feedback survey for Chapter 5

Remix Portal - Student Survey – GIVING feedback

Remix Portal username: ___________________________________

1. What did you like <u>BEST</u> about giving feedback using the…

a. TEXT ONLY method?

b. CONTROL CHANGE AND TEXT method?

2. What did you like <u>LEAST</u> about giving feedback using the…

a. TEXT ONLY method?

b. CONTROL CHANGE AND TEXT method?

3. Do you think the process of giving feedback has helped YOU get better at mixing music? If so, can you explain how?

4. How strongly do you agree or disagree with the following statements: (please circle)

"TEXT ONLY feedback helps me help my classmates get better at mixing music"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"CONTROL SUGGESTION WITH TEXT feedback helps me help my classmates get better at mixing"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"TEXT ONLY feedback helps the receiver see my music mixing process"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"CONTROL SUGGESTION WITH TEXT feedback helps the receiver see my music mixing process"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"TEXT ONLY feedback helps the receiver know what to do to get better at mixing music"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"CONTROL SUGGESTION WITH TEXT feedback helps the receiver know what to do to get better at mixing music"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

Appendix B. Receiving feedback survey for Chapter 5

Remix Portal - Student Survey – RECEIVING feedback

Remix Portal username: ____

1. **What did you like BEST about receiving feedback using the…**

    a. **TEXT ONLY method?**

    b. **CONTROL CHANGE AND TEXT method?**

2. **What did you like LEAST about receiving feedback using the…**

    a. **TEXT ONLY method?**

    b. **CONTROL CHANGE AND TEXT method?**

3. Which type of feedback do you think has helped you the most to improve THE PIECE OF MUSIC YOU ARE WORKING ON?
(mark where the balance lies between the two feedback types)

CONTROL SUGGESTION WITH TEXT								TEXT ONLY

4. Which type of feedback do you think has helped you the most to develop YOUR PERSONAL MIXING SKILLS?
(mark where the balance lies between the two feedback types)

CONTROL SUGGESTION WITH TEXT								TEXT ONLY

5. How strongly do you agree or disagree with the following statements: (please circle)

"TEXT ONLY feedback helps me understand the feedback givers approach to music mixing"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"CONTROL SUGGESTION WITH TEXT feedback helps me understand the feedback givers approach to music mixing"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"TEXT ONLY feedback helps me know what to do to get better at mixing music"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree

"CONTROL SUGGESTION WITH TEXT feedback helps me know what to do to get better at mixing music"

strongly disagree	slightly disagree	neither agree nor disagree	slightly agree	strongly agree