MAMI Tech Toolkit

Utilising Action Research to Develop a Technological Toolkit to Facilitate Access to Music-Making

Submitted by

Asha Louise Ward

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Abstract

Asha Louise Ward

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Music is essential to most of us, it can light up all areas of the brain, help develop skills with communication, help to establish identity, and allow a unique path for expression. However, barriers to access or gaps in provision can restrict access to music-making and sound exploration for some people. Research has shown that technology can provide unique tools to access music-making but that technology is underused by practitioners. This action research project details the development and design of a technological toolkit called MAMI – the Modular Accessible Musical Instrument technology toolkit - in conjunction with stakeholders from four research sites. Stakeholders included music therapists, teachers, community musicians, and children and young people. The overarching aims of the research were: to explore how technology was incorporated into practices of music creation and sound exploration; to explore the issues that stakeholders had with current music technology; to create novel musical tools and tools that match criteria as specified by stakeholders, and address issues as found in a literature review; to assess the effectiveness of these novel tools with a view to improving practices; and to navigate propagation of the practices, technologies, and methods used to allow for transferability into the wider ecology. Outcomes of the research include: a set of design considerations that contribute to knowledge around the design and practical use of technological tools for music-making in special educational needs settings; a series of methodological considerations to help future researchers and developers navigate the process of using action research to create new technological tools with stakeholders; and the MAMI Tech Toolkit – a suite of four bespoke hardware tools and accompanying software - as an embodiment of the themes that emerged from: the cycles of action research; the design considerations; and a philosophical understanding of music creation that foregrounds it as an situated activity within a social context.

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Author’s Declaration

I declare that the work in this thesis was carried out in accordance with requirements of the University’s Regulations and Code of Practice and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this research is my own work. Work done in collaboration with, or with the assistance of others, is indicated as such. I have identified all material in this dissertation which is not my own work through appropriate referencing and acknowledgement.

Publications by the Author which contribute to this thesis:

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Other conference presentations include:

- Ward, A., 2018. MAMI Tech Toolkit. *In:* Whittington, P., and Dogan, H., eds. *Assistive Living Symposium.* Bournemouth 21 May 2018. Bournemouth: Bournemouth University.

- Ward, A., 2017. Music technology for those with complex needs. *Innovation in Music 2017.* London 6-8 September 2017. London: University of Westminster.

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Abbreviations

CYP - children and young people

SEN - special educational needs

PMLD - profound and multiple learning disabilities

MLD - moderate learning difficulties

SLD - severe learning difficulties

MT - Music Therapy

MTs - Music Therapists

ST - Sound Therapy

DHHMD - Digital hand held music device

EMT - electronic music technologies

EngD - Engineering Doctorate

CDE - Centre for Digital Entertainment

BU - Bournemouth University

NIME - new interfaces for musical expression

DMI - digital musical instrument

API – application programming interface

OSC – open sound control

MIDI - musical instrument digital interface

GUI – graphical user interface

AT - assistive technology

MOCAP - motion capture

MPC - music production centre

ACD - augmented communication device

AR - Action Research

MAMI - Modular Accessible Musical Instrument

VST – virtual studio technology

HCI - Human Computer Interaction

IM - Industrial Mentor

CT - Class Teacher

AHT - Assistant Head Teacher

DMSST - Digital Media and Sensory Support Technician

CO - Child One

CT - Child Two

MTA - Music Therapist School A

DMTB - Digital Music Technician School B

DoMB - Director of Music School B

MC - Musician School C

MTC - Music Technologist School C

MTDC - Music Therapist Day Centre

CMDC - Community Musician Day Centre

FSR – force sensitive resistor

LDR – light dependent resistor

1. Introduction

1.1 Overview

This applied research project has been a journey in developing new technological tools with the aim of facilitating access to music-making. The music-making experience is considered crucial to well-being and can provide a vital tool in developing agency and autonomy in an individual. The core ideals of this research have been to develop technology that is both engaging - by being flexible to individual's capabilities, and situated - by working closely with practitioners and users in the field. The technology developed has been a move towards filling gaps in provision and breaking down barriers to participation. The research has been a journey in engineering, in working with people, and in developing research, to create workable technology that fits both users and the ecologies of use (Waters 2007) that the technology sits within. The document presented here is a summation of the journey so far. It has been a diverse project interweaving many fields, practitioners, and research elements, in the bid to move the discourse around the creation and use of technological tools forward. Working alongside an industrial sponsor school as well as several other research sites and individuals, this timely and relevant project aimed to contribute to the fields that interconnected within it, and also leave some legacy – a technological toolkit called MAMI.

There has been a focus on creating *with* people, *in* a context, and then *leaving the technology behind* for others to utilise. The research aimed at: developing an understanding of what was available; what issues were being faced with technology for music-making; what was missing, and what could be an improvement on what was currently available. In this manner, the purpose of this enquiry has been diverse. Robson (2002) describes four classifications of enquiry – 'exploratory, descriptive, explanatory and emancipatory' (ibid, p60. This project could be considered to be drawing on all four to achieve an outcome. The research can be considered to be **exploratory** in terms of finding out what is happening when music technology is used within the particular settings as involved with this research, with the aim to seek new insights and ask questions (ibid). The research was **descriptive** in an effort to accurately portray events, situations, and technologies developed, and the connectedness of the elements that drove the developments. The **explanatory** element sought to explain the relationships at the heart of the research, one between humans, technology, and the use of tools - by exploring patterns and relationships between these convergences to enable the creation of relevant technology. Finally, an **emancipatory** element could be considered present in terms of creating opportunity for engagement *for and with* a marginalised user group.

This industry-based thesis uses a multifaceted and long-term exploration, lasting over five years, of the design and development of music technology to facilitate access to music-making. The research is centred on the development of the MAMI Technology Toolkit with one main industrial sponsor (a special educational needs school) alongside three other organisations (two more special educational needs schools, and one community day centre for adults with disabilities), and one musician in the UK. The toolkit has been delivered to those organisations and is currently in use by them. The design process, starting in October 2014, followed four emergent action research cycles of planning, acting, and reflecting to develop the MAMI Tech Toolkit, and the research presented in this thesis.

The project has been carried out through the framework of an Engineering Doctorate (EngD) by developing on-going relationships with industrial partners, including a main industrial sponsor school and an industrial mentor within this school. In this thesis, a rich description is provided of the use of an action research methodology in gaining knowledge that has informed the development and creation of the MAMI Tech Toolkit, with the needs of those organisations involved at the forefront of the development.

Key domains that correlate within the research are those of human-computer interaction, music therapy, music technology, and action research. At the centre of this are accessible digital musical instruments. Connected to these areas are the theoretical underpinnings and methodology that has been used to inform and underpin the research. The methodology of action research was used to work with practitioners to draw out tacit knowledge and shape the direction and goals of the research. Third-wave HCI theory is used to link the embedded exploration of people using technology - not for work and not in a workplace - and how this has shaped the technology developed. Ethnographic and ethnomethodological methods have been used to gather and analyse data which has subsequently informed design. The design process has been carried out in the mode of the bricoleur in terms of using the stakeholder input and translating this into usable technology. The technology has then been used as a probe to aid in the design process with stakeholders, and as a mechanism to explore the philosophical underpinnings that the tools emerged from.

Following this brief overview, this chapter moves on to establish the underpinning theoretical position, key research areas and core interests are also outlined. A scoping diagram is provided to illustrate the boundaries of the research and make explicit the key domains that correlate within it. A rationale for the research is provided. Following on from this the research aims, objectives and contribution to knowledge are offered. Finally the structure of the thesis is outlined before the chapter ends with a conclusion.

1.2 Theoretical Position

The philosophies underpinning this research are ‘congruent with a postmodern tradition that embraces a dialectic of shifting understandings’ (Kelly 2005, p.66). There is an assumption that our understanding and knowledge of the world is constructed by our actions within it, through experiencing things and reflecting on those experiences. Subjectivity is embraced with an interpretivist theoretical perspective and objectivity cannot be achieved. Theory is generated from experience in partnership with participants where collaboration is key for moving towards a goal and knowledge produced has a focus on individuals, community change, and empowerment (Kelly 2005). In this way, the research embraces the constructivist paradigm assuming ‘a relativist ontology (there are multiple realities) a subjectivist epistemology (knower and respondent co-create understandings), and a naturalistic (in the natural world) set of methodological procedures’ (Denzin and Lincoln 2018, p.20).

This research is about eliciting knowledge from people to enable the creation of technology that takes into account a holistic view of the context those people work within. The research interweaves the relationships between individual users, the tools they use, and the context the tools are used within, in order to produce concrete embodiments of this process in the form of the technological tools presented as key outcomes. The research also maintains sensitivity with regard to the central users of the technology by taking the position that each user is a unique individual, with their own way of interacting with objects, other people, and their own way of being in the world. In the view of this research, this individualistic profile should form the basis of how tools are developed, in order to develop technology with a chance of succeeding at being used in practice, and that enables users to achieve the goals they wish to achieve.

The philosophical rationale and theoretical position underlying the research is outlined in order to make explicit the underpinning philosophy that the research has been based upon, and to contextualise the research activities conducted. The research approach has used qualitative methods to inductively seek out knowledge through the use of an action research methodology over a longitudinal period.

1.3 Key Research Areas and Core Interests

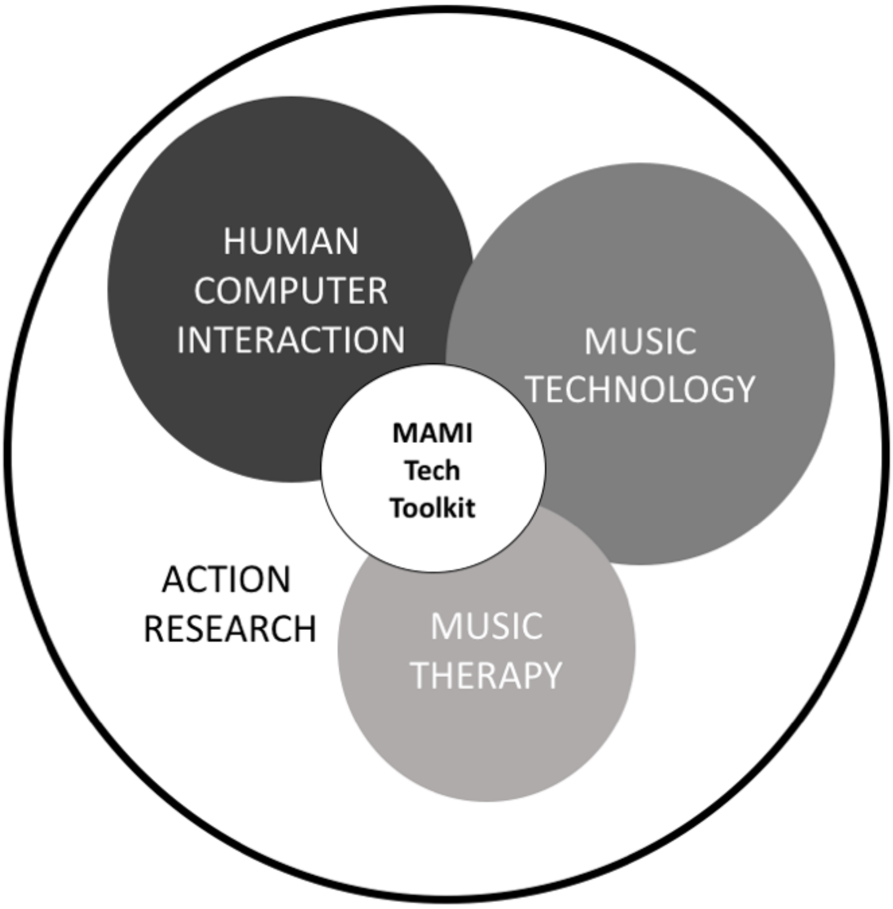

Figure 1 - Scoping Diagram of Key Research Areas

A scoping diagram is provided (Figure 1) to show the interconnecting fields outlining the boundaries of the research. These include the fields of: human computer interaction (HCI) in terms creating technology that utilises the computer, and exploring how we work with computer-based technology as humans. Music therapy as a discipline for promoting health and wellbeing through music with regard to providing a contextual practical setting in which the technological tools are developed and used. Finally, music technology provides a backdrop for the history of music technology that has gone before this development and elements of functionality of the system to a musical end – and in some respects – crosses over with human computer interaction. Action research has been the overriding methodology that has guided the interaction with stakeholders, in order to utilise their knowledge and needs to further the development of the technology.

The three core interests of the research (Figure 2) were:

- Who is going to use the technology? – in terms of user capabilities
- What are they going to use it for? – in terms of their goals of use
- Where are they going to use it? – in terms of the context of the use of the technology

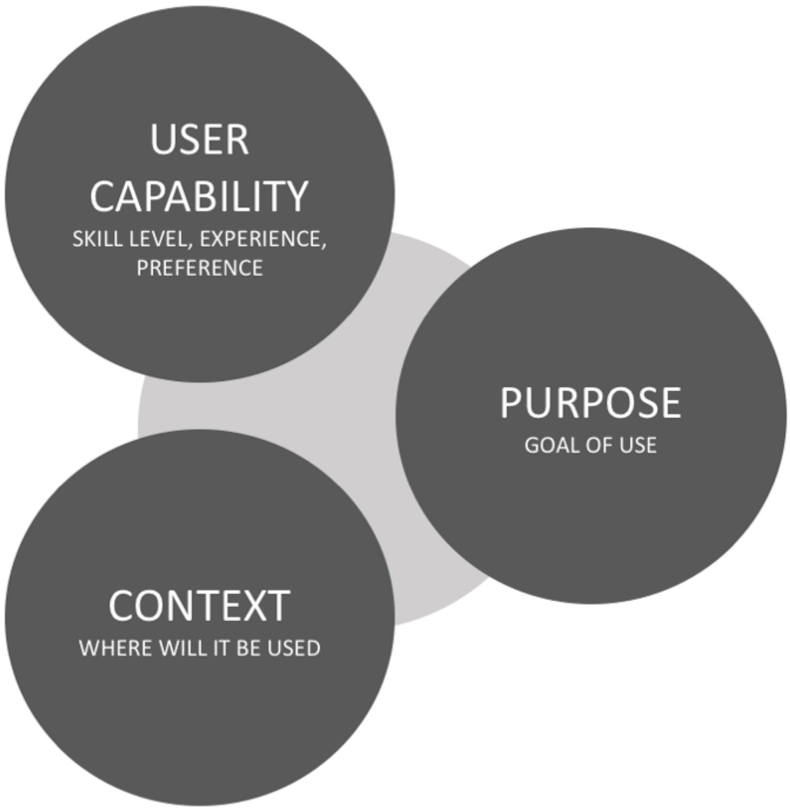

Figure 2 - Core Interests of the Research

1.4 Research Scope

The scope of the research has been to utilise commercially available technology at the research sites, to conduct literature reviews, to elicit knowledge from stakeholders, and to combine the findings from these into the creation of new bespoke hardware and software based technological tools. In combining the key research areas with the core interests, a technical solution was developed that both addresses gaps in current market provision and barriers to use, to achieve the overarching goal of the research – **a technological toolkit to facilitate access to music-making.**

1.5 Rationale

The need for this type of project was identified by the researchers previous work at undergraduate level during a placement (Sandwich degree featuring a year in industry) held at the industrial sponsor school. This placement involved working with the industrial mentor, staff members, and children and young people at the school, to develop bespoke hardware and software based technology solutions to help teach the curriculum. This work then led into a final year project in which a novel device was created for teaching music based concepts to children (Blatherwick and Cobb 2015).

Throughout this prior work what was highlighted was that technology provided unique opportunities to create systems that break down barriers to access. However, that such systems face barriers to use. These barriers included logistical elements (such as cost, lack of space, need for portability), knowledge barriers (including difficulty in incorporating technology into practice and lack of training), as well as issues with technology itself (such as technology being confusing in terms of options to navigate, being hard to set up and use, and/or not tailored to meet the needs of the user). What was also known, and is represented in later parts of this thesis, is that music provides a unique tool that can be used to contribute to a person's well-being and that technology provides a unique tool to create new systems with the user at the centre. Therefore a gap in music-making provision was identified in a lack of tools that appealed to all involved in setting up and using the technology in practice, and that provided access to active music-making for different types of users with differing capabilities.

1.6 Research Aims

Due to the co-inquiring nature of action research, which was led by stakeholder input, activities conducted during the research followed an inductive and emergent process.
The research began with a set of tentative aims. These aims were identified and developed from past experience, and in conjunction with the industrial sponsor. The aims provided a

framework with which to start the inquiry. The objectives emerged from these aims over the course of the research and both research aims and objectives have been solidified as presented here.

1.6.1 Research Aims and Objectives

- **To explore how technology is incorporated into practices of music creation and sound exploration** - *To look at current things*
  - Use current technology with children and young people
  - Gather a group of stakeholders to discuss direction of research
  - Review the literature
- **To explore the issues that stakeholders have with current music technology** - *To see what is wrong with those things*
  - Meet with stakeholders to gather data about technology usage
  - Observe stakeholders as practitioners to identify where technology could help
  - Review the literature
- **To create novel tools that match criteria as specified by stakeholders, and address issues as found in the literature review** - *To create new things*
  - Review gaps in provision
  - Create design ideals in conjunction with stakeholders
  - Create prototype tools
- **To assess the effectiveness of these novel tools with a view to improving practices** - *To see if they work*
  - Iteratively develop prototype tools through practical use
  - Work with stakeholder to ascertain success criteria
  - Analyse created tools against informing philosophical underpinnings
- **To navigate propagation of the practices, technologies, and methods used to allow for transferability into the wider ecology** - *To share these tools and findings*
  - Manage creation of assets relating to development of technological tools
  - Locate appropriate outlets for disseminating the research

1.7 Contributions to Knowledge

Contributions to knowledge are outlined below:

- The themes that have emerged from the cycles of action research
- A series of eighteen design considerations for instruments for users with complex needs in special educational needs settings (Section 4.4.10)
- A series of nine methodological considerations to help future researchers and developers navigate the process of using action research to create new technological tools (Section 5.17)
- The MAMI Tech Toolkit as an embodiment of the themes that emerged from: the cycles of action research; the design considerations; and a philosophical understanding of music creation that foregrounds it as an situated activity within a social context.

1.8 Structure of the Thesis

Chapter 1 – Introduction

An overview of the research is provided. The theoretical underpinning of the research are made explicit. Key research areas, core interests, and scope of the research are outlined. A rationale for the research is provided. The research aims and objectives are broken down, and the contributions of knowledge are stated. The structure of the thesis is also provided.

Chapter 2 – Literature Review

Provides a review of relevant literature surrounding the use of music, barriers to access, and music therapy and its uses. The types of technology pertinent to this research are explored as well as the issues around the definition and creation of new instruments for musical expression. Music technology usage in music therapy and what technology can offer are explored as well as the populations using music technology. There are then sections covering new developments and technologies that are important in this area. The computer as a bridge looks at creating new technology based music systems before a section on incorporating music technology. Also explored are connections of the research to the field of human computer interaction, the research mode of bricoleur, and the social model of disability.

Chapter 3 - Methodology

Outlines the methodology that the research has followed. A background to the research is provided, with a section on the engineering doctorate. Following this there is discussion around the ontological, epistemological, and philosophical foundations that the research is grounded in as well as an exploration of the connection between the research and ethnographic and ethnomethodological methods. The sample population is outlined as well as the positionality of the researcher. The research roles and method of meeting people where they were is covered and the mechanism of technology probes is described. The research process is specified and the sites and stakeholders involved with the research are described. The methodology of action research is then described including the model used, the values and criticisms, and trustworthiness of action research featuring an analysis using the Waterman, Tillen, Dickson, and De Konig assessment (2001). This is then followed by the methods of data collection and analysis. Ethical considerations, and stakeholder involvement are also provided.

Chapter 4 – Action Research Cycles

Presents the four action research cycles that occurred as part of this research. Each cycle is presented separately and includes: details of the research aims that were being explored; who was involved; the activities that took place; the findings from these activities presented as themes; and technical developments that occurred within the cycle, which are outlined and analysed. Cycle one featured the use of current technology in sessions at the industrial sponsor school and emergent themes for both these sessions and interactions with stakeholders. Cycle two presents the development of two bespoke tools, developed alongside emerging findings from interactions with the stakeholders. Cycle three presents a third bespoke tool and emergent findings of the interactions with stakeholders – expanding to the introduction of other stakeholders from the other research sites, as well as a set of 18 design considerations that form a contribution to knowledge of this thesis. Cycle four presents the development of a final tool in the kit, as well as the finalising of the MAMI Tech Toolkit into a cohesive kit in terms of hardware and software.

Chapter 5 – Discussion

Provides a discussion of the research process exploring issues of: creating new tools and issues around such tools; as well as discussing the methodological issues that were found during the research in using action research, and working stakeholders to develop technology, and when dealing with data that arises through these processes. A series of nine methodological considerations are also presented that form a contribution to knowledge of this thesis.

Chapter 6 – Conclusion

Provides a conclusion by returning to the research aims in order to make explicit how the research has or has not addressed each one. The themes from the data are connected to the research aims. An outline for potential future work is given and concluding remarks are provided.

1.9 Chapter Conclusion

This chapter introduced the research by outlining the key areas of focus, the core interests of the research, and the research scope. An outline of the aims and objectives were then provided. The contributions to knowledge were then presented and an outline of the structure of the thesis was provided. The next chapter provides a literature review of pertinent literature surrounding music technology in use for music therapy as well as covering the field of human computer interaction, the research mode of bricoleur and the social model of disability.

2. Literature Review

2.1 Introduction

The previous chapter introduced the research by outlining the key areas, interests, scope, aims and objectives, and contributions of knowledge within the research, as well as providing a structure of the thesis. This chapter seeks to review the literature around music technology and its use within contexts similar to the research sites involved within this research. This is done as to situate the research in terms of addressing barriers to access and gaps in provision. To this end the knowledge base around developments of music technology are explored, with a particular focus on music therapy – the most often used vehicle for music-making opportunities for users in the sites as featured in this research.

2.2 Literature Review Strategy

Keyword searches of Google Scholar, Google, and The Bournemouth University Library Catalogue were used for article selection. The following keywords were used: music technology for music therapy, new interfaces for musical expression, music technology and special education needs, music technology SEN, and music technology complex needs. The Nordoff Robbins Evidence Bank 2014 (specifically account no.16) was also consulted as well as Research and Resources for Music Therapy 2016 (Cripps et al. 2016). This selection of papers expanded as literature was reviewed. Papers were scanned for their significance as they pertained to the use of technology, both novel or off-the-shelf, with users with complex needs for active music-making or sonic exploration, or that they featured details of such technologies in use, or that they explored issues around and/or reviewed usage of such technology in use. Some grey literature was also consulted (Department for Education 2011; Farrimond et al. 2011; Ofsted 2012; O'Malley and Fraser 2004) as this provided a different perspective on technology usage in practice.

2.3 Context of Music Technology Literature Review

Music technology reviews have been undertaken to: address the use of music technology by music therapists (Cevasco and Hong 2011; Clements-Cortes 2013 Crowe and Rio 2004; Hahna et al. 2012; Knight and Krout 2017; Knight and Lagasse 2012; Magee 2006; Magee and Burland 2008; Streeter 2007; Whitehead-Pleaux et al. 2011); outline the aims of national music education plans within government policy (Department for Education 2011; Ofsted 2012); and to guide government policy (Farrimond et al. 2011). Magee (2014) edited a volume of articles drawing together uses of music technology in therapeutic and health settings. These authors highlighted the importance of music technology, the types of music technology used, where technology is useful, and how technology could be improved to break down barriers and allow access to music-making for those with complex needs. This literature review aims to take another step in this discussion, by further organizing this information and providing a timeline of development to the current state of the art, in order to show how the literature has informed the design of the MAMI Tech Toolkit and the components within it.

The use of music technology for clients in music therapy settings is broad, drawing from a variety of fields. Technology usage combines elements of human computer interaction (HCI), music therapy, music psychology, music education, and music technology. The scope of literature featured in this review reflects this, with a focus on the ways technology can be used to increase access to active music-making opportunities for those who are unable to access expression through traditional musical instruments. The primary focus of this review is technology for active music-making, with a focus on alternate controllers that provide control and potential for expression through sound and music. For this review, *active music-making* is defined as playing instruments or actively exploring sound through interaction with technology.

2.4 Music

The following section covers the human relationship with music.

'Music is a moral law. It gives a soul to the universe, wings to the mind, flight to the imagination, a charm to sadness, and life to everything. It is the essence of order, and leads to all that is good, just and beautiful, of which it is the invisible, but nevertheless dazzling, passionate, and eternal form' (In Watson 1995). Music 'becomes the vehicle for revealing new truths and making new orderings of the world we live in' (Krüger 2007, para. 28).

Music is a fundamental human activity. From the moment our senses develop in the womb we are surrounded by sound and vibration. The perception of sound is central to the human condition and provides a unique tool (Ellis and Leeuwen 2000) for exploring and expressing our inner states and our connection to the world around us. Music can provide a tool to access and process experiences without being subject to language in a lingual or verbal manner. Sound has musical potential and music in turn has expressive potential (Ellis and Leeuwen 2000). Through music we can communicate, express emotion (Ellis and Leeuwen 2000; Swingler 1998), enhance our mood, provide comfort, and for nostalgic purposes to relive memories (Kirk and Neighbour 2004).

Making music allows sharing of intimate dialogues through immersive experiences (Hunt et al. 2004). The act of making music and musical interaction is cross-cultural and enables non-verbal communication (Hunt et al. 2004). Music practice can be a solitary pursuit or carried out in groups (Favilla and Pedell 2014) in situations where others are present and through active (e.g. playing instruments) or passive (e.g. listening to music) modes. Music can also be an important tool for establishing identity helping to form musical identity within an individual (Burland and Magee 2014). Nagler (2011) states that music activity is no longer for reason or purpose but for 'social fabric' (ibid, p.197) in that it is ever easier to access, create, partake in, and share music.

Christopher Small argues that taking part in musical acts is central to our humanness and that when partaking in musical activities we are '*musicking*', his definition as a verb 'to take part, in any capacity, in a musical performance, whether by performing, by listening, by rehearsing or practicing, by providing material for the performance, or by dancing' (Small 1998, p.9). He then extends the act of 'musicking' to include the roadies, or the people taking money on the door, anyone who has contributed to the nature of the event. This is an important concept in this research and ties into the underlying philosophy of symbolic interactionalism, in that while the people at the centre of the study may all be contributing in different ways to the music that is happening, they will all be 'musicking', including those that are acting in the role of facilitator or gatekeeper, with 'everyone's musical experience being a valid' (Small 1998, p.13) and necessary component to construct the holistic activity of music-making. Musicking establishes a set of relationships and it is in these relationships meaning lies, not just around the organised sound as music that is created but also between the people taking part, in whatever capacity, modelling or standing for relationships between person to person, and person to sound (Small 1998).

2.5 Barriers to Access

The following section reviews the range of factors that can have an influence on an individual's ability to utilise tools and therefore access musical-making through the systems such as those developed within this research.

Four broad areas of need are identified (Figure 3) by the Department of Education and Department of Health (2015) that are used to identify what action needs to be taken to allow an inclusive system. Whilst it is recognised that individuals may have needs that cross over into the different areas and change over time, and that an individual's strengths should be part of the consideration of any designs, the outlined areas do provide a foundation with which to consider some of the barriers that can be present. Bott (2010) identifies that distinguishing between access needs and learning needs is key to determining musical possibilities with an individual. These can often be interrelated, but making a distinction can start to cut through what might otherwise seem to be impenetrable complexities (Bott 2010). Access needs can be considered related to the broad areas of sensory and physical needs, and learning needs can be considered related to the broad areas of cognition and learning difficulties which may also include elements of social, emotional and/or mental needs, and communication and interaction needs.

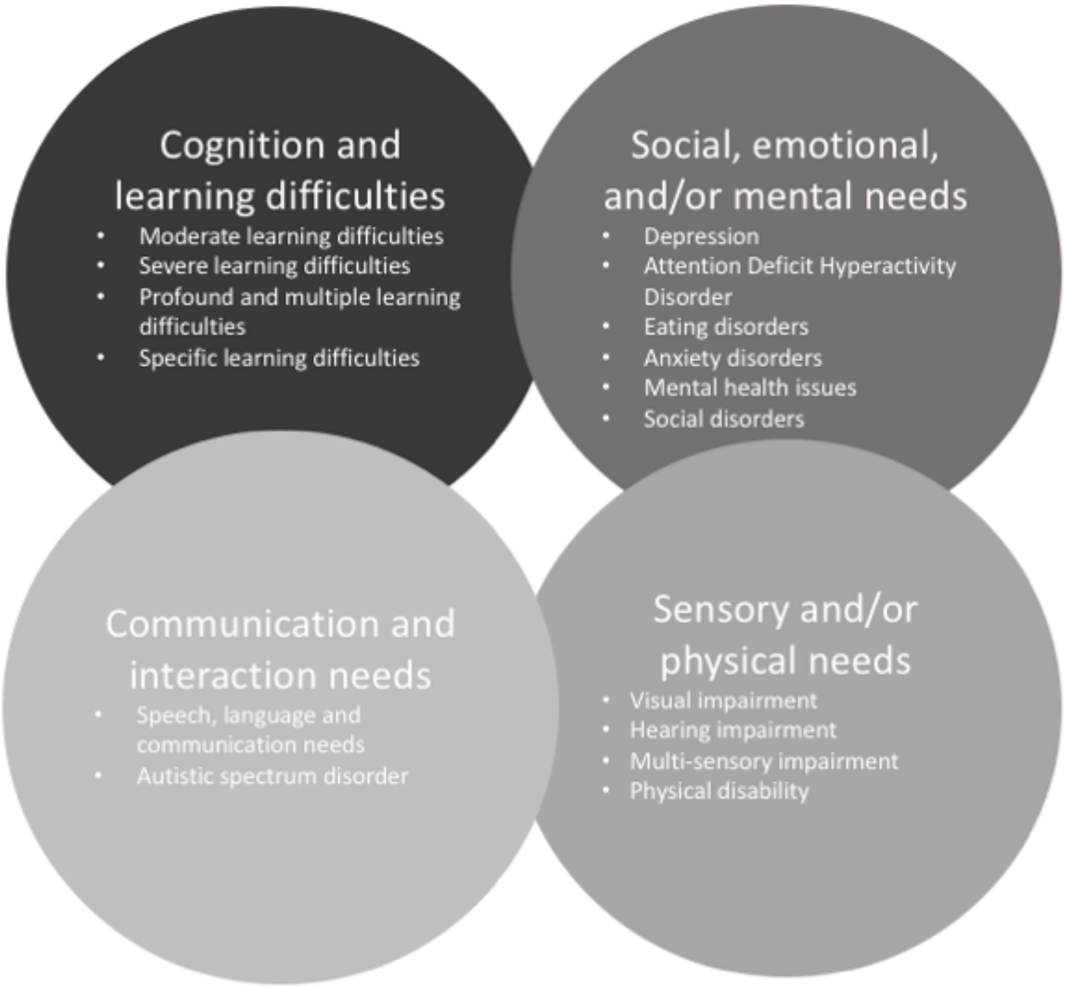

Figure 3 - Four Broad Areas of Need (adapted from Saalma2014)

Impairments may affect physical movement both in terms of amount of movement, whether the movement is disordered, the level of control that can be maintained with the movement, and the sustainment of that control. Since the tools provided in the kit are to be physical tangible objects that will be manipulated to control sound, it is pertinent that these needs should be considered to remove potential barriers or to scaffold capability in order to provide an adequate level of control for the individual user. A joystick for example might be used by someone with movement that might span a few millimetres, or someone that has large movement arcs, in this case the joystick cannot change, however the software can be configured to allow both to trigger or control the same sonic output. Sensory impairments can affect the feedback loop surrounding interaction with the physical tools, meaning that careful consideration is needed both concerning feedback mechanisms, and input mechanisms to maximise accessibility.

Learning needs involve matters of cognition. These might affect understanding of: physical objects; interaction processes; skill acquisition; abstract ideas; generalising from experience; difficulties in speech and language; and /or social and emotional development, which may affect the use of a technological tool or musical system.

'For those whose barriers to participation are more physical than cognitive, the emphasis of provision, whilst primarily meeting the creative preferences of the musician, should aim to maximize individual physical abilities. For musicians that experience more pronounced cognitive barriers, with an emphasis on meeting creative preferences still being paramount, a need to provide musical tools and interfaces that are matched or adaptable to individual cognitive ability might warrant more primacy' (Farrimond et al. 2011, p.5).

2.6 Music Therapy and Its Uses

Music therapy is often one of the only ways people with complex needs access active music-making, in which a therapist and client engage in a dynamic musical interaction (Hunt et al. 2004) as a clinical practice. It is a discipline of promoting health (Misje 2013) used by trained therapist to reach people isolated by mental, physical, or emotional blockages with the aim of providing emotional release (Hunt et al. 2000; 2004), it can also be used to help with control of mood, problem behaviours, and reduce the need for pharmaceuticals and physical treatment (Favilla and Pedell 2014), or to facilitate mobility and general coordination (Hunt et al 2004).

Music therapy takes a view of empowerment with a resource-orientated approach (Misje 2013) focusing on the positive effects that intimate dialogue between people and shared immersive experience can provide, with the view of music as a healing power (Hunt et al 2004). Music therapists see the process of exploration as the important part of music-making, where the 'effectiveness of music is viewed as part of a larger interactive encounter (Misje 2013, p.5)' and where the character of music itself can be viewed as an object that is related to the aesthetics and the qualities that the listener affords the music with, this is perhaps in contradiction to traditional Musicology which perceives music as synonymous with musical work (Misje 2013).

Music therapy usually uses traditional instruments and/or pitched and non-pitched percussion for therapeutic interventions and sessions. Depending on the framework the music therapist uses, sessions can be led by the music therapist (for example they play and sing and hand-out tools for joining in with the song) or led by the client (the therapist reacts to the client's interest and curiosity) or a mixture depending on the needs of the client. Sessions can also be one-to-one or in a group.

2.7 Types of Technology

Crowe and Rio (2004) completed a comprehensive historical literature review of technology and its implication in music therapy practice and research for music therapy education. From this, they organized the types of technology into taxonomical structures. They concluded that there were seven types of technologies: '(a) adapted musical instruments, (b) recording technology (c) electric/electronic musical instruments, (d) computer applications, (e) medical technology, (f) assistive technology for the disabled and (g) technology-based music/sound healing practices' (Crowe and Rio 2004, p.291). These categories are exhaustive in terms of covering all types of sound based technology used in the music therapy environment but do not focus on those used primarily for active music-making. The categories also include technology that is used for 1) analysis and logging of data about client progress, 2) creating and hearing listening material, and 3) medical technology that involves sound waves.

The rate of change within the technological environment of electronic music has meant that there have been several developments since the creation of these categories that are difficult to place within them, and there is technology that crosses between them. Magee's classifications (2006; 2012) reflect more up to date inclusions of self-contained music creating devices (such as synthesizers), music listening devices (such as mp3 players like the iPod), digital hand-held music devices or DHHMDs (Nagler 2011) (such as the iTouch app and iPads), and music games (such as Guitar Hero). Krout (2015) subsequently provided four categories of electronic music resources based upon those that had been reported as being useful in music therapy clinical practice, and were also affordable and available. These were general or stand-alone products, computer software, electronic keyboards, and tablet computers (e.g. iPads). The categories suggested above focus on 'off-the-shelf' technologies and cover both passive (such as listening) as well as active music-making technologies.

2.7.1 Digital Hand-held Music Devices

Digital hand-held music devices (DHHMDs) have become part of everyday life in an unanticipated convergence of technologies that has altered the practice of music therapy in a profound manner (Nagler 2011). They have become aids for music-making and offer a new class of music listening experiences, predictive selections, and active music-making without need for therapeutic interventions. These devices are multitasking musical companions allowing complex musical ideas to be created and shared without technical training (ibid, 2011). New technologies such as tablets featuring touchscreens, particularly the iPad, have created a shift toward screen-based mobile music-making. The touchscreen allows direct interaction to music apps using intuitive motion (Krout 2015). Comprehensive reviews of iPad resources are available to help clinical practice (Knight 2013). With each of the four methods of music therapy (recreating, improvising, listening, and composing) being able to be accentuated by apps (Knight 2013).

2.7.2 iPads and Apps

iPads have become prolific in school settings, offering multi-functionality, the ability to tailor to individual styles of use, ease of use, portability, and high quality of graphics and sound (Krout 2015). iPads have been used to create powerful and expressive controllers for digital music (Favilla and Pedell 2014) with many music-based applications developed to meet different needs. Some apps tie into existing software to provide a new facet of access while others offer experiences unique to the device. Krout (2014b) provides an exploration of a number of apps for engaging young people with Autism Spectrum Disorders, the needs they address, and their efficacy in music therapy. He suggests that the therapist must balance the advantages and disadvantages of using such technology against each client’s needs, abilities, and goals.

Apps such as Beatsurfing (Lobby and De Ridder 2012) allow the creation of custom graphical user interfaces (GUIs). These can be designed by the user through building with lines, polygons, circles and faders. Parameters such as size, colour, orientation, 3D position and value that can also be customized (ibid). These GUIs can then be connected to MIDI compatible software, hardware, or other MIDI enabled apps to provide bespoke interaction and allow configurable sonic output. One such app is Thumbjam (Sonosaurus 2009) which provides a vast array of features. Included in the app are over 40 sampled instruments, hundreds of scales, and an array of customisation of how it can be played, and what is displayed on screen (including user uploaded backgrounds) (Matthews 2018). Thumbjam also offers arpeggiating, looping, recording, effects selection and manipulation, instrument creation, and the ability to import and export data. The ever-growing app market means it is easier than ever to find screen-based applications that fit the needs of the user and also offers access to the developers in terms of suggesting updates and tailoring for specific needs. A discussion of the issues around the use of iPads is provided in the section entitled '5.3 Unknown Unrecognised Issues with the iPad' on page?.

2.8 Defining Accessible Electronic Music Technology

Electronic music technology (EMT) that increases accessibility for clients with complex needs has been defined as a range of tools and devices which are able to generate musical sounds through electronic, digital or mechanical means (Magee 2012). Definitions include: 'any equipment, device, or method that systematically fosters independent functioning, including the production of or response to music' (Crowe and Rio 2004, p.283); 'the activation, playing, creation, amplification, and/or transcription of music through electronic and/or digital means' (Hahna et al., 2012, p.456), and; 'a wide range of devices, equipment and software, spanning amplification devices, MIDI (musical instrument digital interface) devices and instruments, computer software, assistive devices, brain computer interfaces, as well as electronic musical instruments and specialist interfaces such as switches and sensors' (Burland and Magee 2014, p.179). These types of technology, and their relationship to music therapy clinical practice, began being discussed in the late 1980s (Krout 1987) and early 1990s (Krout 1992), with the use of music technology for those with complex needs also being covered in popular music magazines (Thomas 2012).

While the term EMT covers a wide range of technology to facilitate musical interaction within the field of music therapy (Magee and Burland 2008), instruments created with technology are often called digital musical instruments in the field of HCI by conferences such as the international conference of new interfaces for musical expression (NIME) (Poupyrev et al. 2001).

Since the 1980s there has been a rapid expansion of electronic music technology use with the field of music therapy (Whitehead-Pleaux et al. 2011) and many digital musical instruments have been developed both commercially and for research purposes. Digital musical instruments can be aimed at a typical population or can be bespoke. Bespoke instruments use technology or combinations of technology to allow an individual access to active music-making. These technologies can include hardware and/or software. Accessible digital musical instruments (ADMIs) is a term given to digital musical instruments that have a particular focus on being accessible. Reviews of accessible digital musical instruments have been conducted in literature (Ward et al. 2019; Frid 2019).

Moving back to more general electronic music technology reveals a wide-reaching branch of technology that has progressed over the last 30 years. Developments in hardware and software, and creation of new instruments that utilize technology, have pushed boundaries forward both in terms of the creation and production of music. While the history of the development of electronic music technology, specifically electronic instruments, is beyond the scope of this review, overviews can be found in literature (Bongers 2000; Challis 2009; Paradiso 1997) along with proceedings from dedicated conferences like new interfaces for musical expression (NIME). Comprehensive introductions to the world of NIMEs can be found (Lyons and Fels 2015) and books such as those by Miranda and Wanderley (2006), offering a reference point for the control of sound using technology and issues surrounding the creation of new instruments (Ward et al. 2017).

2.9 Music Technology Usage in Music Therapy

The literature around music technology usage in music therapy provides insight into gaps in provisions and therefore guidance to developing tools that are able to be instantiated into practical use. This helps with the first two aims of this research in terms of exploring issues with current music technology and exploring how technology is incorporated into practices of music creation and sound exploration.

Music technology offers up new possibilities for exploration within music as part of the larger framework of music therapy (Misje 2013). Music technology has been used for many music-making activities both as an active music technique (singing, music composition, instrument playing) and as receptive intervention such as listening. Technology has also enabled the exploration of activities such as songwriting, recording, improvisation, listening, recreative, and multimedia project development as well as studying, learning, and composing and serving the needs of individuals with disabilities both in medical practice and research (Crowe and Rio 2004; Viega 2016). Music technology in music therapy has been used to address identity development (Magee 2006); express thoughts and feelings (Whitehead-Pleaux et al. 2011); promote empowerment (Burland and Magee 2014; Cappelen and Andersson 2013); construct meaning (McDowall 2008), and develop agency (Kruger 2007). The development of on-task behaviour, concentration, cooperation, communication, self-expression, problem solving, and decision-making have all been shown to be supported through the use of technology (Crowe and Rio 2004). Technology can be particularly useful for instantaneously provide relevant and enticing responses to interaction, leading to enhanced focus and the potential to transcend disability (Swingler 1998). Technology can be used to provide individual control in community participation (Misje 2013). This can be seen in the work of Andersson and Cappelen (2013) through the RHYME project using tangible interfaces for musicking (Small 1998).

Several large surveys have been published (Crowe and Rio 2004; Magee 2006; Streeter 2007; Magee and Burland 2008; Whitehead-Pleaux et al. 2011; Cevasco and Hong 2011; Knight and Lagasse 2012; Hahna et al. 2012) that cover factors that affect music technology usage by music therapists in practice, offering insight into how many music therapists use technology, trends in usage relating to age, gender, and geographical location, types of technology used, and reasons for not using technology. The studies point to some barriers to use. Barriers stated are the general lack of training in the use of music technology, technology and its changeability (both constant updating/creation of new technology and configuration of any given piece of technology), and technology being seen as a challenge to use in practice or inappropriate for music therapy or clients. Music therapists have stated a lack of time to learn and lack of experience of using technology (Hahna et al. 2012) as problems. Cost of equipment, difficulties regarding portability, and time needed for setting up equipment (Magee 2006) are more factors for lack of use. These points further strengthen the rationale for the use of action research in working with stakeholders to address some of these problems, in order to explore how some of the above can be mitigated within situated practice.

2.10 What Technology Can Offer

Technology offers the ability to control and trigger sound in different ways that extend past that of acoustic instruments. Technology can also provide responses to interaction in ways that acoustic instruments cannot. It can offer physical and/or cognitive support, and scaffold capability to give users access in ways traditional instruments do not allow. Paine and Drummond (2009) suggest there are two distinct approaches to computer-assisted music: 'control of predetermined sequences of sounds (such as the triggering of sound samples) or creation of sounds in real-time by the manipulation of software synthesis variables' (p.2).

Swingler (1998) suggests that few children have the physical coordination or control necessary for traditional performance. As such, technology can help to shift beyond traditional musical qualities toward a new and developing musical aesthetic, one enabled by the introduction of electricity to musical activity. He suggested that this allows the opening up of many musical doors so all can enjoy being expressive with sound: ‘Many techniques can be made easily available to virtually all kids through technology’ (Swingler 1998, p.5). Through technology, small motions can lead to sound production and engagement. For example, with even something as simple as a microphone there are great opportunities for utilizing feedback and amplification to allow the ‘tiniest voice and smallest nuances to be enhanced and extended’ (Ellis and Leeuwen 2000, p.8).

Music technology can therefore help to:

- Transduce movement and gestures into musical expression (Hunt et al. 2004)
- Make it possible for a client to realize a creative idea regardless of implementation or user and to give the opportunity for an aesthetic experience (Misje 2013)
- Allow people to lose themselves in artistic expression (with a quality of interaction so high that they aren’t aware they are using technology) (Hunt et al. 2000)
- Give initialization opportunities to usually passive users enabling the concept of selfhood, which can be inhibited for individuals with profound and multiple learning disabilities (PMLD)
- Provide, sometimes for the first time (Swingler 1998), that ‘make something happen!’ moment as described by Ellis (1997), which is a foundational experience of learning.

These simple but crucial experiences may help users to encounter and develop communication skills through sound. This control can lead to changes in behaviour patterns beyond the environment of a therapy session with individuals becoming more self-aware and interactive outside of the sessions, more tolerant, and with a growing awareness of others (Swingler 1998). Hunt et al. (2004) suggested that technology offers access to real time sound control to those with limited movement, along with new sound worlds and timbres (Ellis and Leeuwen 2000; Hunt et al. 2000; Kirk et al. 2002; Misje 2013). Computer music can be intriguing, particularly to young people, who may find traditional instruments, which are often associated with strict disciplined methods, off-putting (Hunt et al. 2004).

Technology can offer the sense of control and autonomy (Crowe and Rio 2004) removing the need for prerequisite skills for learning to occur (Nagler 2011). This can help users reach peak experiences that would be difficult using traditional instruments (Misje 2013). Technology can offer the ability to readily create music, learn to play an electric instrument, use computer programs, and/or to write and record. These activities can be condensed into a small amount of equipment, by offering the potential for many instruments to be accessed from one set-up. This provides a blank sheet (Kirk et al. 2002) onto which individual instruments can be built for different uses/users. 'This aural richness and variety provide the internal motivation..… In addition, the technology also provides physical access for [people with disabilities]' (Ellis 1997, p.176). In cases where affordability is an issue, technology could be beneficial, given how expensive acoustic instruments can be. 'It is possible to create sounds with as much musical interest as familiar orchestra instruments, but which could not be produced by a known instrument. A new dimension for interaction can then be opened up, offering radical possibilities for performance' (Kirk et al. 2002, p.1023) that allow for and support unconventional playing (Ellis and Leeuwen 2000). Digital musical instruments do not need to sound or play like conventional instruments, and they can be created to be operated by any part of the anatomy with no right or wrong technique, only that which is appropriate to the individual (Ellis and Leeuwen 2000).

2.11 Populations using Music Technology

Technology for music-making has been used across the lifespan in clinical settings from neonates through to older people (Magee 2012). Music technology is also used cross culturally (Ellis and Leeuwen 2000), and can be used in group settings, diodes, or individually, and also individually in group setting. There are also a range of technologies which have been adapted for users with differing abilities (Magee 2012) and used with many different types of populations (Magee and Burland 2008) including those with physical disabilities, sensory impairments, and learning difficulties. Music technology has been extensively with youths and adolescent children (Swingler 1998) for identity and socio-cultural (Misje 2013) work, with adults and children with neurological problems, people with developmental disability, physical and cognitive impairment, and also people with social and emotional difficulties (Crowe and Rio 2004).

Music therapy with technology has been shown to be effective in a range of medical, educational, home, clinical, nursing, and rehabilitations unit settings (Magee 2012). Those with the most profound disabilities have shown responses to music and sound therapy by exploring and discovering their own personal expression and actively participating in, 'performing, listening, verbalising, and 'composing with sound' (Swingler 1998, p.5) for extended periods of time, with concentration not revealed elsewhere. Showing ‘aesthetic resonance’ through facial expression and significant physical responses in movement or gesture that have not been independently made previously (Ellis and Leeuwen 2000). Technology has been used by those with physical disabilities ‘in order to play pre-composed music with assistive devices such as switches and control devices and to promote movement’ (Hahna et al. 2012, p.457).

2.12 New Developments

A number of recent related developments have impacted the world of digital musical instruments (DMIs). Common communication protocols such as MIDI, Micro-controller boards like Arduino (Arduino 2007), affordable computers such as the Raspberry Pi (Raspberry Pi Foundation 2012), and software such as Max/MSP (Cycling’74 1997) allow for bespoke systems to be created. These physical computing systems allow for sensors to be used to capture a person’s input which can then be integrated as a control device for software, or stand-alone bespoke devices can be created at a low cost. The development of the Internet of Things Council (2009), and Web portals and Webpages with tutorials such as Instructables (Autodesk 2018) have provided a community of DIY developments and assistance (in the form of forums) for those wishing to create bespoke instruments. Hacker communities are also providing space and tools, along with ‘hackathon’ style competitions (often 24 hour themed competitions which are supplied and sponsored by companies), allowing for rapid prototyping of accessible instruments and new tools while also bringing together people with a range of skill sets to create and share information online. There are now also many intermediary applications that allow for the quick creation of enticing interfaces to trigger music and sound.

Musical Instrument Digital Interface (MIDI). A critical music technology development is that of the musical instrument digital interface (MIDI) specification as a communication protocol. The MIDI specification was born out of a realisation between manufacturers that a lack of compatibility between the synthesizers would inhibit sales (The MIDI Association 2020). This technologically revolutionary specification stemmed from a paper presented by Smith and Wood (1981) at the Audio Engineering Society (AES) convention of 1981 outlining the concept of a ‘universal synthesizer interface’ (p1). The following year at the AES convention Dave Smith (founder of synthesizer maker Sequential Circuits) and Ikutaru Kakehashi (founder of the Roland Corporation) are credited with creating the first version of MIDI (The MIDI Association 2020). The creation of the MIDI specification was officially launched at the 1983 National Association of Music Merchants (NAMM) trade show, at which the electronic keyboards of two competing companies (Sequential Circuits Prophet 600 and the Roland JP-6), were connected and used MIDI to communicate with each other, thus revolutionising the world of electronic music (The MIDI Association 2020). The way that MIDI works has not changed since its inception and it is still in use today. The specification has grown from the initial 14 page document to a 58 page protocol that now spans a wide variety of technical uses - including programming and controlling sounds, and controlling recording equipment and studio lighting. The fact that the specification is still widely used over 30 years after its initial release is a monument to its technical efficacy.

Max/MSP. A crucial technical component within this research is a software called Max. Max is a visual coding environment developed for artists and educators to create flexible systems that use audio, visual media, and/or physical computing. Max was developed in the mid-1980s by Miller Puckette and was originally entitled 'The Patcher' (Puckette 1988). The software was created with the aim of providing composers with a graphical user interface for creating interactive music scores. The first commercial release was by Opcode Systems, Inc in 1990 who continued to publish the software until Cycling'74 acquired the rights. Cycling '74's first release of Max was in 1997 and was partly derived from Puckett's work on Pure Data (Puckette 1997) - an open-source software that shared many of the principles of Max. The 1997 release of Max combined the work of Puckette alongside additional development from David Zicarelli (1997) who was the founder of Cycling'74. These principles included the use of objects that could be patched together in a modular fashion. This modularity allowed for flexible systems to be constructed around the needs of the users, and allowed for sharing of abstractions of code between users. Both softwares used a public application programming interface (API) which allowed users to openly extend the software through the creation of their own objects and packages of these. Cycling'74s 1997 release (called Max/MSP) made it possible to manipulate real-time digital audio signals without the need for dedicated digital signal processing hardware meaning a personal computer could be used to program control of sound.

Software applications can be created directly from within the software for both Windows and Mac operating systems. The software can be used to create intricate modular systems and further to this user friendly graphical user interfaces (GUIs) that can become the front-end of user created applications. This functionality is accessed through the softwares 'presentation mode' in which interactive, informational or decorative objects can be added. These features of Max mean that Max provides a holistic programming environment to conceptualise ideas, create systems, make the systems usable, and form applications - with the ability to share all of these at any stage and in a modular fashion.

Max/MSP also integrates with Arduino, and uses common communication protocols such as MIDI and open sound control (OSC) to allow communication with other software and hardware. Other common music technologies such as virtual studio technology (VST) and programs such as Ableton Live can also be integrated into Max projects.

Makey Makey. Packages such as the Makey Makey (Makey Makey 2012) allow conductive objects (e.g. fruit, putty, metal) to be connected to a microcomputer to emulate keyboard presses, which can then be used to trigger sound. For example, users could create a piano from bananas by using Makey Makey and connecting it to software such as Garageband or SoundPlant (Blum 2018). Both these softwares allow sounds to be assigned to keyboard presses.

Bare Conductive. Bare Conductive Touch Board (Bare Conductive 2009) is another microcomputer featuring 12 touchpads that allow conductive materials to be connected via crocodile clips. The out-of-the-box setup allowed 12 sound samples to be triggered monophonically from a memory card placed in a slot embedded on the board which then play via an on-board headphone jack or connected to a speaker. The board is well documented and designed to be used with minimal technical knowledge. The board also offers expansion for those with more technical knowledge as it contains a built-in general MIDI chip for those wishing to reprogram the board to allow polyphonic notes, or to allow creation of bespoke MIDI enabled instruments. The Bare Conductive website (https://www.bareconductive.com/) features very comprehensive step-by-step guides for setting the board up and provides ideas for utilizing the board practically. These new developments expand possible modes of interaction by providing off-the-shelf software and hardware that may be commonplace in music therapy settings, or simply using everyday items that the client may find enticing and motivating to engage with.

Leap Motion. Other new technologies such as the hand gesture tracker Leap Motion (LeapMotion 2010) offer toolkits to build custom systems. The Leap Motion system converts hand movements to data, thus providing a flexible tool for mapping client specific movements to sound (Uwyn.com, 2018).

Microsoft Kinect. The Kinect (KinectSEN 2018) is a camera-based movement tracker made by Microsoft that allows body movement by skeletal tracking to be used to control data, thereby producing sound through movement.

GestureSEN. An excellent resource for gesture based systems used in special education is the gestureSEN website (https://web.archive.org/web/20180723042755/ https://kinectsen.wikispaces.com/home). The site, run by teachers in special schools, aims to explore how established and emerging gesture-based technology could help people with severe learning difficulties with their engagement, creativity and independence skills (Gesturesen.wikispaces.com 2018). The site featured information on using eye gaze, Kinect, Leap Motion, iPad, and Virtual Reality in special education settings. Unfortunately, due to the closure of Wikispaces website, the content from the gestureSEN website is only viewable through internet archive websites such as https://web.archive.org/.

Games Controllers. Finally, game controllers such as the WiiMote and the Xbox controller alongside music themed games can also provide unique mechanisms through which to access musical interaction, with schools typically having these resources available for general use.

All of the above offer new methods of access to music-making with the computer that move away from the keyboard and mouse paradigm. These tools provide the flexibility to create systems that tailor to client capability, motivation, and curiosity.

2.13 The Computer as the Bridge

Traditional acoustic instruments are ‘stand-alone’ in the fact that they are composed of an excitation mechanism (string, reed, skin etc.), a resonant capacity (the body of the instrument), and the specific timbre they produce. If, however we add a computer as a bridge in this system, we arrive at digital musical instruments (DMIs). A DMI ‘implies a musical instrument with a sound generator that is separable (but not necessarily separate) from its control interface’ (Malloch et al. 2006, p.49). DMIs break the coupling between the action used and the sound produced. This can be thought of as a three-layer system (Figure 4) consisting of the control interface, the processing (which can be achieved via a separate computer or an on-board system), and the effort mechanism or output (audio/visual/haptic feedback) (Hunt et al. 2004).

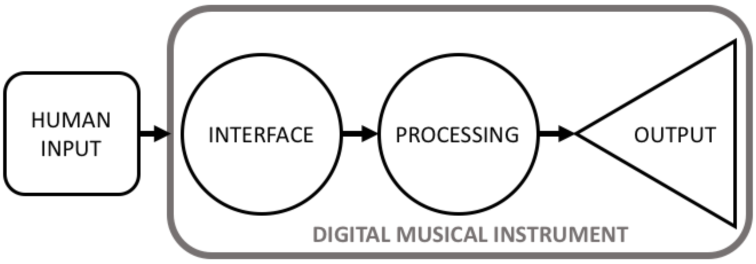

Figure 4- Digital musical instrument architecture

Useful methods of classification can be adopted from the fields of human computer interaction (HCI), music technology, and new interfaces for musical expression (NIME), when categorizing new technology which uses the computer as the bridge. Wanderley (2001) suggested the term gestural controller to describe interfaces that consist of two elements. The first element is an interface that features one or more sensors to detect the physical interaction of the performer (these can be in the form of body movement, empty-handed gestures, or object manipulation). The second element is the auditory, tactile-kinaesthetic, and/or visual feedback given to indicate the instrument's status the performer.

Wanderley (2001) proposed a three-tier classification of such controllers as:

- Instrument-like controllers - where the input device design tends to reproduce each feature of an existing (acoustic) instrument in detail (for example an electric keyboard)
- Augmented Instruments (also called Hybrid Controllers) - instruments augmented by addition of sensors - for example the Yamaha Disklavier
- Alternate controllers - whose design does not follow one of an established instrument - for example the Hands (Waiswisz 1985)

Alternate controllers offer unique opportunities to create interactive musical systems from the ground up to specifically suit client need. Using new or bespoke modes of interaction and processing these interactions into meaningful content provide unique potential to increase accessibility to active music-making. Alternate controllers can be designed with client capabilities at the centre of the design process, can be built to assist both in terms of physical access and learning needs, and can be tailored to provide feedback to suit the client or context they are being used in.

2.14 Alternate Controllers

Alternative controllers take two forms: 1) those that require physical touch to control, which are referred to as touch-based, and 2) those that do not, which are referred to herein as empty-handed.

2.14.1 Touch-based Alternate Controllers

Touch-based controllers use direct physical interaction with a control interface to acquire control data for musical systems. Notable developments in this area are discussed below.

MidiGrid. One of the first examples of using a touch-based alternate controller was explored by Hunt and Kirk (2003). In their long-term project (beginning in 1987) titled MidiGrid, they utilized the mouse and keyboard to control sound in software used by children and young people in a music therapy setting. Hunt and Kirk (2003) used the advent of musical instrumental digital interface (MIDI) within their project. The MidiGrid project was furthered by the development of MidiCreator (Kirk et al. 1994), which converted signals from electronic sensors into MIDI. MidiCreator could then be connected to the MidiGrid software. A computer could be equipped with MidiGrid allowing users to explore the creation and composition of musical work without the need to learn a traditional instrument. MidiGrid has been used by a wide range of people, such as composers, schoolchildren, special needs teachers, and their clients (Hunt and Kirk 2003).

Skoog 2. A more recent development is the Skoog 2 (Skoog 2016), a wireless Bluetooth enabled tactile foam cube with companion app and software. Manipulation of the Skoog 2 surface can be mapped to proprietary sounds within the software or can connect to external MIDI compatible software. The system provides a wealth of resources ‘out-of-the-box’, allowing for user customizable sounds and notes as well as controllable sensitivity settings for note triggering. This provides a hands-on musical experience for those with no previous musical knowledge affording individual exploration in a solo setting (Nath and

Young 2015). Skoog music have also released the Skwitch – a single 'squishy' tactile button that clips onto the iPhone to control sound (Skoogmusic 2018).

Music production centres (MPCs). Music production centres are generic devices developed for electronic music-makers that feature triggering pads often used with MIDI compatible software. They provide another modality of interaction that can be used as a tool to increase accessibility; however, these devices require a person familiar with music technology to set them up. The configurability of these devices allows adjustment to fit specific client requirements; additionally, functionality allows user profiles to be stored and recalled as needed. In a setting where resources have to be shared, this is an important feature as it provides the flexibility to allow users with different abilities to dictate the media content being triggered by the pads. This also allows for different levels of support (from simple note triggering to timing support) depending once again on client needs and preferences. This type of music technology is often attractive to children and young people, providing a motivator for engagement.

Switches. Another touch-based alternate controller used extensively, particularly for clients with severe disabilities, is the switch (Crowe and Rio 2004; Bache et al. 2014). Switches are electronic or mechanical devices which, via a control unit or cordless receiver, provide a simple mechanism for choosing and communicating (Magee 2012). Switches use physical action or gesture to give direct access to a variety of electronic music devices. There are a large range of switches that offer many forms of control. Bache, Derwent, and Magee (2014) provide a comprehensive overview of switches and their use with those with complex needs. Switches are a commonplace assistive technology that can be used in combination with specialist or commercial software. Custom built switches based on motor, cognitive, or sensory needs facilitate interaction based on clinical need. Sounds triggered by a switch can give a sense of control to clients, reinforcing a sense of self and allowing for expression (Swingler, 1998). Communication by using switches is often a starting point for non-speaking clients (Hunt et al. 2004; Magee et al. 2011)

Mogees. An alternate controller providing an out-of-the-box package is the Mogees (Mogees 2015). Mogees is a contact microphone which when placed on any surface detects when the surface is 'played'. Mogees has the potential to be used in a variety of settings and with objects that users are familiar with or motivated to interact with. It is highly portable and affordable.

Musii. Finally, another interesting alternate controller is the multi-sensory interactive Musii (Musii 2014). Musii is a soft inflatable object that emits sound and illuminates with colour when touched. It enables any non-musician to experience the act of creating music by translating physical interaction with the device into stimulating audio, visual, and tactile sensation (Musii 2014), with settings being controlled via a separate interface.

2.14.2 Empty-Handed Controllers

Empty-handed controllers do not require physical touch and use mechanisms such as infrared light, ultrasonic sensors, electromagnetic fields, radar, cameras, or microphones to detect sound or physical movement. Sonic parameters can be mapped and controlled from this information. This can be particularly useful in facilitating clients with complex needs by providing high levels of control, especially for those with physical disabilities or impairments.

The earliest empty-handed controller is considered to be the Theremin, patented in 1928 by Leon Theremin, in which the player uses the proximity of their hands to two metals aerials to control frequency and amplitude of a sound. The earliest documented use of alternate controllers for music-making in music therapy can be traced back to 1987. Nagler and Lee (1987) used microcomputers in music therapy sessions to 'investigate the possibility of enabling a severely physically handicapped person to create music with minimal assistance' (ibid, p.72). Using an Apple II microcomputer, Mountain Computer Music System, Express 3 infrared tracking device, and the Viewpoint optical indicator (an infrared light beam) clients could control the music based on their head movements, allowing them to achieve independent music-making.

Soundbeam. One of the first empty-handed commercially available alternate controllers for music therapy was the Soundbeam system (Williams 1989). Soundbeam is a tool that converts movement within an ultrasonic beam into MIDI information. Although it can be found in the equipment stores of many special educational needs' schools in the United Kingdom, it has been described as poorly used (Magee 2012). Factors that contribute to this may be that due to its complexity - specialist training is required to use the device and there is an inherent difficulty in placing the beams optimally to suit the movement of some users. The beams travel out linearly which can be unsuitable for users who cannot follow that axis of movement (Ellis and Leeuwen 2000). The lack of tactile feedback can also mean a disconnect between cause and effect for some users. Despite these drawbacks, Soundbeam has been extensively used in practice, possibly due to the unique mode of interaction it affords and the fact that there is a wealth of material and resources to enable people to use the system (Soundbeam 2018).

Music Maker. Other motion capture systems use cameras to capture movement data. A notable development is Music Maker, which turns body movements into sound using a non-obtrusive camera. Music Maker uses displays of cartoon drawings or pictures of musical instruments to give an element of fun and can be adjusted according to patients' levels of support needed, therapeutic goals, and type of equipment available in hospitals or patients' homes (Gorman et al. 2007).

Eye gaze systems. Additionally, some control mechanisms include eye gaze systems. These detect the user's direction of gaze as control information, often utilizing a 'dwell' type eye event to elicit a mouse click. Eye gaze systems are often the only access method available to those with diagnosis of 'locked-in syndrome' (Vamvakousis and Ramirez 2016), they are used due to the efficient and less effortful way they can be used to provide access to the computer (Bache et al. 2014). Hardware and software developments by commercial companies such as Tobii, Sensory Guru, and Smartbox (Bache et al. 2014) have pushed forward the development of the musical applications of eye gaze. One such example is EyeMusic, which provides a 'system that transforms eye movement data into musical compositions and data sonifications' (Hornof and Sato 2004, p.185). However, use of such systems do require skills developed over time by the client.

Clarion. A notable recent development in this area is the Clarion (Farrimond 2014). The Clarion is a highly configurable software instrument developed as part of the Open Orchestras project (Open Orchestras 2018). The Clarion allows the client to specify 'the sound the instrument makes; the number of notes that are available to play; the shape, position and colour of the notes; and crucially the way in which [you] play them' (Farrimond 2016). It integrates with eye gaze systems, SmartNav and the iPad, allowing use with existing hardware resources. Clarion comes as part of a package offered by Open Orchestras which includes the Clarion software, repertoire, training resources and support, and an evaluation framework.

2.15 Available Technology

As evidenced by the literature presented, there are many technologies available for aiding accessibility to music-making. As a growing field that crosses many disciplinary areas, challenges are created for music therapists. The primary challenges are knowing where to find this technology, examples of its use in similar contexts, and guidelines for integrating it into clinical practice.

The table (appendix A) provides a summary of developments, including off-the-shelf digital music instruments (DMIs), that have been used with clients who have complex needs. The DMIs included in the table were selected because there is evidence that they been used with people with complex needs, through either peer-reviewed published literature, anecdotally, or observed first-hand by the researcher. The DMIs reviewed are further organized into two categories: 1) commercially/freely available, and 2) research only. This decision was based on the fact that while some of the research and technology developed may show great promise for clients with complex needs, they have not subsequently been made available for wider use. The two categories are then further divided into three sub-categories: touch-based, software based, and empty-handed.

2.16 Incorporating Music Technology into Practice

Digital musical instruments can be considered to be created from: the materiality of the their construction; the modes of interaction they offer; the level of agency the system has; the level of interaction the system offers; and the feedback that is emitted (either digital or physical resonance) including the sounds it produces. How each element and the mechanisms within, are constructed and operate together form the device as a tool.

The individual device can be a tool for making music - **a piece of equipment** (the device) **for a particular kind of work** (making-music), but also the system could be a tool to facilitate access to music-making - **anything** (an assemblage of technology) used for the **particular purpose** (facilitating access to music-making). The tools created as part of this research form a toolkit defined as ‘a set of tools designed to be used together or for a particular purpose’ (Collins 2020c para 1). This particular purpose may fundamentally be to make music, in which the tools become a musical instrument by being a device or ‘object which you play in order to produce music’ (Collins 2020 para 1) or it may be that the particular purpose is to be a facilitation tool in order to enable access to music making.

This device then sit within the other elements that constitute the holistic tool assemblage. This assemblage consists of the individual tool (device), alongside the other elements of the system that interconnect to form the web of use that the device sits within (for example the computer, the iPad, the speakers, the facilitator). The tool assemblage is also then set within a real-time contextual scenario that involves the space and time that the tool is used within. Thus the experience of using a tool can be considered as part of an ecology of use that involves the relationships between the human, tool, environment (Waters 2007), and others – these others can be those facilitating the central user or those facilitating the music-making activities that they are carrying out.

Nagler (2011) suggests the next steps for the inclusion of technology (specifically digital hand-held music-making devices) in music therapy clinical practice are: the creation and development of applications that allow for music therapists to use musical methods analogous with practices achieved using traditional instruments, thus allowing for 'demonstration of patient progress toward specific goal attainment' (p.198); and the development of accepted, common guidelines from experts in the field with best practices needed to dictate methods. Nagler (2011) suggests that the development and sharing of technology could be spurred on by the use of Creative Commons licensing and open-source networks. This includes the need to create a taxonomy of understanding (to codify the pitfalls, methods, and potentials) incorporating the vocabulary, structure, and architecture of technology (specifically of hand-held music devices) into clinical practice

Farrimond et al. (2011) suggest simplifying the complexity of available technology by distinguishing between access needs and learning needs to aid in finding technology that is suitable for providing musical possibilities for clients. This can then lead to an emphasis on the creative preferences and needs of the individual. Magee and Burland (2008) echoed this by advising 'recommendations from allied fields advise that access to music-making for an individual with disabilities needs to start with examining the variance of the individual's abilities, the type of input required to achieve a task, and the possible mappings between the two' (p.126).

Further, developments in music education such as the Sounds of Intent framework (Vogiatzoglou et al. 2011) seek to provide 'evidence-based guidance on appropriate music pedagogy for all children in special education (thus informing policy and practice)' (Welch et al. 2015, p.3). The resources they provide are aimed at mapping the musical development of children and young people in special education settings.

Finally, a key issue for designers of new technology to consider is the 'musicality, usability, accessibility and affordability' of technology (Challis 2011, p.6). In following these guidelines there is the chance to maximize the potential for new developments to be incorporated into practice, make technological tools less daunting to everyday users, and foster creativity and communication among users.

2.17 HCI connections

When creating new technological systems a large part of the scope of the work falls into the field of human computer interaction (HCI). Historically HCI theory has been seen as 'difficult for designers to use and generally too theoretical to be relevant to a practical human focused solution developed in the timeframe of a design project' (Rogers 2004, p.25). However, this research follows a move away from predictive and prescriptive approaches (ibid) towards more social and situated approaches. This has been in an attempt to 'show the importance of considering other aspects besides the internal cognitive processing of a single user – notably, the social context, the external environment, the artefacts and the interaction and coordination between these during human-computer interactions. All of which can help towards understanding central aspects of the diffuse and boundless field that HCI has become' (ibid, p.27).

Traditionally HCI has drawn on applying basic research rooted in cognitive psychology and conducted in scientific laboratory settings. As such methods and theory with these roots cannot account for developments that are used in 'messy' real-world settings or with technology based tools that move away from the mouse and keyboard interaction paradigm. 'People rarely perform a task in isolation.... they are instead constantly interrupted or interrupt their own activities, by talking to others, taking breaks, starting new activities, resuming others, and so on' (ibid, p.4). This can be more acute in a special educational needs school setting where flexible and pragmatic problem solving is constantly in use to deal with unpredictable logistical and people related matters. Many of the theories derived from lab based controlled settings are not applicable to this type of real-world setting. To add to this, predictions based on basic cognitive theories about interfaces in terms of what makes them easiest to learn, most memorable, easiest to recognize and so on, were often not supported' (ibid) in the real world. This is true of this research in that basic cognitive theories and theories around practical based interaction tasks vary in use with the individuals that are using them. Cognitive modelling of users carrying out tasks or achieving goals with a computational system would not be a viable method to use within this research as this modelling can only ‘make predictions about isolated predictable behaviour’ (ibid, p.5). This would have been impossible to achieve within this research as there is not a predictable typical user or a typical goal, however there are typical requirements and design constraints that can be worked within to create new solutions with input from the users. These developments featured within them what the users consider important within a technological solution, and what they might want to use it for. This research is about making things work in context and so can be considered to be situated within the third wave of HCI that embraces the above.

2.18 Third Wave Human Computer Interaction

The three waves can be defined as follows:

- First wave – based in cognitive science and model-driven. Human factors methods focusing systematic testing with formal, strict guidelines.
- Second wave – extension of above to include distributed, collaborative, and mediated applications within work settings. More participation from systems users.
- Third wave – engaging beyond the workplace alongside growth of ubiquitous and pervasive computing. Emphasis placed on human meaning making, situated knowledge, experience and values (Filimowicz and Tzankova 2018).

This third wave ’takes into account the ‘messy’ context of socially situated and embodied action which introduces humanistic and social science considerations into design research’ (Filimowicz and Tzankova 2018 p3). Third-wave HCI engages beyond the workplace (Bodker 2006), with an emphasis on human meaning making, situated knowledge, and the grappling of the full complexity of the system (Harrison et al. 2007). Third-wave HCI values a ‘phenomenological matrix’ (Filimowicz and Tzankova 2018, p.3) which includes groupings of value sensitive design, participatory design, user experience design, ethnomethodology, interaction design, critical design and embodied interaction (ibid 2018 p2). This move interchanges models of efficiency of information transfer and operation, into more socially situated and embodied views of the interactor (ibid 2018) in a ‘turn to practice’. This turn to practice moves away the ‘snapshot of the interaction at the moment, usually focused on an individual, centred on the human-machine dyadic relationship itself' (Kuutti and Bannon 2014, p.3543) with its methods generally involving lab based, short-term, and task based studies with the individual, into a Practice paradigm that incorporates a more holistic view. One within which longitudinal and embedded practical use and methods and methodologies associated with gaining knowledge from such activities can be used.

This Practice paradigm situates the research in time and space, interweaving the surrounding material and cultural environment. 'The whole practice is the unit of intervention; not only technology, but everything related and interwoven in the performance is under scrutiny and potentially changeable, depending on the goals of the intervention' (Kuutti and Bannon 2014, p.3544). The Practice paradigm features in situ, extended activities involving people and artefacts: within their daily practices; within their organisational routines; with more developmental and phenomenological orientations being used (Kuutti and Bannon 2014). This move towards a more value orientated and person-centric view of HCI is congruent to the use of action research as a methodology which itself has a value and person-centric focus on practical development.

The shifts in practice based HCI can be seen in the topics undertaken within it of; understanding context, appropriation of technology, in-the-wild studies, complex real-world problem solving, materiality, embodiment, performance, digital ecologies, and the explicit mention of practices in research (Kuutti and Bannon 2014). These topics are ones which are infused throughout the explorations within this thesis. The tools formed involve the material assemblages they are constructed from, how they work alongside the user and each other to form an experience of use – both materially and temporally, and the context they are used within. Using action research as a methodology to work *with* and *for* practitioners, in the real world, with real problems that they face, this research aimed to create embedded tools that were situated within the context of use.

2.19 The Bricoleur and the Participatory Design Process

The researcher has assumed the mode of bricoleur to carry out the design and construction of the tools within the toolkit. Denzin and Lincoln (2000) describe the researcher as a 'bricoleur' or quilt-maker who is adept at performing a range of diverse tasks in order to piece together or construct new tools and techniques in an emergent fashion with 'choices as to which interpretive practices to employ' (p4) not necessarily being set in advance. This position is useful as it allows for the flexibility to respond to stakeholders needs and to the research situation, and allows for the quilt to be made as new knowledge emerges with skills being developed as needed. The research required management of three intertwining elements (Figure 2). These are the collaborative action research process (including the practical activities that happen as part of the research with stakeholders, as well as the academic output); the technological solutions (developed from the action research process); and the individual thesis (a documentation and reflection on the research process). Each part of these has several roles within them, depending on the stage of the cycle, that the researcher has to assume to ensure all elements of the research work together.

Researcher as bricoleur originated with Levi-Strauss (1994). Crotty (1998) describes the bricoleur as a 'makeshift artisan, armed with a collection of bits and pieces that were once standard parts of a certain whole' (para 27) not engaged in self-reflexion instead 'utterly focused on what they have to work with' (ibid). Crotty states that research in the constructivist vein, and in the mode of the bricoleur requires the removal of the straitjacket of conventional meanings that are taught as association to objects and instead to approach an object openly to allow for new and richer meanings to come to the fore (1998). In this spirit, the research presented here whilst not creating any novel technology, is recombining existing mechanisms/technologies/systems, in the style of the bricoleur, to forge new meanings and allow existing technology to come together to serve different purposes, and in new settings.

The bricoleur of Crotty (1998) focusses on what is to hand and what is there to work with, the focus squarely on the object. Looking at objects in terms of their touch, smell, taste and so on, descending down to the most minuscule and infinitesimal detail to get the nuance of the object (Crotty 1998). This framing of what the bricoleur pulls together is useful when considering the construction of instruments or tools for music making, in that they are in themselves usually highly representative artefacts, objects that carry pedigree, and a weight of meaning within their construction as explored in the section above. The mode of the bricoleur can be invoked to pull together these material assemblages into tools that aim to fit the needs of the stakeholders.

2.20 Social Model of Disability

When considering the sites that the research has occurred within, it might be pertinent to talk about the social model of disability, and to explore the literature around this area in order to establish the core ontological values around the human that have underpinned the research. Historically disability discourse has belonged to two pertinent schools of thought.

The medical (or individualized) model and the social model. The medical model being focused on the individual and the social model shifting the focus to society, and its role as a disabling factor. Oliver (1996) states that fundamentally 'the individual model locates the 'problem' of disability with the individual (ibid, p.32)' whereas the social model of disability 'does not deny the problem of disability but locates it squarely with society' (ibid, p.32). Going on to state that 'it is not individual limitations of whatever kind, which are the cause of the problem, but societies failure to provide appropriate services and adequately ensure the needs of disabled people are fully taken into account in its social organisation' (ibid, p.32). The British social model of disability centres around the idea that disabled people are an oppressed social group, the social model of disability defines 'disability as a social oppression, not the form of impairment' (Shakespeare and Watson 2002, p.4). Oliver (1996) states that it is 'society that disables physically impaired people' (ibid, p.3) with disability being imposed on top of impairments by the 'exclusion and isolation from full participation in society' (ibid, p.3). In this way, it is not the individual that needs to 'get better' but society that needs to change by breaking down the barriers to participation, and recognising that disability and impairment are, while strongly linked, not interchangeable. A person with an impairment can be 'disabled' by being denied access. The definition by Oliver (1996) serves to illustrate this: 'We define impairment as lacking all or part of a limb, or having a defective limb, organism or mechanism of the body and disability as the disadvantage or restriction of activity caused by a contemporary social organisation which takes little or no account of people who have physical impairments and thus excludes them from participation in the mainstream of social activities' (Oliver 1996, p.22).

Therefore, it is important to consider how the research presented here could engender emancipatory foundations that sit within the realm of the social model of disability.
Stone and Priestley (1996) developed six principles of emancipatory research that were used to help guide the research. Through the course of their research, grounded in the social model of disability, they set principles that state that the research should:

- have an epistemological basis in the social model of disablement
- eschew objectivity to commit to the self-emancipation of disabled people
- only focus on practical benefit to the self-empowerment of disabled people and/or the removal of disabling barriers
- be fully accountable to disabled people and their organizations in anything produced

- give voice to individuals experiences as well as shared discourse of disabled people
- adopt methods for data collection and analysis determined by needs of the participants

This research is conducted in the spirit of the social model with an ontological assumption of disability as suggested by Shakespeare and Watson (2002) that everyone is impaired, and that the false line between who is normal and who is impaired should be demolished, in their attack on the concept of physical normality. Everybody faces the human condition and the 'inescapable essence of being alive' (ibid, p.26) suggesting the breaking of the distinction between disabled people and non-disabled people instilling the idea that there is no qualitative difference, because impairment is not a core component of disability, it is inherent in human nature (Shakespeare and Watson 2002). They suggest we need to move beyond the dichotomy between 'able-bodied people' and 'disabled people to focus on 'the continuum of impairment and embodiment (ibid, p.28)'. That we need to recognise and maintain sensitivity to the fact that individual bodies and minds may impose limitations that can be trivial or severe, but there is still a minority of people that society has excluded, disempowered or oppressed. In that it is essential that we focus on the connection between impairment and embodiment, rather than trying to break the link between impairment and disability (Shakespeare and Watson 2002). These views are echoed by Barnes and Sheldon (2007) when they state that 'emancipatory' disability research cannot be built upon ontological foundations that construct disabled children and young people as having needs that are 'special'. Instead, it must be recognised that they are children like any others, but their needs are not currently met' (ibid, p.240). In the case of this research, the music technology provisions in the research sites that the stakeholders attend and practice in, are seen as not currently meeting these needs.

The view of this research is that conventional instruments can disable people by remaining static in their physical construction, and by being intrinsically void of cognitive support for those playing them. It is with the flexibility of technology that new systems can be created to empower the individual by permitting physical capabilities to be supported, and/or support/scaffolding cognitive capability. Tools can be created to help break down the barriers to making-music, with the aim of creating more inclusive and expressive tools that are designed from the bottom up, rather than the traditional instrument top down approach. This ontological assumption falls in line with the theories of emancipatory research as laid out in the introduction, in that 'emancipatory research *must* adhere to the social model of disability' (Barnes and Sheldon 2007, p.238). The model of accessibility for all is the aspiration of the development. This includes the trickle-down effects of designing from the bottom up, with the hopes that catering towards universal access – with foci on usability, accessibility, and acceptability.

2.21 Literature Review Conclusion

While it is clear that utilising music technology to facilitate active music-making has a myriad of potential benefits, it is also clear that the ever-changing landscape of technology can be overwhelming. This can create gaps between developer, practitioners and users. This ever-changing landscape may be particularly overwhelming for music therapists not already steeped in technology, as these systems often consist of several layers of technologies that require technical skill to combine. Practitioners may find it difficult to keep up with changes in technology and figure out how to combine and integrate them into their practice. Still, despite these technical and financial challenges, the utilization of technology provides unique access to music-making for those that cannot access traditional instruments. Alternate controllers, in particular, provide a means to explore new ways of utilizing an individual's physical and learning abilities to provide meaningful and motivating musical experiences in a tangible and physical way. This leverages the unique properties of technology to provide unique systems for interaction to allow that instrumental resistance to be provided in a capacity relative to the user's needs. Using music technology in this manner, on its own or alongside traditional instruments, requires a different approach to integration, repertoire, and skill set of the users. This approach must take into account the type of technology, how it will be used, and also the intended outcome. The potential in using technology is evident from the developments presented in this chapter; this potential, however, must be discussed, shared, and best practices developed. This practice is an interdisciplinary pursuit between practitioners, users, and designers and something that this research aims to contribute towards.

2.22 Chapter Conclusion

This chapter has reviewed the literature around music technology, especially in the form of alternate controls, that are used in the realm of music therapy to facilitate access to music-making. A review of developments is provided as well as an exploration of technological advancements involved in facilitating new developments. The research is then grounded in the field of third-wave HCI and the mode of the bricoleur is also explored in the creation of new technological systems. The underpinning philosophy of the social model of disability is discussed. The next chapter presents background information on the research including the underpinning philosophical foundation of the research. The methodology and methods utilised within the research are explored in terms of collecting, analysing, and synthesizing data into technological development and into new knowledge.

3. Methodology

3.1 Introduction

The former chapter provided a literature review of the pertinent issues surrounding the creation and utilisation of technological tools for use in active music-making – focussing on the alternate controller used in a music therapy context. The research was grounded in the field of HCI, the research mode of bricoleur was discussed, and the social model of disability was presented as the underpinning philosophy to this research.

This chapter sets out to detail the research design and demonstrate its suitability in responding to the research aims, and its appropriateness for gathering compelling data related to the topic area. A roadmap is provided to show the philosophical underpinnings (Figure 5) used within this research. Rationales are presented for the approach to the research by making explicit the methodological assumptions involving the ontological and epistemological underpinnings of the research. Also detailed are the sample population, the positionality of the researcher, and the research roles. The method of meeting people where they are and the use of technology probes are outlined. Action research is specified as the methodology supported by followed by a description of methods used for data collection and analysis. Ethical considerations are addressed and stakeholder involvement is explored before the chapter concludes. The above are explicated in the hopes of achieving a sense of the validity, reliability, credibility, and rigour to the research.

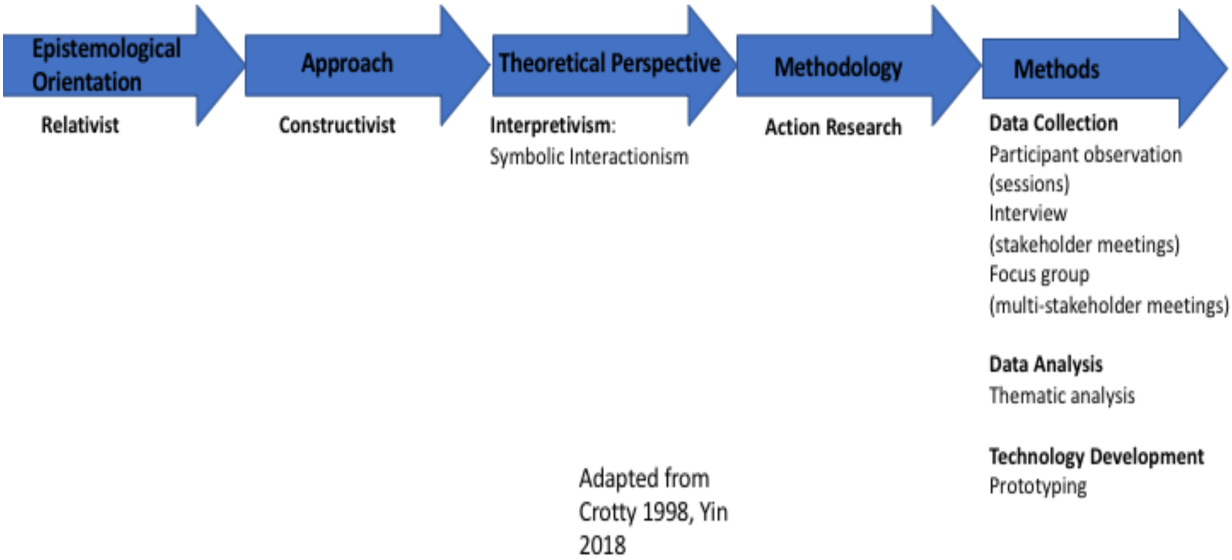

Figure 5 - Roadmap of Research Philosophy

3.2 Background

The foundation of this research began in 2012 during which the researcher held a nine month placement with the industrial sponsor school as part of an BSc in Music and Audio Technology. The placement involved working to create interactive technology to help children and young people (CYP) access curricular content. It was through this embedded placement within the industrial sponsor school, and in working with the interaction designer at the school, the researcher developed a strong interest into how technology could be used to help people. Technology during the placement was used to facilitate learning and give access to the curriculum to those who faced barriers to learning when using traditional classroom techniques.

The researcher - having a background in music-making technology – wanted to explore the creation of technology that could enable access in music-making. Through observing gaps between the types of technology being used in school and the types of technology that were available or able to be created, the researcher wanted to explore where gaps in provision could be filled and barriers to access and use could be broken down. This involved thinking holistically about the ecology of use of such systems, why technology would not be used, and what could be created that would address these gaps and barriers.

The research has been approached with the goal of affecting change within practice, both of the researchers own, and the practitioners and children and young people that have formed the stakeholders within the research. That is - to use technology to help, as it has helped in the past, and to translate that knowledge to the domain of music.

3.3 The Engineering Doctorate

The engineering doctorate (EngD) is a four year programme in which the researcher is embedded within an industrial partner organisation who sponsor them as a research engineer to deliver applied research. The doctorate is supported through EPSRC funding via the Centre for Digital Entertainment doctoral training centre, which is housed within Bournemouth University. As such supervision is provided by both academic supervisors and an industrial mentor. The EngD package provides a stipend, and a generous budget to purchase equipment and fund research activities such as conference attendance. The EngD programme combines access to the Bournemouth University, doctoral centre, and industry sponsor resources and infrastructure as a framework for the research. The EngD differs from a traditional PhD in that it has a foundation of working within industry and features an additional taught element. The first year is a taught year in which a unit at masters level and researcher development programmes are undertaken (a unit in usability engineering was completed as part of this research, as well as courses in ethics and research methods). The further three years of the research were spent working directly with the industrial sponsor.

3.4 Ontology in Emancipatory Research

This research draws on key ontological assumptions within emancipatory research that ‘that there are multiple realities’ and ‘knowledge is not only created by the elite researcher or dominant group’ (Noel 2016 p.4). There is an assumption that there is an interactive link between researcher and stakeholders that this is historically and socially situated (Groat and Wang 2001). This required the researcher to be aware of the social and historical contexts of the stakeholders and the research sites in which the research operated, and to maintain sensitivity to the issues which potentially could arise within the context. To be emancipatory there was also the need to recognise the researchers own privileges and their position within the dominant group (Noel 2016). There is also the methodological assumption that emancipatory research takes a collaborative and participatory approach, which fits well with the action research methodology. Both aim to remain grounded in a context of shared experiences leading to the flourishing of individuals or communities.

Action research provides the opportunity to seek empowerment through collaboration (Lions 2016), allowing for the researcher's involvement to be explicit, and provides the opportunity for the research to follow the needs of the stakeholders, this means there is no prescriptive population that is selected and studied, rather there is the openness and flexibility to move with the needs of the stakeholders and context when addressing the above concerns. 'Therefore, emancipatory research principles are relevant, to ensure that the projects do in fact empower the communities that they seek to support' (Noel 2016, p.5).

3.5 Epistemology

Whilst the epistemological basis for this research is relativist, the research approach has been based in constructivism. 'Constructivism is the recognition that reality is a product of human intelligence interacting with experience in the real world. As soon as you include human mental activity in the process of knowing reality, you have accepted constructivism' (Elkind 2005, p.334). The constructivist philosophical standpoint guiding this research assumes that people construct understanding and knowledge of the world through experience and reflection on experiences. This research moves out from the individual to consider knowledge in terms of a group of stakeholders and in this vein, moves into a collective generation of meaning. 'It would appear useful, then, to reserve the term constructivism for epistemological considerations focusing exclusively on 'the meaning-making activity of the individual mind' and to use constructionism where the focus includes 'the collective generation [and transmission] of meaning' (Crotty 1998, p.58).

Based on these definitions the philosophical assumptions that this research will make are:

- Knowledge is relativistic involving multiple individual perspectives and opinions with a 'respect and interest in understanding and depicting individual and social group differences (i.e., their different perspectives) and a respect for democratic approaches to group opinion and value selection (Johnson and Onwuegbuzie 2004, p.16) (relativism)

- Meaning is created from our interaction with the world and therefore meaning is constructed about tools as we use them (constructivism)
- Meaning and its construction is dependent on the context that it is constructed in (constructionism)

3.6 Interpretivism

While positivism states that reality consists of what we can sense, what we can see, smell, touch, etc and that scientific observation and empirical inquiry are used to gain knowledge with logical and methodological principles that deal with facts not values (Gray 2009), interpretivism states that there is not a direct relationship between ourselves as subjects and the world as objects but that the world is interpreted through schemas of the mind (ibid).

There are many examples of interpretivist approaches to research including symbolic interactionalism, phenomenology, realism, hermeneutics and naturalistic inquiry. This research will focus on an interpretivist approach of symbolic interactionism and incorporate some elements of naturalistic inquiry. As the research is driven by human interests, an inductive approach is used to construct theories and to gain knowledge around the use and creation of technological tools.

3.7 Phenomenology as methodology

Whilst phenomenological methodology could have been a viable alternative to action research in focussing on the human experience of using tools to make music. It was felt that this would have restricted the research to very individualistic experiences. This research has had a focus on the bigger context of the use of technological tools within their ecology of use. The research had the stance on creating tools that are ultimately useable not just by the person at the centre of the experience, but also with the experience being at the centre of the context. This involved considering not just how each tool would be used and what the outcome of the interaction would be – but how that outcome could be adapted in real-time, with minimal barrier between what the user and/or therapist wanted to achieve and how the technology could be accessed to allow for this. This meant creating a system that could be changed on-the-fly and adapted to match the users individual cognitive, sensory, and physical needs by providing a tool that they could interact with, and an outcome of the interaction that was engaging for them. There was a move away from describing the essence of the experience was taken and a more practice-based approach to design was followed. The aim of this research was not to richly recreate what is was like to be there. The slant has always been on what needs to be developed from this technically, what is missing and what is working, how are things working together. In this way, practice would become a unit of analysis or design rather than a focus on individual action or changing behaviour (Entwistle et al. 2015). Action research offered the capacity to include a more extended view of the devices developed in that other people, places, and things that come together to co-construct meaning in the style of constructionism. The aims of this was to provide stronger contextualisation of the research problem which in turn manifested the contributions to knowledge. Whilst the ultimate aim was to enable a positive experience for the person at the centre of the music making, this experience would not be possible and sometimes has been made impossible with past technology due to the control of use of technology being outside of the hands of the person central to the experience, and as such this contextual co-created knowledge was essential to gain better understanding of the problem and to work towards better technical solutions.

3.8 The 'ethnos'

Whilst the majority of this research has been conducted in the vein of action research with the ethos of being *for* and *with* people in a participatory way, the research also features an ethnographic component in that the researcher observed practitioners in real world every day work settings, and further to this ethnomethodology in that the researcher conducted sessions with technology in an embedded way to explore the web of use (in terms of socio-cultural and personal elements) that these technologies sat within.

3.8.1 Ethnography

Ethnography has been utilised in part within this research as an observational method to explore the use of technology in practice. Ethnography is centered on credible, rigorous, and authentic stories which give voice to people in their local context (Fetterman 2010). 'This story is told through the eyes of people as they pursue their daily lives in their own communities' (Passos et al. 2012, p.9). The goals of ethnography are to gain in-depth rich and detailed social accounts by focusing on culture and values. To do this participant observation is used within fieldwork that is holistic, comparative, and contextual, with the final product being an in-depth description of the focus of the subject (ibid). ‘The intention of ethnography is to see activities as social actions embedded within a socially organised domain and accomplished in and through the day-to-day activities of participants, with workplace ethnographies identifying new orientations for design when considering the creation of shared artefacts and the structures of practice with these’ (Carroll 2013, para. 4).

The approach to ethnography has been one of distancing from preconceptions thus providing the opportunity to explore the tension between the researcher as the designer and the researcher as the fieldworker in order to explore the difference between ‘good *abstract* design and good *practical* design solutions’ (ibid, para. 19).

Ethnography has been used to explore the differences between what stakeholders say they want and what seems to be required in practice by offering ‘the opportunity to reveal needs or practices of users which they may not themselves attend to because they take them so much for granted........ 'needs' which they cannot articulate because of the bureaucratic or power relationships within which they are placed or because they are simply too busy’ (ibid, para. 4). As a tool this has been useful in allowing the researcher to use their knowledge in combination with the practitioner as a way of one enhancing/informing the other.

Whilst ethnography offered the holistic in-field description it was felt that the participatory nature of action research could be used create new knowledge by including the stakeholders voices to inform the creation of technical solutions. This cyclical process can then be based in a direction outlined by the stakeholders. In this way, the combination of action research was used to guide where to look and as a tool to assess the progression of the developed technology. The use of technological tools and their embedded nature, was explored using ethnographic methods. Data was elicited from the practice of using technology, both from the researchers own perspective of use, and the integration of technology into practice - by observing practitioners going about their daily practice in order to gain additional real-world knowledge of the routine ways which both technology is used, and in similar contexts, where technology isn’t used, why, and how it might be incorporated.

3.8.2 Ethnomethodology

Originally developed by Harold Garfinkel in the 1950s, ethnomethodology can be defined as analysis and systematic description of the ways socio-cultural groups practice their everyday activities, with an interest in exploring the order of shared meaning-making that maintains social settings. Ethnomethodology has two main concepts - indexicality (there are no fixed meaning and meaning is relative to context) and reflexivity (common sense knowledge is utilised to ascribe meaning to situations), which are locked in an interplay to create social order. This order is then maintained by those within the context of the situation.

Within the realm of HCI ethnomethodology has been used to inform design through 'fieldwork investigations that develop an understanding of work and organisations from the "inside", providing innovative insights into the organisational situatedness of work and the methods and practices through which work activities and interactions are assembled........and by developing an understanding of the temporal organisation of activities and interactions, revealing them to be a moment-by-moment organisation, and in so doing furnishing new concepts around which to generally consider the design of technology' (Dourish and Button 1999, p.401).

Ethnomethodology can be useful to gain a fuller understanding of the contexts within which the technological tools become a useable part of. This is an attempt to intertwine requirements capture from the stakeholders directly, as well as through observation of practitioners in sessions with or without technology, and by using technology first-hand, in order to provide a 'lay of the land' of the web of use in which the technology sits. This web features both abstract and concrete components, from both personal to socio-cultural perspectives, that coalesce to fundamentally affect the successful and continued use of such technological tools. This research moves towards situated tools that are designed to work within the milieus they are used in.

The combination of action research, ethnography and ethnomethodology converge with the alignment of this research to the third-wave of HCI. The creation of the tools has been carried out in the mode of the bricoleur. The research has been guided by action research - in that it used stakeholders input, was cyclical, and used feedback in a capacity *with* and *for* stakeholders to guide the design (in terms of what the technology needs to do, and how the technology might work in practice). Ethnomethodology has been used to understand the technology within context in order to guide design. This has consisted of exploring: gaps in provision - by looking at what is used, how, and what could be used?; and barriers to access – by considering why technology is not used, and what could be improved?

The use of ethnographic observational methods - with the researcher becoming embedded and contributing to part of the context - has been used to provide in-depth and rich accounts of this context in order to highlight where technology could potentially fit. The intertwining of all of these elements has led to the final MAMI Tech Toolkit.

3.9 Symbolic interactionalism

The above section is a quasi-roadmap of the research design of this research. Presently we return to the underlying framework of this research which is used to outline the assumptions made around social meaning-making.

Symbolic interactionism grew out of the work of John Dewey and George Herbert Mead and was further developed by his student Herbert Blumer. Symbolic Interactionalism centres on human behaviour via people's practices and lived realities (Gray 2009) stating that human interaction with the world is mediated through the process of meaning-making and interpretation. As such this underlying framework is congruent with previously discussed philosophies of phenomenology, and with the alignment of this research to constructivism and interpretivism.

Symbolic interactionism can be encapsulated in Blumer's three premises (1969):

- People base their interactions with things upon the meanings that they have ascribed to those things
- The meaning of things is derived from, or arises out of social interaction – with things having different meanings for different people
- Meanings are modified through an interpretive process - when the individual deals with the things/individuals/contexts they encounter meanings may be updated and reformulated

Whilst this theoretical perspective is commonly aligned with ethnography, it can be useful as a framework for an action research project. Combining the above theoretical propositions of symbolic interactionalism with the action research methodology provide a framework to think, question and theorise about the meaning making process of using music-making tools, as well as how these meanings arise and are modified. This research explored how meanings manifested and were modified when stakeholders were both interacting in their societal context and with technology. The flexibility to follow the stakeholder's direction in the style of action research was underpinned by the framework that symbolic interactionalism provides in order to draw out questions of meaning based in practical application and on praxis. Looking at: the 'things' 'objects' or 'tools' and the meanings that they have, potentially have, or did have; and how these meanings are used/modified in 'context' or 'practice' or 'theory' has provided an appropriate research design to elicit credible knowledge that has been used to inform the design of the technology. This process required the researcher to enter the field in order to gain first-hand knowledge of the subject's actions, from both the perspective of the subjects themselves (Gray 2009), as well as from observation. The researcher became embedded within the field, working alongside the stakeholders and using a range of methods to discover their perspectives and provide new solutions whilst observing what worked in context. As such both symbolic interactionalism and action research intertwine with the focus of exploring the meanings people give to the tools used for music-making, and how this interlocks with the social interaction of the setting, and how these are modified.

3.10 Naturalistic Inquiry

Naturalistic inquiry states that inquiry is value bound by the perspectives of the researcher and that phenomena are not able to be isolated and can only be understood in context of their setting. Research designs therefore cannot be pre-specified but emerge and unfold during the research process (Lincoln and Guba 1985). This perspective is especially helpful in the school setting where the research can progress as the needs of the stakeholders emerge and as the situation unfolds. This also fits with action research as there is flexibility to adapt the design of the research, the research process, and the analysis to move with the feedback from the stakeholders, and to embrace the tenets of naturalistic inquiry. There is also the recognition that the researcher does not act in isolation and that the perspective of the researcher has an effect on the path of the research, this is then supported/opposed by working with stakeholders, and it is through this discourse (both between researcher and stakeholder and stakeholder to stakeholder) that knowledge is created, issues are explored, and new technological solutions can be explored and have a better chance of being adopted.

3.11 Sample Population

The stakeholders involved with this research are both the central users of the technology (the children and young people at the school) as well as those facilitating this use (the practitioners that surround them). The research sites and participants selected as stakeholders represent practical users of accessible music technology and therefore could illuminate issues around such use. Purposeful sampling (Creswell 2007) has been used to gain stakeholders, this has been criterion based (Creswell 2007) in that the stakeholders have interest in using, have used, or do use music technology. The selection of these stakeholders has been opportunistic in that they have presented themselves throughout the undertaking of the research activities. Where the sample has been stakeholders in the form of children and young people, they have been selected by stakeholders in a snowball (or chain) manner (Creswell 2007), in that the practitioners know of children, or know of teachers of children, that had an interest in being part of this research, which could also be considered criterion sampling in of itself.

3.12 First, Second, and Third Person Research

The research has followed an integrative approach to inquiry that has aimed to incorporate the voices of the researcher (first-person), others on issues of mutual concern (second-person) and create broader communities of inquiry (third-person).
Reason and McArdle (2004) state that ‘good action research will strive to stimulate inquiry at each of these levels and to create connections between levels’ (p.114). They go on to expand the categories below:

- First-person action research practices address abilities of the individual to foster inquiring approaches through acting *awarely* and *choicefully*, while assessing effects to the outside world
- Second-person action research practices address the ability to co-inquire face-to-face with others into issues of mutual concern. Cycles of action and reflection lead to understanding and knowledge of practice as a matter of mutual concern

- Third-person action research practices includes the drawing together of a wider community of inquiry involving persons who cannot be known to each other face-to-face. (Reason and McArdle 2004)

3.13 Positionality

‘In action research, the concept of positionality is referenced in terms of the researcher's insider or outsider relationship to the community engaged in the inquiry’ (Coghlan and Brydon-Miller 2014, p.627).

Much of action research is concerned centrally with issues arising from the relationship between insiders and outsiders. This relationship can affect the gathering of quality and valid data. Herr and Anderson (2005) refer to the positionality of the researcher on a continuum between insider and outsider featuring six categories: insider (researcher studies own practice); insider in collaboration with other insiders; insider in collaboration with other outsiders; reciprocal collaboration (insider-outsider teams); outsider in collaboration with insiders; and outsider studies insiders. They acknowledge that it is no simple matter to define one’s position in that the relationship and status of the researcher can change over the duration of the research. Thinking about these issues, and the benefits and pitfalls of the insider/outsider status, can help clarify them to ensure research is ethically sound, and research validity is addressed (table1).

INSIDER	**OUTSIDER**
Advantages • Seen as members of group • Add new/ignored perspectives to theory • Familiarity with culture and conditions • Easier to gain trust, co-operation and acceptance • Less liable to construct stereotypes • Established foundation of knowledge • Less preparation to entry into field • Access to context and activities	*Advantages* • Not committed to group • Will not be entrenched in the setting • Viewed as objective observer • May not have access to sensitive information if seen as temporary • Can see properties lost to familiarisation

Disadvantages	*Disadvantages*
• May be viewed as advocates • Can be biased towards interpretations and findings • Conflicts of role may occur • Area of focus potential to skew • Reliance on more well-known participants/stakeholders • Not seen as researcher	• Culture shock may interfere with research • Times taken to integrate into setting - gain trust, understand culture/jargon • Unknown culture and conditions may desensitise researcher to needs • May receive expected rather than true/accurate responses • May need to utilise experts from the field to gain data

Table 1 - Insider/Outsider - Advantages/Disadvantages, adapted from Bonner and Tolhurst, 2002

'Traditionally action researchers were seen as outside change agents' (Herr and Anderson 2005 p.29) in that the research was initiated by an outsider and that the outsider would involve insiders in the process of research, to a greater extent than with traditional research. Practitioners and researchers may also be one and the same in that action research is often done by practitioners motivated by their own setting and as such use reflective research to problem solve or deepen and develop professional knowledge within their field.

This relationship can be seen to be fluid and can shift throughout the study (Herr and Anderson 2005 p.32). As action research is chiefly about working with stakeholders to co-inquire, this status may impact the data that can be collected, the access to, and ease with which data can be collected.

> 'The researcher as friendly outsider is an approach that explicitly rejects the idea that researchers should distance themselves from the 'subjects' of their research in the name of objectivity. Instead, AR requires researchers to become 'coaches' who are skilled at opening up lines of communication and facilitating research activities *with* community partners rather than designing and implementing research *about* them. Likewise, the research facilitator co-designs interventions and change *with* community partners, not *for* them. In this model, researchers may support community collaborators in critical thinking and academic reasoning, but this view privileges local knowledge as being as important as scientific or scholarly knowledge. Thus, all involved are co-investigators of, co- participants in, and co-subjects of both the change and evaluation activities of the project' (Hayes 2016, p.54).

In this manner, a friendly outsider status was achieved within the school's ecosphere within which other insiders were worked with. Prior first-hand knowledge and previous work with the industrial sponsor school led to a foundational knowledge of the school framework, the teachers and the pupils, alongside knowledge of some of the issues faced within this particular setting. This knowledge was utilised at the start the research to gain access and to forge relationships with the stakeholders. Although over the course of seven years of collaboration with the industrial sponsor site there has been changeover of students and staff that have meant that insider/outsider status has constantly been in fluctuation.

Insider/outsider status has also fluctuated depending on the research site, the subject discussed during the research, the research activity, and those present during the research activity. In this way, there was multiple levels to the insider/outsider status. One may be an insider in terms of the knowledge about a particular subject or practice, however an outsider to the context or the stakeholder, or an insider with a particular stakeholder but an outsider to others in the setting. It is the negotiations of these relationship that has been navigated to come to the final development.

Both emic (from within the social group) and etic (from the perspective of observer) viewpoints have been intertwined throughout the research. Etic with regard to the use of observations of sessions and technology in use, and emic in terms of attaining data about technology usage and when developing technology with the stakeholders.

3.14 Research Roles

Action research is a participatory process and the researcher can assume many roles within the research. Roles that have been assumed so far by the researcher have been of researcher (collating, analysing, synthesizing, and disseminating data), practitioner (designing and running workshops with the children and young people), and technologist (designing and creating novel technology).

3.15 Meeting People Where They Were

The research approach used throughout the data collection can be considered to be an example of 'starting where you are' (Lofland and Lofland 1994; Robson 2002, p.49) in that it was began through personal interest and with several connections to stakeholders already in place. Throughout the research there was an aim to enact an insider stance, in that the research endeavoured to *meet people where they were*, and to carry out the research by following the stakeholders lead where possible. Ultimately, as a researcher, not being embedded full time in any of the organisations, there was always an element of the outsider present, however there was always an effort to maintain the stakeholder needs as central to the developments. Meeting them where they were meant both physically going to their sites of practice, and interacting and elucidating information through naturalistic methods such as observation of practice, and relaxed and open talking about their practice. This also extended to remaining open with the agenda of the research in order to follow the needs of the stakeholders.

Cornwall (1996) describes a continuum of purposes that can be helpful for locating the positionality of this research in terms of the overarching connections with stakeholders. She describes six modes of participation combining the involvement of the local people, and the relationship of research and action to the local people. These are co-option, compliance, consultation, co-operation, co-learning and collective action. This research lies between the consultation and cooperation modes of participation. Consultation - as local opinions were fielded, and the researcher, as friendly outsider, analysed and decided on a course of action (research that has a for/with relationship) and cooperation - in that local people worked together with outsider facilitation to share knowledge, create understanding, and work together to form action plans (Cornwall 1996).

3.16 Technology Probes

A key mechanism throughout this research was the use of the tools within the kit as 'technology probes' (Hutchinson et al 2003). The *'tool as probe'* mechanism was used to elicit requirements from the stakeholders through an iterative design process. Technology probes included in the MAMI Tech Toolkit were developed throughout the research with each element of the kit moving through a series of iterations. Probes can be considered a method to allow users to more directly shape technologies as they are developed. Technology probes are defined as simple, adaptable, flexible technologies with three main goals:

- A **social science** goal of 'collecting information about the use and the users of the technology in a real-world setting' (Hutchinson et al. 2003, p.18)

- An **engineering** goal of field testing the technology (ibid, p.18)
- A **design** goal of inspiring users and designers to think of new kinds of technology (ibid, p.18)

The main characteristics of technology probes are that they were an aid to gathering knowledge about technology in-situ, were intended to work in a real-world setting, and were not designed to solve technical problems, but as a collection of technical features that are combined to function for a purpose. Technology probes were used in this case as a precursor to the final forms of each tool. Probes can aid in the above goals by following the guidelines below:

- Functionality - they should be simple with a single main purpose/two or three easily accessible functions
- Usability – they do not focus on usability in the traditional HCI sense, functions do not change or adapt with user input as in the case of prototypes. The initial software of the system was made usable to the researcher alone, with the probes being functional but not robust. The final system packaged as the MAMI Tech Toolkit focussed the creation of easy-to-use graphical user interfaces, providing user documentation that did not contain jargon and that used mechanisms such as highlighted screenshots, as well as visual guides to the tools in the kit (Welcome to the Kit (appendix B) document) to enhance usability.
- Logging – can be used to contextually collect data about the music/technology relationship and used to generate new ideas for future iterations leading to the final prototypes
- Flexibility –should not offer many choices in terms of functionality and should remain open ended to encourage users to reinterpret them. In this way probes are used to generate discussion and develop technological ideas
- Design phase – they are intended to be used early on in the design process as influencers for future design

Technology probes can be useful when it is challenging to learn about the attitudes and needs of users towards technology using traditional HCI methods (Hutchinson et al, 2003). Through the use of technology probes the research was able to move between what was created and what was needed, back and forth towards final tool design. The use of the technology probe proved a fervent starting point aimed at addressing some issues whilst looking to provoke a reaction to others. The technology probes were used in this way as a frame to reference what was working or not working and what was ‘good’ or ‘bad’ in a tangible way for the stakeholders.

In solidifying the probes functionality there was exploration of what could be achieved and from this there was development of what was possible. This was then fed back into the design process which currently stand as the elements of the kit as they are today, these can still be considered probes in themselves, which lie in wait of future development.

3.17 The Research Process

The research process (Figure 6) involved both action research (by planning, acting, and reflecting with stakeholders) and technological solution development (by reviewing the literature around the development of music technology in the field of music therapy and interactions with stakeholders to inform technological development). These two elements were intertwined throughout the research ending with the final MAMI Tech Toolkit. The thesis writing process then examined further how each strand had affected the other, and further analysed the findings that emerged from both the data and the process to solidify the themes presented.

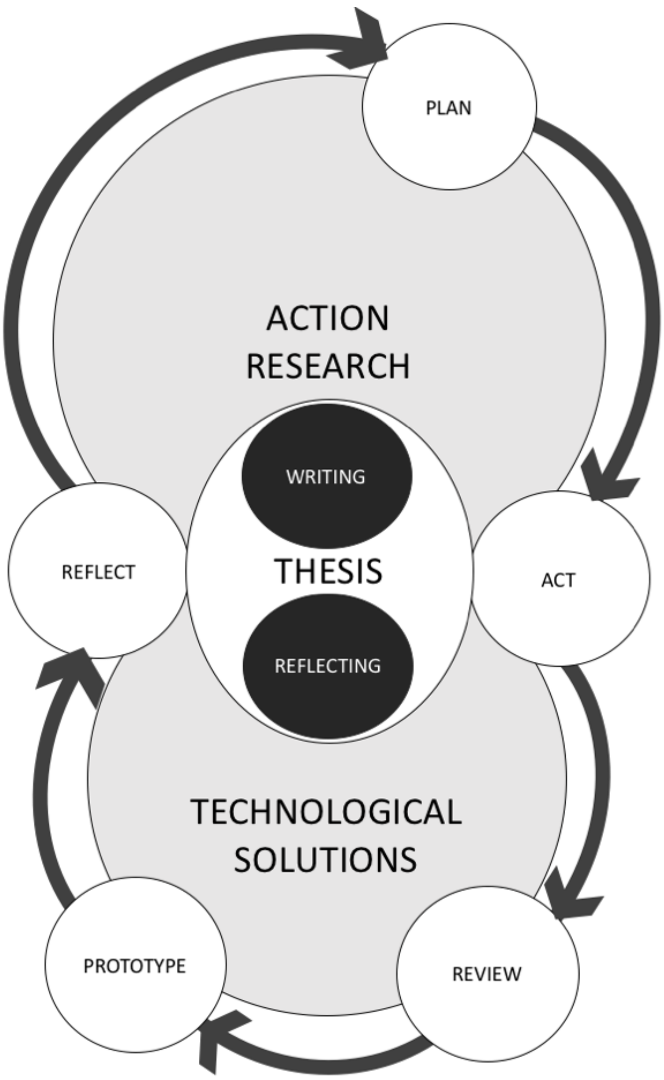

Figure 6 - The Research Process

3.18 Research Sites

The main industrial sponsor for this research was school A. However, several other stakeholders from different research sites have fed into the research. An overview of each research site is provided below with a description of their general level of technology usage (resources available, staff involved, physical spaces used) at the time that the research began. An outline of how the researcher was connected to the site and how stakeholders at that site became involved is also offered. Five MAMI Tech Toolkits were created and delivered to school A, school B, school C, a community day centre, and an artist/musician.

3.18.1 School A

School A - a special educational needs school providing for 220 children and young people with a wide range of Special Educational Needs and aged between 4 and 19 years old. The industrial mentor (IM) for this research worked as the interactive designer and creative technologist within the school and was the researchers supervisor during the degree placement. The connection with this school stemmed from the undergraduate degree placement. The industrial mentors main place of work within the school was the sensory studio - a unique egg-shaped room, with 180° video projection and 12:1 surround sound controlled via a central computer, and accessible via an iPad. Existing assistive and commercial technology in combination with Arduino based micro-controllers, various sensors, and physical props, were used to create engaging and immersive environments and experiences within the sensory studio. The school also has an in-house music therapist that utilised technology such as the Tenori-on, the Theramini, and the iPad when working with the children and young people. The music therapist worked from their own room within the school or visited classrooms three days a week, running both one-to-one and group sessions in classrooms. This research continued the relationship the researcher had with the school throughout undergraduate studies.

3.18.2 School B

School B - a non-maintained special school offering specialised education, therapy and care for young people aged 3-19 and a residential transition service for 18-25 year olds. The school has an in-house digital music technician (DMTB), who used various technology including physical hardware (Soundbeam) and software (Magix Music Maker) frequently, and a director of music (DoMB) who have contributed as stakeholders to this research. The first contact with school B was through a final year undergraduate pilot study conducted by the researcher with a development called the SenseEgg (Blatherwick and Cobb 2015).

3.18.3 School C

School C - a special school which supports a comprehensive range of special educational needs and disabilities. The school had a musician (MC) that ran session within the school, and an in-house dedicated media and music technology subject co-ordinator (MTSC) who used technology frequently. The relationship with school C was formed through meeting the musician, leading to developing a connection with the music technology subject co-ordinator. Both of whom contributed to the research as stakeholders.

3.18.4 The Day Centre

The day centre - provided leisure and learning opportunities for adults with disabilities. The relationship with the day centre began via a meeting with the music therapist (MTDC) who ran sessions in the day centre one day a week. Through this initial connection, a community musician (CMDC) who worked three days a week at the day centre, came on board as a stakeholder. Both of whom did not use technology often.

3.18.5 Multimedia Musician

A self-described 'multi-furious' and multimedia artist expressed an interest in testing the technology at a demonstration stand and so was included in the kit recipient list to provide a different angle on the kits usage.

3.19 Stakeholders

A team of stakeholders (table 2), with practices directly related to the research, was used to assist with the research. Outlined below are the roles of the stakeholders, the site that they work within and the activities that they were involved in as part of the research. The stakeholder are divided into **representational** stakeholders and **central user** stakeholders (further covered in section 3.23). The latter is defined as the central users that use the technology directly in practice, and the former as those that represent them and are the facilitators of the music technology in use. The split reflects the focus of the research to aid the facilitators of music-making activities in order to help those they facilitate to access music-making.

Representational Stakeholders	**Code**	**Research Site**	**Activity**
Industrial Mentor	IM	School A	Meetings/group meeting/sessions
Class Teacher/Head of Music	CT	School A	Group meetings/Sessions

Assistant Head Teacher	AHT	School A	Group meetings
Digital Media and Sensory Support Technician	DMSST	School A	Group meetings
Music Therapist	MTA	School A	Group meetings
Digital Music Technician	DMTB	School B	Meetings
Director of Music	DoMB	School B	Meetings
Musician	MC	School C	Meetings/session observations
Music Technologist	MTC	School C	Meetings/one-to-one sessions
Music Therapist	MTDC	Day Centre	Meetings/session observations
Community Musician	CMDC	Day Centre	Meetings/session observations
Central User Stakeholders	**Code**	**Research Site**	**Activity**
Seven Children and Young People	n/a	School A	Group sessions using commercial technology
Child One	CO	School A	Using bespoke technology within a group session
Child Two	CT	School A	Using bespoke technology within a group Sessions

Table 2 - Stakeholders, Sites, and Involvement

3.20 Action Research

This section will give an overview of action research (AR), the chosen methodological paradigm for this research. Reviewed are: the AR process; values, criticisms, and trustworthiness of AR; AR in HCI; and models and cycles of AR; before a conclusion on AR is presented. AR is described with links to relevant literature, a brief history is provided, and the tenets and components that make research action research will be presented.

AR differs from other research methods because of its focus on problem-solving, change and improvement by using collaborative and integrative approaches to the research. AR sees participants as co-researchers aiming to create a democratic atmosphere allowing for all aspects of the research to be considered by a team. The team is created from stakeholders in the research, anybody who that research could affect, or anyone who can contribute expert opinion to the research problem. It is an overarching framework that allows for the use of other quantitative and qualitative data collection methods within it. Rather than a methodology it is an ‘orientation to inquiry’ (Reason and Bradbury 2008, p.1) that allows for human flourishing through people working together to address problems that are key within their community (Reason and Bradbury 2008). This approach demands flexibility and responsiveness to adapt the research agenda and methods as the project unfolds (Hayes 2011), something that has been important within this research, when dealing with delicate situations, sites and users.

Action research is carried out in a participatory way in collaboration with community partners and stakeholders who have a vested interest in the research output. Whilst the definition of AR varies according the level of emphasis put onto empirical and logical problem solving (Reason and Bradbury 2008) there are core values and principles that identify research as AR and offer guidance for the conducting of this type of social enquiry (Hayes 2011). AR has at least three common features (Gray 2009, p.313): the participants are co-researchers (Burian et al. 2010) engaged in a democratic partnership with the researcher; the research is ‘seen as an agent of change (Gray 2009, p.313); and there is a direct relationship with the co-researcher participants which leads to data.

Reason and Bradburys SAGE handbook of AR (2008) follow this working definition;

> *‘Action research is a participatory process concerned with developing practical knowing in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solution to issues of pressing concern to people, and more general the flourishing of individual persons and their communities’* (p.4).

In the case of this research, the pursuit was providing access to music-making where traditional musical instruments were not usable or appropriate, and the practical knowledge was found in both the developmental process, and the final technology toolkit and the tools contained within it.

The term action research was first coined by Lewin in 1946 (Gray 2009) stemming from the work of the pragmatists, combining theory based and practical problems with a view of social change. While knowledge creation and experimentation were still valued Lewin believed that it was important to conduct them within and social framework and natural settings as part of a holistic look at the subject at hand (ibid). According to Gray there is no unified theory or definite approach however it is recognised that action research emphasises 'raising awareness, empowerment, and collaboration' (ibid, p.313). Fundamentally AR is about conducting research *with* people not *about* them. Reason and Bradbury's description of Action Research can be expanded below:

- 'A set of practices that respond to peoples' desire to act creatively in the face of practical and often pressing issues in their lives in organisations and communities' (Reason and Bradbury 2008, p.3):

This allows for research to be sculpted around the situation at hand. The flexibility that AR offers the ability to respond to the situation and issues at hand whilst still aiming for the developments of knowledge and solutions. This is a commonly seen practice in other areas of technological developments such in information systems and software developments where iterative loops of developments allow for issues to be cycled over and best solutions to be developed.

- Engagement with people in a collaborative relationship, opening up communicative spaces in which dialogue and developments can flourish:

AR allows co-researchers to bring to the table their values and expertise without prescriptive research agendas which can then lead to a more holistic view of the problems face from each individual perspective. A key aspect of this is creating effective communicative spaces that facilitate communication by developing relationships that are harmonious and effective to the attainment of group or organisational goals (Stringer 2007). Within any space where multidisciplinary teams get together there is potential for the communication to be jeopardised when 'people feel that the manner of communication is inappropriate' (ibid, p.31). The notion of communicative spaces is based Jurgen Habermas's (1971) ideal speech situation with four fundamental conditions for communicating effectively:

- '*Understanding:* The receiver can understand what is being communicated.
-*Truth:* The information is accurate and is not a fabrication.

-*Sincerity:* The communicator is sincere in his or her attempts to communicate and has no hidden agendas.

-*Appropriateness:* The manner, style, and form of communication are appropriate to the people, the setting, and the activity' (Stringer 2007, p.30).

Creating effective communicative spaces meant that a variety of multidisciplinary stakeholders could come together and communicate about an issue of importance. A good communicative space provides an atmosphere that allows everyone's voice to be heard in a democratic fashion. This means that problems, and critiques, as well as general information can be shared and worked on from many different viewpoints at once. Problems can be rapidly discussed through dialogue between all involved in the research as the co-researcher team. Effective facilitation is key to create spaces that allow for everyone to feel comfortable in communicating.

- Draws on many ways of knowing, both in the evidence that is generated in inquiry, and its expression in diverse forms of presentation as learning is shared with wider audiences

As AR draws on collaborative and multidisciplinary teams, there is the need to gather data that is suitable for different stakeholders and then share this information between the stakeholders that are involved. Three types of writing are widely used within AR:

'- reports for the local group

- scholarly works for research community closely aligned with community partners

- scholarly work for the research facilitators and research community (Hayes 2011, p.11).'

Each stakeholder may have different approaches of gathering, utilising, and disseminating information within their practice and these can be used as part of the process, providing that everyone can understand each other's approaches.

- Value orientated, seeking to address issues of significance concerning the flourishing of human persons, their communities and the wider ecology in stakeholders participate:

This is a key aspect of this research. The aim is ultimately to add value to the lives of those involved in the research, by providing tools that can then reach further into the community and beyond. It is hoped that what has been created will have a legacy value by being able to be used in other situations and therefore be useful to the community and the wider ecology of practice. This can be achieved through the work of the stakeholder practitioners that utilise the technology, the children and young people that use the technology, and those who recreate the technology using online resources made available through this research.

- A living, emergent process that cannot be pre-determined but changes and develops as those engaged deepen their understanding of the issues to be addressed, and develop their capacity as co-inquirers both individually and collectively' (Reason and Bradbury 2008, p.4).

Using AR has meant that this research has followed the direction of the stakeholders. Eschewing long-term planning, the solidifying of aims and objectives, and locked down timescales in favour of flexibility to move with the needs of the research and as understanding and knowledge revealed themselves. This has been a key aspect that has allowed issues and development to be addressed in terms of the stakeholders, with the aim of the stakeholder ultimately having control of the research as it develops. Through this it was felt that the technology would stand a better chance at being adopted and being used after the researcher left.

This meant beginning with fuzzy 'tentative aims'. Dick (2001) documented this initial 'fuzziness' in terms of fuzzy questions and fuzzy methodology gradually clarify over the course of the research as a convergent process. Although when building or facilitating a collaborative approach to improvement, a strong recommendation for success might be to have clear goals from the outset, this research developed and utilised tentative aims from the outset – as a mechanism to stimulate inquiry. Activities were conducted and the research path was taken out of discussion with the stakeholders and throughout the cycles. This moved with the needs of the research at the time. Aims and objectives for the research were subsequently developed or modified by the stakeholders as the project began to evolve through the action research process and indeed did clarify and solidify as presented within this thesis.

3.20.1 The Action Research Process

The following section gives an overview of the process that AR follows, how AR fits this research, some criticisms of AR, and the frameworks that can be formed within AR. This will help to provide a clearer picture of how the research took place by tying into the fundamental ethos of AR.

The process of AR follows a spiral approach with distinct phases of planning, action and reflection. There are various models for the AR process such as Stringers model (2007) which shows at least three cycles of act, look, and think. Lewin's original model (1948) includes fact finding, planning, action, evaluation, and amendment. Kemmis and Mactaggart's (2005) model consists of plan, act and observe, and reflect. Another model is Piggot-Irvine's (2006) that shows each distinct cycle of plan, act, and reflect, as well as a progression through time reflected in the content of the cycles. These repeated cycles allow for learning to occur continuously until convergence on a conclusion (Dick 2001), in the case of this research – a technical solution. All models of AR feature a spiralling process for fact finding, planning, and identifying issues, then taking action and evaluating and that action before moving through the spiral again iteratively. This cyclical approach mirrors a common method in other areas of human computer interaction (HCI) (Hayes 2011) where iterations of cycles are used to challenge and interpret earlier ones, allowing for both refining of question and method, and deciding on next steps (Dick 2001) to be worked over. AR within human computer interaction (HCI) has be used to address human issues through computing solutions (Hayes 2011).

The model used for this research (Figure 9) shows cycles for analysis of the current situation, tool design as two cycles to emphasise how developments inform each other, and the integration of these tools into a cohesive kit – the MAMI Tech Toolkit. Each cycle contains within it phases of planning, acting, and reflecting. Tool design is featured twice as both feedback and feedforward were used to cyclically iterate technical development of the tools as the research progressed.

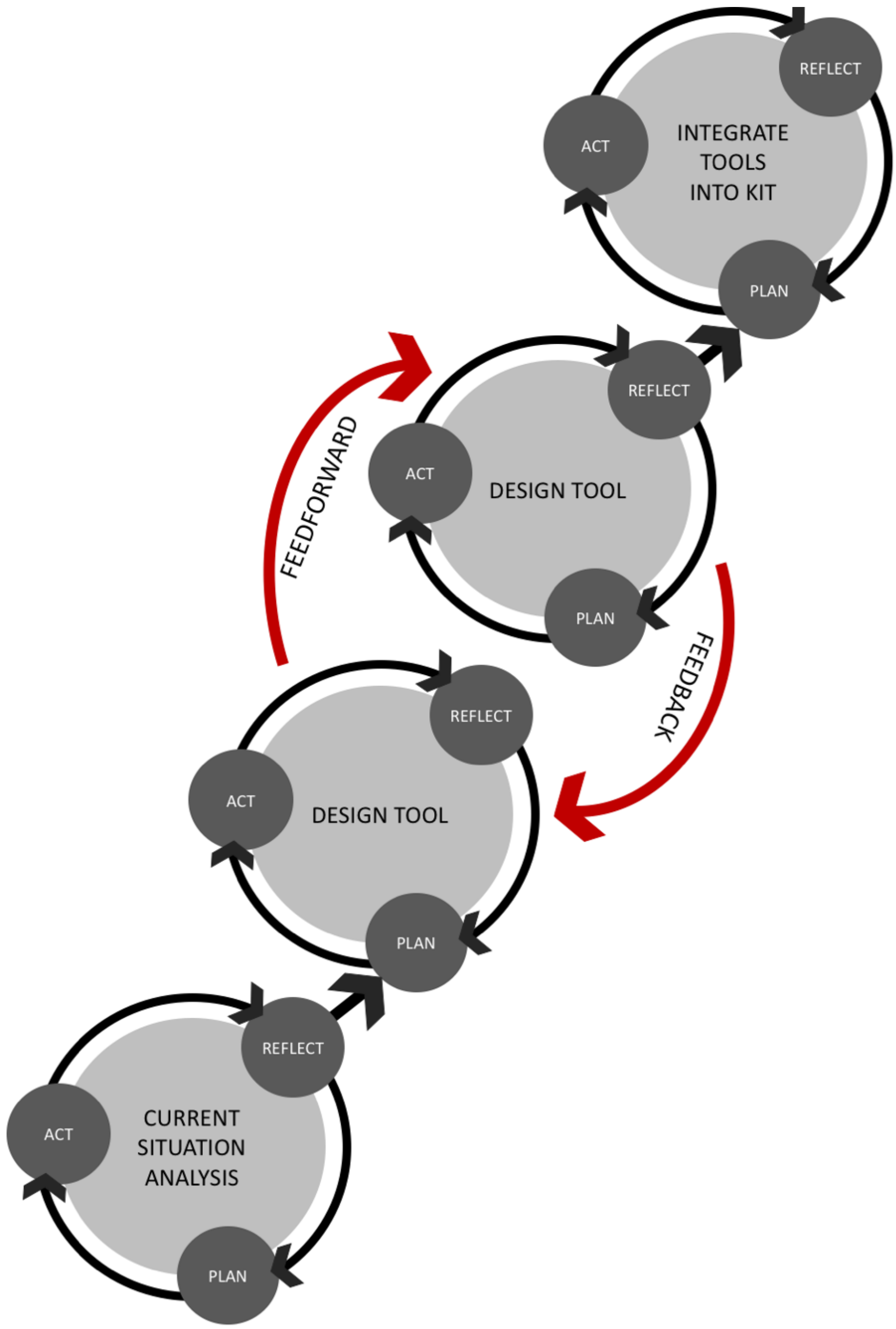

Figure 7 - Action Research Model adapted from Piggot-Irvine (2006)

Within each cycle, the phases of plan, act, and reflect, can be guided by the stakeholders to enable issues to be discussed, action taken, and reflections carried out in a manner that fits with the stakeholders and their needs. Although the cycles for this research are separated into distinct cycles, there was substantial overlap between cycles with an element of feedback and feedforward that informed the iterative development of the tools as reflected in the red arrows (see Figure 7).

3.20.2 Action Research model and Cycles

The model followed is shown in figure 7. The three phases of planning, acting and reflecting are repeated within each cycle. In the current situational analysis planning stage, stakeholders were selected by the industrial sponsor and researcher to participate in the research, a chosen intervention was prepared that was mutually acceptable to researcher and stakeholders (the commercial technology used in the school sessions). In the action stage the research activity is conducted, stakeholders are interviewed, and the data are summarized and analysed. In the reflection stage 'researchers and practitioners reflect on and articulate lessons learned and identify opportunities for improvement for subsequent research cycles' (Deluca et al. 2008, p.54). Reflection on both techniques and methods used occur to allow contributions to knowledge to begin to form. This ended the first cycle of AR which then fed into the next cycle planning stage. The basic steps are then germane to further cycles with the outcomes of designing the tools, and integration of these into a final MAMI Tech Toolkit forming as the goal of the final cycle.

3.20.3 Action Research Values

AR is a methodology that is about making a change and adding value to society (Hayes 2011). It goes beyond finding out knowledge regarding a situation in an attempt to create a positive imprint that will be left after the research is finished. Rather than following a position of hard positivist science with its need to have a testable hypothesis, which can be generalised out as a stance on a situation or phenomena, AR offers the chance to incorporate elements of qualitative and quantitative methods to provide an improvement in current provision, there is no final solution only continual movement towards improved solutions and knowledge. 'AR values responsiveness over replicability' (Dick 2001, p.45). AR is about looking at a problem within a community and working with that community to create better solutions than already exist within it (Hayes 2011, p.7). AR, according to Hayes, uses; 'action as a means for developing knowledge with researcher and participants as an explicit part of this, where researchers recognise their role and effect, and an emphasis on understanding the local context' (ibid, p.7).

It was the view of this research that the stakeholders working on the ground were the best placed to know the requirements of technology, and as such guided the creation and use of the tools. AR allows for ‘teamwork, continuous improvement, empowerment, and problem solving at a practical level (Burian et al. 2010 p.45)’ using a pragmatic process-orientated methodology with a flexible approach. The action researcher is directly involved with the research and the participants become co-researchers. The researcher is not a contaminant or bias in the system but another member of the team contributing, facilitating, and adding their own values which are explicitly integrated and recognised as not being value neutral. This means that the researcher has to relinquish some control over the research to allow the co-researchers (stakeholders) control in a democratic process.

The partnership of researcher and stakeholders is at the centre of the process and affects all aspects of data collection, analysis of data, how the data is reported and what change is implemented as well as validation of any findings. Any decision or discussions that are undertaken and any data that is collected or solutions designed has to be done with the stakeholder team as core components in the decisions. This is achieved by constant interaction with stakeholders and through planning research activities with them. The use of AR particularly suited the industry based engineering doctorate through the researcher being embedded within the research site. The stakeholder team must effectively validate everything that occurs within the research to ensure that the research is truly democratic, in this manner key findings from research activities were delivered to the stakeholders both to reflect on the action and to plan for the next action. Determining the methods used for data collection would be a democratic process that would use the researcher’s knowledge, in conjunction with past experience, as well as continued collaboration with stakeholders to assess what would work in practice, as it may not be realistic to expect stakeholders to know about research methods. The researcher would respond to the needs of the research and the knowledge of the stakeholders in order to fill any gaps that may exist between theory and practice or between practice and research. Using AR with underpinnings in symbolic interactionism allows for interdisciplinary work by opening up dialogue between stakeholders thus enabling learning from each other’s practice, which can then be used for ‘transforming both theory and practice’ (Kemmis and Mactaggart 2005, p.283).

3.20.4 Some criticisms of AR

Criticisms of AR often centre around ensuring rigour and trustworthiness. Rigour, when considered as rigorous study of phenomena, can be enhanced by ‘analysing data and theory from a variety of sources, and by using multiple methods, including measurement’

(Deluca et al. 2008, p.53). Rigour intertwines with relevance as synergistic objectives requiring critical reflection of the research setting and its social and historical background (ibid, p.53) to forefront issues of importance to both the researcher and the stakeholders. Within this dialectic there is a trade-off between 'tightness of control and richness of reality' (ibid p.54) with a goal of plausible and consumable knowledge that is practically actionably and socially situated (ibid). Deluca, et al (2008) discuss eight difficulties, misunderstanding, and criticism surrounding action research. These are:

- Lack of recognition due to ARs 'newness' to mainstream research, which historically has tended toward positivism. Suggesting that research conducted with a post-positivist perspective, featuring an expanded acceptance of 'falsifiable, common-sense hypotheses (not null hypotheses) and qualitative methods' (ibid, p.50), could lead to AR being more readily accepted into the mainstream.
- The misconception that AR is not valid due to not being conducted 'behind the glass' (ibid, p.50) in controlled settings. AR is conducted in concert with practitioners in a naturalistic setting. This naturalistic setting offers a strength to satisfy both conceptual and practical goals and in effect a practical setting can be considered a *natural laboratory*.
- 'Lack of consistent research paradigm vocabulary' (ibid, p.50) can leave AR vulnerable in terms of stating the mechanisms of AR that were used. This can be mediated by clear definitions and descriptions of the application of AR given alongside a 'consistent and deliberate description of the research paradigm employed' (ibid, p.50) to alleviate misunderstanding.
- Difficulty of presentation of the research due to multiple forms of AR. In describing the research paradigm used, the form of AR used should be made explicit. Forms of AR include key characteristics and assumptions [that] are identified according to the process model (iterative, reflective or linear), structure (rigorous or fluid), researcher involvement (collaborative, facilitative or experimental) and primary goals [organizational development, system design, generation of (scientific) knowledge or training]' (Davison et al. 2004, p.68).
- Theoretical basis is often not evident. Accordingly, an explicit theoretical component should be presented to allow for presentation of knowledge and results with regard to informing the wider research-based audience and connection to the scientific field.

- Issues of rigour surrounding qualitative methods - that can be addressed by applying systematic approaches to collecting and processing qualitative data, and outlining these as used.
- Large amounts of primary qualitative data amassed that are multiplied by cycle leading to unwieldy lengths of written accounts of AR. This required the careful and systematic processing, and transparency of process to allow authentic and genuine data to be presented that was not reductive nor overwhelming.
- Lack of effective dissemination of AR results. Guidelines for engaging AR studies in design, process, presentation, and criteria for evaluation should be utilised as a framework to present AR to the wider community. AR is typically reported as a series of cycles (as is the case for this research), by distinct research sites, and/or based on chronology (as is also the case for this research in that each cycle began after the start of the previous – although overlap did occur).

3.20.5 Trustworthiness

In traditional positivist scientific research there is a strong desire for generalisability as a recognised outcome. Although the debate 'still rages about generalisability' (Hayes 2011, p.2) there is a recognition that feasible solutions developed directly with people, and for the problems they address, can provide valuable contributions to knowledge. In the last decade there has been growth within the HCI community of 'civically engaged research (Hayes 2011, p.1)' and as such while AR seeks to improve the professional practice of both the researcher and those who take part, by being civically engaged, there is no claim to generalisability.

Within post-positivistic paradigms there is a focus on demonstrating transferability through trustworthiness and rigour as an appropriate alternative to the generalisability that positivist research usually requires. 'Rigour in action research is based on checks to ensure that the outcomes of the research are trustworthy (Stringer 2007, p.57)'. This trustworthiness Stringer (2007) suggests comes from rigorously establishing validity of the information and analysis emerging from the process of the research. Contributions to rigor can be made by cyclical research (Deluca et al. 2008) by using similar and tested tools and consistent protocol in each cycle for reliability and using group level generalizing for internal validity. Use of consistent data and units in each AR cycle aids replication and external validity' (Deluca et al. 2008, p.54). Additional checks against bias included seeking confirmatory and disconfirmatory evidence through successive iterations alongside utilising problem solving as part of learning. Construct validity is gained by multiple sources of evidence and from multiple cycles (Deluca et al. 2008).

Lincoln and Guba (1985, p.300) suggest that this trustworthiness can be assessed through the following four distinct but related concepts of credibility, transferability, dependability, and confirmability. Lincoln and Guba's guidelines (1985) can be explored in relation to this research:

- Credibility enhances the plausibility and integrity of the study, this includes prolonged engagement, persistent observation, triangulation, member-checking, participant debriefing, diverse case analysis, and referential adequacy, these are expanded below with relation to the current research.

The research took place over the course of four years through prolonged engagement with several stakeholders in several sites, and through several AR cycles. This allowed for extended opportunities to explore any issues arising from the stakeholders or practices they were involved in. Any observations were done so persistently over time, and in context, to allow for exploration of how actions and events change. The researcher spent weekly sessions visiting the industrial sponsor school over the course of several months, as well as visits to other sites, to carry out observation and discuss the research with the stakeholders. Diverse sources were used for triangulation in terms of use of various stakeholders, sites, and activities as well as different methods of data collection (observations of stakeholders as practitioners as well as activities with stakeholders, interviews with stakeholders in groups and one-to-one). In this manner method, sources, analysis, and theory triangulations were used. A member-checking structure has meant that stakeholders were involved with any data analysis as reports produced after the various activities within the research were reviewed by them. This was to ensure that their perspectives and experiences were represented accurately and allow them to review any issues. Debriefing was used throughout the cycles and activities within them to allow for stakeholders to express feelings and responses to events. Interactions with practitioners and children and young people as stakeholders were utilised within this research, with the intention to capture the diversity of the subject. The final credibility criteria of referential adequacy were used to identify material which did not form part of the analysis at the time of technological development but were later consulted to support development of knowledge or enrich meanings.

- Transferability- the possibility of applying the outcomes of the study to other contexts

Whilst generalisability is not the aim of AR there is the possibility of transferability. This can happen only when the description of activities, contexts, and events are detailed enough to enable others to see if there is potential transferability to their context. To this end an effort has been made to outline the activities conducted, the research sites used, the stakeholders and their contributions, and the events that have occurred to create a paper audit trail showing an authentic outline of the research process. This has also extended to the data analysis and transformation of this analysis into knowledge, by explicitly mapping out connection of components and how they interlock and inform each other, in an attempt to show the research as it has occurred within its contextual situated surrounding it.

- Dependability- research procedures that are clearly defined, describe changes in context of the research, and are open to scrutiny

Detailed description of procedures used during the research in terms of methods of data collection, analysis, and synthesis are clearly defined. Using an action research methodology meant that any changes that occurred in the context of the research were discussed with the stakeholders, and thus have been described within the written work pertaining to the research. Limitations of procedures used have been made explicit in the hope of demonstrating that a systematic review has been followed when using any method, to aid in trust in the outcomes of the research, and the process that occurred to achieve the outcome.

- Confirmability- evidence that the procedures described actually took place

An audit trail is available which contains information on any data collected, any methods used, and any artefacts created during the research. This is an attempt to allow for the trustworthiness of the research to be confirmed or corroborated by others if needed. AR produces a 'documentation trail for organisational learning and adds[ing] to knowledge in the field' (Burian et al. 2010, p.48) which can be important consideration when an aim of this research is to create resources to propagate knowledge further.

3.20.6 Waterman, Tillen, Dickson, and De Koning Analysis

Waterman, Tillen, Dickson, and De Koning (2001) lay out 20 questions as guidance for assessing action research projects. Presented below are the questions with regard to assessment of this action research project.

1. Is there a clear statement of the aims and objectives of each stage of the research?

Research aims were developed at the onset of the research, these were then used to form objectives which in turn dictated the methods that should be taken to fulfil the aims. The research aims centred on music technology in its current state, exploring issues with music technology, making new technology, efficacy of the new technology and propagation of the newly created technology. Within each cycle different aspects of the research aims and objectives were addressed.

2. Was the action research relevant to practitioners and/or users?

The research addressed local issues to practitioners and central users concerning the access to music as a valuable resource. In contributing to the understanding of these issues and by being situated and immersed in the practical use of music technology within the settings of the research, the research remained relevant. The situated nature of the research enhanced the relevance to the experience of those participating. Ideas around further research emerged throughout the research. The research has highlighted issues around music technology that in turn has had influence on considerations around the practical use of such music technology.

3. Were the phases of the project clearly outlined?

The research began with initial analysis of the situation and three further cycles followed on in an emergent fashion. Problems were identified, plans were made, and action taken before evaluation was used to then move forward into following cycles. Each cycle influenced the process and progress of the following cycles.

4. Were the participants and stakeholders clearly described and justified?

Stakeholders within the research were a mix of children and young people and practitioners. The selection process for each of the stakeholders has been outlined and their connection to the research has been made explicit. The justification of the stakeholders is evident in the explanation of how those stakeholders came to be part of the research and in what they contributed to it.

5. Was consideration given to the local context while implementing change?

The local context was central to this research. The research sought to select a context that was relevant to the development of music technology and to those that would benefit from such development. Local values, structures, and power relationships within the context were critically examined in order to navigate through the research. There was thorough discussion of who would be affected by the research and in what way in order to ensure success.

6. Was the relationship between researchers and participants adequately considered?

The level of participation is outlined for each stakeholder and the extent of this participation is made explicit. This includes the evolution of the relationships over the course of the research. The stakeholders were encouraged to critically examine what they would require of music technology as well as how their practice could utilise music technology. In confronting their potential biases and influences the stakeholders produced data which was utilised to ensure the creation of music technology that was successful and thus the project would be successful.

7. Was the project managed appropriately?

Key people were approached when appropriate dependent on the needs of the research. The skills they had, and what was required to engage with the project, were intertwined and both affected each other. Although a rigid plan was not set, the plan did evolve organically with the skills, resources, and time available. This plan was flexible to the stakeholders needs and the resources available and was adjusted throughout. There was clear discussion of the actions taken and the methods used to evaluate these.

8. Were ethical issues encountered and how were they dealt with?

There was consideration given to the stakeholders of the research in how the research process would affect them and in terms of safeguarding. Ethical issues were identified and monitored throughout and actions taken to ensure an ethical process was followed (see section 3.22). When considering professional values, the approach of 'meeting the stakeholders where they were' was used in order to explore and realise how these were used in practice. Confidentiality and informed consent were addressed by ensuring that the relevant policies and procedures were followed as laid out by the Bournemouth University, the Bournemouth University ethics panel, and the policies and procedures of each research site.

9. Was the study adequately funded/supported?

The project was supported by a generous package through the Centre for Digital Entertainment at Bournemouth University. Costs and resources required were assessed throughout and the final outcomes of the project were centred around supplying as much music technology to the participating stakeholders as possible. There was no identified conflicts of interest.

10. Was the length and timetable of the project realistic?

The timetable of the project was flexible and moved organically with the development. This however was locked into school timetable and therefore naturally had constraints on when work could progress. As much forethinking was used as was practicable to predict what might be achieved and by when, with 'stretch' goals added, or explanations of why goals were not achieved as part of the reflexive process of this research.

11. Were data collected in a way that addressed the research issue?

Tentative aims were created at the start of the research and then objectives were developed around these. Data collection was guided by these aims and objectives and the advantages and disadvantages to the various methods used were discussed. There was some systematic elements to the data collection however this could have been more rigorous. It was at times difficult to elucidate why some data was collected as an emergent strategy was used so as to open up the research to an organic inductive process. However, all methods of data collection and analysis used were outlined and systematic record keeping was used. Any methods that were modified, any issues with methods, and any new methods have been described within this thesis.

12. Were steps taken to promote the rigour of the findings?

Differing perspectives were sought from a variety of stakeholders. Triangulation of methods was used through collecting data in a variety of ways as outlined in section (3.21.1). Theoretical triangulation was used to analyse the data through different lenses in order to produce new knowledge. Key findings were fed back to participants throughout the research and in a manner that was digestible to them. Consultation with stakeholders was performed in order to ascertain these methods and to give them opportunity to give feedback. This feedback was then used to inform both how the research was being carried out as well as to ensure the aims and objectives were still relevant and augmenting them if not and this was performed in a cyclical manner. A reflexive account is evident within this thesis and the use of this reflexivity to inform the research is documented throughout each cycle, as well as when reflecting on the research as a whole.

13. Were data analyses sufficiently rigorous?

There was a systematic analysis of the data that is described in section (3.21.2). The data selection process is described in order to make explicit the selectivity that was used. Data is discussed in terms of how it was used to inform the research activity within this thesis and the knowledge generated. Themes and considerations are derived from the data and the connections between the two are made explicit where necessary. Where there were points of tension, these were also discussed and were necessary taken back to the stakeholders and contradicting arguments are presented for consideration.

14. Was the study design flexible and responsive?

Findings were used to generate plans and ideas for change in a flexible and responsive way to the needs of the stakeholders. The context of use of what was developed through the research was considered at all stages and the approach was adapted to take into account these circumstances. If plans did change then justifications were offered as to why these changes occurred.

15. Are there clear statements of the findings and outcomes of each phase of the study?

The finding are presented as distinct cycles and the activities of each phase of each cycle is outlined in order to make them explicit and easy to understand. What occurred with whom and the outcomes of this are presented, both as thematic analysis and as a summary of technical developments. The findings are critically analysed per cycle and the research is critically analysed as a whole. There are discussion of the personal and practical developments that occur throughout each cycles in the sections entitled 'moving forward' for each cycle in chapter four as well as an overarching discussion of personal and practical development of the research as a whole.

16. Do the researchers link the data that are presented to their own commentary and interpretation?

There is discussion of the stakeholders reflections on both the activities of the research and of the products of these activities. The data is presented and it is indicated when interpretation is applied in order to analyse the data. When interpretation of the data has occurred there has been critical examination of the researchers/stakeholders role in this interpretation and evidence is provided to support the conclusions of these interpretations.

17. Is the connection with an existing body of knowledge made clear?

This research produces a range of outcomes that connect with existing bodies of knowledge and the links between these were made clear. These came in the form of methodological contributions, contribution to the theory around the creation of music technology as well as contribution to knowledge around the practical application and practical development of music technology. Theoretical and ideological insights are offered in the above areas as well as about action research in a more holistic manner considering the research as a whole and its relation to other action research.

18. Is there discussion of the extent to which aims and objectives were achieved at each stage?

The aims and objectives that were being addressed were discussed per cycle with an overarching discussion of the aims and objectives and how the research on the whole addressed them in section 6.2 of the thesis to outline how the action research objectives were met. The technical, theoretical, practical and methodological successes and failures of the cycles, and the research as a whole, were analysed both to assess what happened, and also to generate the new knowledge as a contributary outcome of the research.

19. Are the findings of the study transferable?

Many of the findings are transferrable to other settings. Fields that involve development of new musical interfaces and tools for interaction may benefit from some of the findings. Practitioners of music therapy may benefit from some of the findings. Action researchers may benefit from some of the methodological findings. The context of the study is clearly described with information about the research sites, stakeholders, and background and contextual information given to provide a clear picture of the holistic context of the research.

20. Have the authors articulated the criteria upon which their own work is to be read/judged?

The scope of the research is outlined and the key fields that are interconnected within the research are provided. A struggle occurred in the presentation of this research when considering how to pitch the information. The thesis aimed to detail authentically what happened throughout the research, detail technical developments, and present new knowledge but also to reflect on the whole research process and the process of using action research. Specified within the thesis are the underpinning perspectives and values that guided the research and these can be used to aid in interpretation. There are offerings for practitioners who actively use music, creators of new technology, and action researchers. The thesis also had to consider the stakeholders as readers and as such adjustments were made to account for this.

3.20.7 Conclusions regarding AR

This research concerns those that are underrepresented and the tools they use to express themselves. It also concerns the acceptance of such tools by the gatekeepers and stakeholders surrounding them who must feel confident in using the tools. Such tools are often developed in isolation from the problems that they are attempting to deal which may lead to a diminished experience by those they are designed for. This can stem from: flaws within the design - i.e. they are not accessible to the target audience – which can tie into access or learning needs, or that they are not motivating; or flaws within the use of the design within the setting - i.e. they are not accessible to those facilitating use and do not consider the context of use– either by being hard to set-up, not easily integrated logistically (through size, cost, or to work within the given scenario), or not offering outcomes that are motivating to either party. AR has provided an approach that allowed development of tools that were both empowering to these underrepresented people and also to those around them, by providing unique technical solutions that were robust against some of the pitfalls of previous developments, or those created without users at the centre. These pitfalls have been explored and questioned using AR in communicative spaces that have allowed for all stakeholders contribute their views.

Having stakeholders as co-researchers means that they have involvement at every stage of the research, from conception of the issues, to collection and analysis of the data, through to designed interventions and reflection periods, all in an immersive fashion, where they can not only add to the knowledge gathered but validate it. This egalitarian approach has been used to deal with issues that are personal to participants and as such has been used in research for under-voiced groups. The research used prolonged engagement allowing for deep seated issues to be raised and the uncovering of tacit knowledge which is difficult to obtain in studies that have single focus group or interview sessions only and legitimises the use of longitudinal research such as this. AR has provided the benefit of allowing the stakeholder team to be fluid and develop by allowing the inclusion of voices as needed from a wider contingent of people (not just those at the school A). The input from these has then fed back into the development of tools, ensuring that the situation is viewed from a multidisciplinary angle.

AR has provided reflexivity (Scrivener 2000) in its iterative cyclical form that has helped when responding to users with complex needs and their requirements, allowing for response to issues that could not be foreseen, and in ways that make sense for the stakeholders. Dick (1997b) argues that any research methodology faces threats to validity when participation and flexibility are needed to respond to complex situations, however that AR can better meet threats in those circumstances than more conventional research methodologies (ibid).

AR follows a systematic collaborative approach that can be used to satisfy the need for scientific rigour and promote social change that is sustainable (Hayes 2011). The judgement of quality within AR comes from the ability to form a workable solution for some real-life problem (ibid, p.5) that can then be used beyond the study.

3.21 Methods

Methods used for data collection have taken place in the field or in connection with the field (email etc.), in naturalistic settings, and out of the field (personal reflective data) to both gather information about technology as it stands, and to inform the design process of the toolkit. These have included observations, interviews, and focus groups. Data analysis was conducted in the form of theoretical sampling and thematic analysis. Throughout the research 'transcript summaries' (Saunders et al. 2015, p.576) were produced comprising of collected data compressed into key points. These summaries were then fed back to the stakeholders after each group meeting or activity. Self-memos were also used to record ideas about aspects of the research as they occurred. A research notebook was maintained to record activities chronologically, this was used to record reflective and descriptive data. Electronic notebook tool Evernote was used to create, collate, and store non-confidential data, and GitHub was used to store technical development data and code. The data from these summaries, memos, and notebook was used to guide the direction of the research and contribute to technological developments.

3.21.1 Data Collection

The data collection process involved stakeholder meetings with multiple stakeholders, individual discussions with key stakeholders, and practical sessions with the children and young people using technology. The data collection methods used for this research are reviewed in table 3 (page 99). This table is an amalgamation of both Yins (2018) and Creswells (2014) categories of evidence sources. Yin (2018, p.114) identifies evidence from six sources that can be used to support research methodology alongside strengths and weaknesses for each. These are documentation, archival records, interviews, direct observations, participant observations, and physical artefacts. Also included are elements from Creswell's (2014) table of qualitative data collection types to further illustrate sources of data collection used within this research (as a section entitled 'options within types' (ibid, p.191) to further categorise within each broad category). This research required looking to a broad range of sources and combining them as a strength of the study. In addition to Yin's sources another four sources, which have been fundamental and significant within this research, are included in table 3. These are technical documentation, self-reflective documentations, focus groups, and audio-visual material. The technical documentation has been critical to keeping track of the development in terms of logging researcher progress, facilitating discussion with the industrial mentor, and logging of requests from stakeholders. Self-reflective documentation in the form of journals (consisting of both physical hard cover notebooks and e-resources such as Evernote and self-email), and technical notes stored in Evernote or via GitHub, enabled both in-the-moment problems to be logged and issues to be updated as resolutions occurred, as well as the locating of materials to aid in development through the use of metadata (tag searches etc). The use of GitHub also provided a transparent audit trail of technical development and a platform for propagation.

Descriptive observations were carried out with the researcher's role known, both as a participant and through complete observation (not participating). The advantages of this is 'that the researcher has first-hand experience with participant, the information can be recorded as it occurs, unusual aspects can be noticed during observation, and are useful in exploring topics that may be uncomfortable for participants to discuss' (Creswell 2014, p.191). The limitations are that 'the researcher may be seen as intrusive, private information may be reported that researcher cannot report, research may not have good attending and observing skills, certain participants (e.g. children) may present special problems in gaining rapport' (ibid, p.191). For the observations of sessions using technology with the children and young people, a plan for the session was developed with stakeholders, the session was then facilitated by the researcher and the industrial mentor alongside teaching assistants, observational field notes were taken and then analysed to provide feedback to the stakeholders of issues and successes, and to develop a plan for the next iteration.

Interviews/meetings were conducted face-to-face on a one-to-one basis, over the telephone, via email, and with focus groups (for this study labelled as group stakeholder meetings). These have been useful in allowing access to participants as needed, or when it suited them, and permitted participants to provide information as needed to clarify issues. The researcher being present in real-time meant that the line of questioning could be controlled (Creswell 2014) as issues could be explored openly and in-depth. Limitations are that the information is indirect (as it relies on what the participant tells the researcher), and that the researchers presence can bias responses, and also that people's perception and articulation can vary (Creswell 2014). For the interviews with people on a one-to-one basis there were no observational protocols followed however agendas were developed with questions and issues taken forward from the previous cycle or activity.

Focus groups can be considered a type of interview, but the strengths and weaknesses differ from other types of one-to-one interview, hence movement into its own category. Focus groups were used initially to allow communicative spaces (Bevan 2013) to be formed for the interdisciplinary coming together of relevant stakeholders, and to facilitate open discussion around what had been done previously in the setting and what was being done, and what could be done next. For the stakeholder meetings communicative spaces in the form of focus group style discussions were utilised. An agenda was given at the start of the meetings which were recorded and transcribed. Thematic analysis was performed to find key themes in the transcriptions and supporting statements from the stakeholders were allotted to these key themes. A report of these key findings was then fed back to the stakeholder team via email and discussed at the following meeting for discussion.

Technological developments have been following a rapid prototyping methodology with documentation in the form of a lab book and an online blog showing iterations of the technology development, and reasoning behind developments. Further into the project GitHub was used as a repository for the documentation of technical elements of the development and to store code.

Audio-visual material was also collected in the form of video recordings and sound recordings. The advantages of these are that they are unobtrusive (Creswell 2014), they are an opportunity to capture the activity of the participants for later review. The limitations are that interpretation can be difficult, the presence of the observer (filming or recording) may disrupt and affect responses (Creswell 2014). Videos were taken of particularly poignant use of the tools and analysed by the music therapist in school A (appendix C).

A key method used within action research was journaling, as a way to both record events, and develop reflective skills. By self-reflecting and evaluating events researchers can trace and reveal how their interpretations of events might have led to decisions (Coghlan and Brannick 2014).

Sources of data	Options within type	Strengths	Weaknesses
Documentation	Emails, Agendas, key point feedback, session structures, observational notes from sessions, interviews and stakeholder meetings	Stable, reviewable, unobtrusive, specific, broad – over time/events/settings, researcher can learn participant language and obtain their words, time convenient, represents participant reviewed data, saves transcription time (Creswell 2014)	Hard to find/maintain/access, biased selectivity, bias by author, ethical considerations, handwritten notes may need transcribing, materials may be incomplete, documents may not be accurate or authentic (Creswell 2014)
Technical Documentation	Journal of technical development (E-notebook (Evernote), GitHub)	Reviewable, contextual, ability to equip with metadata	Difficult to analyse, difficult to decipher if improperly maintained, pragmatic rather than insightful (Haskell 2016), targeted to development, may be incomplete
Interviews (participants)	Face-to-face, one-to-one, in person, telephone, email, video call.	Can target focus, insightful – providing views and explanations, contextual, people who cannot read or write are not discriminated against, 'useful for when participants cannot be directly observed'	Bias due to poor questions, response bias, poor recall leading to inaccuracies, 'reflexivity (interviewee says what interviewer wants to hear' (Yin, 2018, p.114), data collected at

		(Creswell, 2014, p.191), participants can provide historical data (Creswell 2014)	designated place not necessarily in the field/context (Creswell 2014), not all participants will be perceptive or articulate
Self-reflective documentation	Self-memos (technology development notes, notes on research and analysis) Research notebook (chronological) recording of events) E-notebook (Evernote)	Reviewable, reflective, synchronise with events, insightful, electronic documents enable ease of sharing, allow keyword search, allow versioning of development, ability to equip with metadata	Difficult to decipher if improperly maintained, bias by author, subjective, difficult to maintain unless in a unified place, need for ethical protection (electronic documents)
Focus groups	Stakeholder meetings (communicative spaces)	Group interaction, rich qualitative data, allows emergent topics, chance for interdisciplinary discussion, natural quality control between participants (Robson 2002), participants have some ownership, people who cannot read or write are not discriminated against, mutual support from other participants to support all to contribute	Harder to facilitate, personality domination, difficult to organize, time consuming to transcribe, difficult to analyse, participants may feel uncomfortable, limited amount of questions, fear/inability of all to share, domination of discussion can bias outcome, extreme views may dominate (Robson 2002), personality conflicts,

			confidentiality issues, not generalizable or representative of wider population, may not provide individual answers or may move beyond research initial focus
Direct observations	In the field sessions with technology, observing practitioners	In-the-moment, can include non-lingual, body expression, contextual, insightful into activities and behaviour, direct – don't ask but watch, real world, useful in exploring uncomfortable topics, or difficult to describe topics	Time-consuming, hard to document especially if also facilitating etc., observer bias, reflexivity (Hawthorne effect), disengagement from taking ownership (leave tech to the researcher), position of researcher linking to insider/outsider issues (see section 3.13), researcher may be seen as intrusive, information may be shared that researcher cannot report (Creswell 2012, p.191), may be hard to gain rapport (especially with children)
Physical artefacts	Technology Probes (Hutchinson et al 2003)	Insightful into technical development, reviewable, pragmatic development tool	Difficult to analyse, difficult to encapsulate, difficult to log progress and link to outcomes

			(can’t timestamp the development with the feedback), pragmatic development tool
Audio-Visual Materials	Video of sessions, video of practitioner reviewing sessions, photographs, sounds	Reviewable, contextual, real world, may be unobtrusive, direct sharing of participant reality (Creswell 2014)	Time consuming to analyse, elements could be missed/hard to decipher, ethical issues could arise in capturing non-participants, may not be accessible, presence of equipment may disrupt or affect responses

Table 3 - Sources of Data Strengths and Weaknesses

In making field notes there have been nine dimensions of descriptive observation used, these were: ‘space, actors, activities, objects, acts, events, time, goals, and feelings’ (Robson 2002, p.320). Where possible recording of data were made on the spot, these were then used to spark memories after the fact. In transcribing field notes, further information was included alongside the running descriptions including recalls of forgotten material, interpretive ideas, personal impressions or findings, reminders to look for other or further information (Robson 2002).

3.21.2 Data analysis

Thematic analysis was used to analyse the data gathered throughout the research using a process as described by Saunders et al (2015, p.580). Data was coded manually on an activity by activity basis, with codes being grouped into themes. Both inductive and deductive methods were using during coding using a data-driven approach. Codes were assigned by the researcher based on describing the unit of data, themes were then grouped by describing the overall subject of the individual codes to allow the data to be presented to stakeholders in a digestible manner. For the final write-up, constant comparison was used to further analyse the coded and themed data in the manner of axial coding in order to finalise the themes presented.

The data analysed throughout the process of the development of the kit was performed to extract information to apply to the design of the MAMI Tech Toolkit. The analysis of the data as performed for the writing of the thesis was done with the mind-set of adding a contribution to knowledge around the use of such technologies in practice and in connecting the practical development of technology with what the stakeholders wanted.

In analysing the data, a slant has been put on the research outputs towards the designers of new interfaces for musical expression or DMIs, and as such contributions to knowledge around this area are offered in the design considerations (section 4.4.10). The representation of data as technical development, and practical and contextual knowledge is in line with this third wave HCI in terms of grounding the technology development within its holistic context and web of use.

3.22 Ethical considerations

Ethical approval has been granted by the ethics panel at Bournemouth University (appendix D). To satisfy Bournemouth University ethics panel requirements all activities were to be assessed on a work package basis, meaning for each significant stage in the research a new ethics pack was created to cover those activities or individuals involved. Each ethics pack was signed off by Ann Bevan (supervisor) or submitted for further approval from the panel depending on the nature of the research involved. Each of the research sites ethics policies were also remained under throughout the research. As part of the ethics pack all stakeholders were given a participant information form and a participant agreement form which detailed information of the study, the data that would be collected and how it would be used. The information form illustrated the aims of the research, the ways in which the participants were helping, as well as information regarding contacting the researcher. Since the user group is a vulnerable one all laws and legislation pertaining to working with vulnerable adults and children were followed and procedures and policies were continually reviewed to ensure compliance. Where permission could not be obtained from the stakeholders directly (as was the case for some of the children and young people involved) the parents or legal guardians of any children and young people wishing to partake in the research was sought. The inclusion criteria were discussed with the stakeholders for selecting children and young people as participants and recipients of any interventions, and included children aged between 5-19 of differing abilities. The process of selecting children and young people to take part involved teachers being contacted about students they felt would benefit from using music technology to partake in the sessions, which comes with it inherent biases in that not everyone had the opportunity to take part, and that the selection criteria was made by the teachers involved, who were often not involved from that point onward due to the constraints of their work.

For participating stakeholders a participant information form and participant agreement form was given or in the case of the children and young people this was sent out to the parents via their teacher. Within these forms there was explicit guidance as to what the footage was used for in terms of analysis or for presentation. Data related to individuals was anonymized as much as possible, full names were shorted to first letters within written work that was personal to the researcher. The researchers university email address was used for any correspondence that contained information about the children and young people. Data was stored behind a password secured university digital storage area or in a password protected Dropbox when not sensitive/personal to stakeholders. When videoing the stakeholders care was taken when framing the shots and the teachers permission was always sought as to identify those who were not allowed to be filmed.

The World Medical Association (2013) released the Declaration of Helsinki in order to provide ethical principles for medical research involving human subjects. This research aligns with the 37 principles of this declaration (minus the principle around the use of placebo) by holding the health and best interests of the stakeholders as the first consideration of the research. The research has been a response to the needs of vulnerable groups and individuals in the hopes that these groups and individuals then benefit from the knowledge, practices, and interventions utilised throughout the research.

The NSPCC Research Ethics Committee (NSPCC 2020) provide a research ethics guide that sets out five principles around ethical policy. This guide was used to ensure that this research adequately followed the guidance offered with regard to applying these principles in practice. This guidance was particularly useful in consideration of gatekeepers as intermediaries between the users of the technology and the researcher.

Every effort was made to ensure that the stakeholders were made comfortable and that as far as was possible the activities carried out maintained as much normalcy as was possible in terms of the physical spaces used and those that were present within the spaces. The technology when used had the aim of blending in with the proceeding and that the proceedings were commonplace ones – such as being used as part of an ongoing series of sessions.

3.23 Stakeholder Involvement in Action Research

‘Action Research works on the assumption that all stakeholders - those whose lives are affected by the problem under study - should be engaged in the process of investigation. Stakeholders participate in a process of rigorous inquiry, acquiring information (collecting data) and reflecting on that information (analysing) to transform their understanding of the nature of the problem under investigation (theorising). This new set of understandings is then applied to plans for resolution of the problem (action), which in turn, provides context for testing hypotheses derived from group theorising (evaluation)’ (Stringer 2014, p.15).

Dick (1997) describes stakeholder involvement using the following categories:

- non-involvement
- indirect consultation through representatives
- direct consultation
- process consultation
- co-research
- full client responsibility

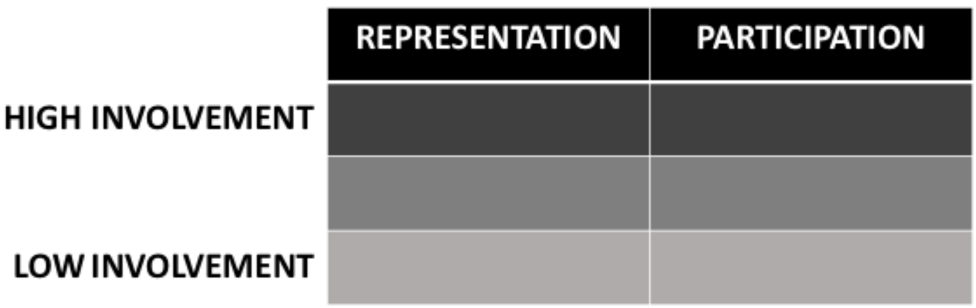

Figure 8 - Stakeholder involvement and representation (adapted from Dick 2002)

These lie in a continuum from non-involvement to full client responsibility and can be placed in a matrix with stakeholders providing representation or participation (Figure 8). Representation uses a small group of people that represent a larger number of people.

Participation implies that all stakeholders are involved, or at least are given a chance to be involved. This is especially useful when considering research that has several separate elements that involve several separate stakeholders who are working together to create the final research output. Also, in research where the views of some stakeholders are obtained from 'proxy' voices (Börjesson et al. 2015) in that the stakeholders are responding in a way that they feel is appropriate on behalf of another. For this research, representative stakeholders have helped with the development of theory around technology usage and participatory stakeholders have helped with the practical sessions using technology.

3.24 Chapter Conclusion

This chapter has outlined the background to the research and the framework it was conducted within. t. The philosophical underpinnings, methodology, and methods were outlined and discussed in order to explicate the choices made. The benefits and limitations of the above were discussed in order to demonstrate sound research design decisions within this research. The sample population and the positionality of the research were provided. The mechanisms of meeting people where they were and the use of technology probes were discussed. The research process, sites, and the stakeholders involved were described. Ethical considerations and stakeholder involvement were discussed.

The next chapter presents the activities of the cycles of action research by reviewing each cycle with regard to: who was involved, the activity that occurred, the themes that came from the data analysis, and the technological developments made within each cycle.

4. Action Research Cycles

4.1 Overview

The former methodology chapter presented the framework the research used, the methodological underpinning, and the design of the study. This chapter presents the research activities of four cycles of action research which were carried out throughout this project. The developments, while presented in the chronological order that they started, did run concurrently thereafter. For ease of representation the cycles are split into distinct sections as follows:

Cycle One: Electronic Orchestra
Cycle Two: Developing filterBox and squishyDrum
Cycle Three: Developing The Noodler
Cycle Four: Developing touchBox and the final MAMI Tech Toolkit

Each cycle includes sections on: stakeholders - to clearly outline who was involved and to what level with each part of the project (both to have a clearer audit trail of ideas and link to the transparency required in AR); an overview of the data collection methods - to show how the data was collected during the cycle; thematic analysis – to present the themes as developed from the data of the cycle; technological developments – to outline the development of the technology within the cycle; analysis – to analyse the themes and technical developments in order to inform future cycles; and conclusion – to synthesise the findings from the cycle. A section on 'moving forward' is presented per cycle in order to show the links between the cycles. A time line is provided (Figure 9) to highlight activities and their relationship to the overarching cycle that they sit within.

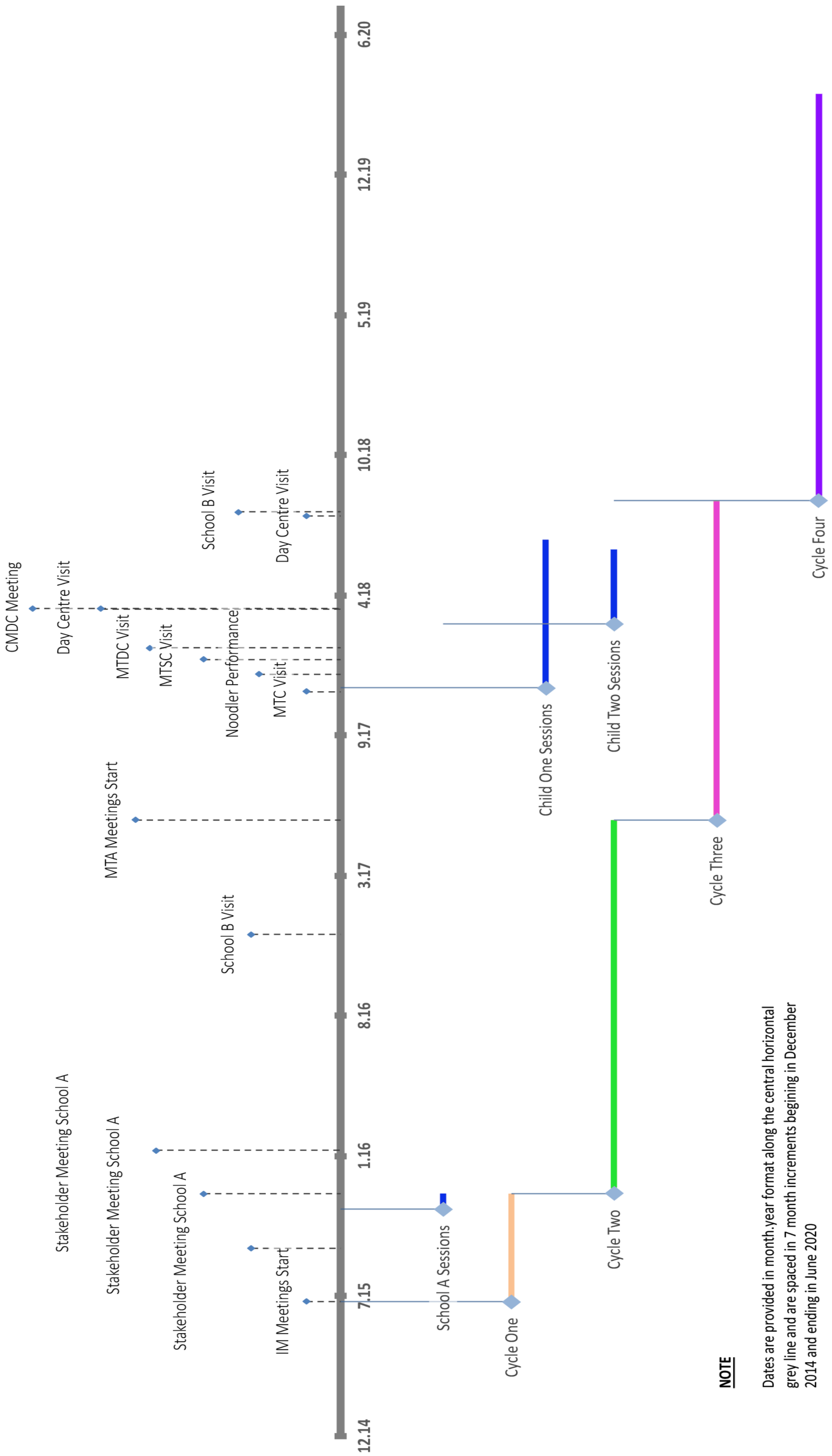

Figure 9 - Timeline of Key Research Activities

4.2 Cycle One – Electronic Orchestra

4.2.1 Introduction

Presented here are the research activities of the first cycle of this action research project. The overarching aim of this cycle was to work with stakeholders to explore the current use of technology and the issues surrounding this use. The activities of this cycle relate to the research aims of:

- exploring how technology is incorporated into practices of music creation and sound exploration - by using current technology with children and young people, gathering a group of stakeholders, and reviewing literature
- exploring issues with current music technology and usage in practice - by meeting with stakeholders and gathering data about their technology usage
- identifying gaps in provision that can be addressed through the creation of novel tools, and the formation of design ideals to guide tool development

The main activities in the cycle have been placed in the diagram below (Figure 10). These show the activities occurring in the phases of planning, acting, and reflecting. The activity is specified alongside the method of data collection. An overview of the cycle is presented. The stakeholders involved have been listed and each activity is then described. Thematic analysis of the interactions with the stakeholders and from the sessions conducted are presented. Themes that emerged from the stakeholder meetings were:

- Barriers to effective use
- Gaps in provision
- Pulling apart the instrument

Themes that emerged from sessions were:

- Interaction styles
- Technology pros and cons
- Sonic games

The themes are analysed and discussed before a final section provides a conclusion. A 'moving forward' section is then offered to lead into the next cycle.

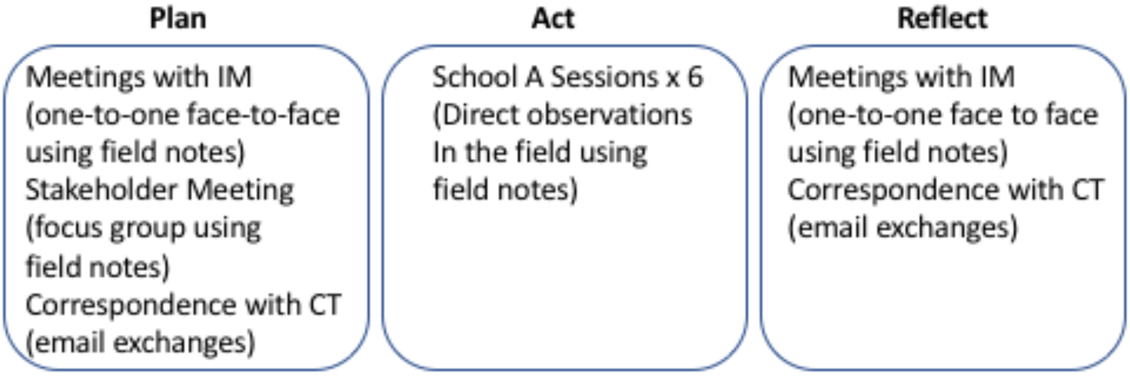

Figure 10 - Activities of the Cycle in Phases

4.2.2 Overview of the Cycle

Sessions were conducted by the researcher with children and young people from school A using existing technology for active music-making. A stakeholder group was created featuring practitioners within the school. The planning phase of this cycle began with three meetings with the industrial mentor at school A, before a meeting was held with a group of stakeholders consisting of existing connections known to the researcher, also within school A (CT, AHT, and DMSST). Followed by six further meetings with the industrial mentor. Six sessions were also conducted with children and young people within the school using existing technology.

4.2.3 Stakeholders and Activities

4.2.3.1 Stakeholders

- Industrial Mentor (IM) School A
- Class Teacher who was also the Head of Music (CT) School A
- Assistant Head Teacher (AHT) School A
- Digital Media and Sensory Support Technician (DMSST) School A
- Children and Young People (CYP) School A

4.2.3.2 Meetings with the Industrial Mentor (IM)

Eight meetings were held in this cycle to discuss what had worked in the past and potential research directions, potential involvement of others within the school and preliminary ideas about how to explore current technology in terms of what was already available within the school. The initial sessions in school A were set-up during these discussions.

4.2.3.3 Meetings with Stakeholder Group: 21st September 2015

The meeting aimed to re-establish connections within the school, discuss previous work, and give an overview of this research. Several practitioners who had shown interest in the research or been involved in similar research conducted in the school previously were invited to this meeting. The meeting gave several staff members a communicative space to come together, and discuss this research and issues around the use of music technology to facilitate active music-making, in relation to previous other research that was conducted using technology to make music within the school. There was a brief overview of this research offered including a short introduction to action research.

4.2.3.4 School A Sessions Using Existing Technology

The action stage featured six sessions of music making with some children and young people at school A using existing technology. The stakeholders suggested the format and structure of having a small group of children and young people working together, and the potential for sessions to include bespoke tools.

Two sessions were conducted one day a week for two weeks (with separate primary and secondary/sixth form children), followed by a session a week for another two weeks (with both groups merged). These sessions ran from the 16th November 2015 until the 7th December 2015 (six sessions in total). The sessions explored using technology to create a music ensemble using existing technology, specifically the iPad with Orphion app (Trump 2016) and the Kaossilator. The use of these tools allowed children and young people present to all have the same setup. The aim was to review holistically and first-hand what was necessary to run a session, both in terms of set-up of equipment, assistance and teaching strategy, and how the intervention worked in terms of allowing different students to participate. Sessions would allow problems to be elucidated in practice and a deeper knowledge of technology being used in this context to be gained. Each session had a skeletal plan that was devised by the researcher and then checked by the IM and the class teacher.

This was done to ensure that the content of the session connected with outputs that matched the stakeholders needs, and that it was representative of the kinds of musical activities that would typically be explored in a similar scenario. There was to be a specific focus on involving the children and young people by asking their thoughts on the sounds and instruments as well as their thoughts and ideas about further sessions. Each session was set up (equipment) and ran by the researcher and the IM. The researcher also took field notes and observational notes and held a post session plenary with the IM and the class teacher stakeholder where possible.

Session agendas

Presented below are the agendas behind each week, with the same agenda used for primary and secondary/sixth form sessions. The technical setup and the participants who took part are presented. The sessions all occurred in the art room of school A, which had within it the music equipment cupboard.

Week 1 - The agenda this week was to get the children and young people present to listen to some new types of music that was not typical of what they may have heard before and to explore some of the ideas from this music in the equipment supplied. There was a focus on creating new sound worlds with technology and moving away from established traditions to explore new arenas for expression. The initial setup featured 4 iPads with Orphion app (each with a bass sound setup of three notes with a different octave per iPad), and 3 Kaossilator (set to a soft lead sound, a lead sound, and a bass sound). This setup allowed for the different Kaossilator and Orphion sounds to be audible alongside each other. Each instrument was connected to its own amp. Observational noted were taken during and after the session. Week 1 session 1 - the session was held with two primary aged children and their teacher. Week 1 session 2 - the session was held with four secondary/sixth form children and young people and their teacher.

Week 2 - The agenda this week was aimed at thinking about musical technique and styles of playing, alongside turn-taking. There was also a recap on what was done the week previous and also a short plenary at the end. The initial setup featured 4 iPads with Orphion app all with the same notes. Observational notes were taken after these sessions and during where possible. Week 2 Session 1 - the setup this session was 4 iPads with Orphion app connected to an amp each. Three children attended as well as a class teacher. Week 2 Session 2 - four children and young people attended the session. The class teacher was present for the start of the session.

Week 3 - The agenda this week was aimed at thinking about playing together and performing cohesively. There was also a recap on what was done the week previous. The initial setup features 3 iPads with Orphion app and 1 Kaossilator. This session also saw the mixing of acoustic alongside the technology. We added a Cabasa (they were in the room) and a floor tom with drumsticks and beaters. The floor tom was added to accommodate one of the children and young people who already played the drums. Only one session ran this week as two students could not attend and two had been moved to the second session. Over ear headphones were provided as ear defence for one individual. This week 4 children and young people attended the session. At the end of the session there was a discussion with the class teacher regarding what we had been covering, this can be found at the bottom of the observational notes that were taken after the session.

Week 4 - This was the last week of the term. The agenda for this week was changed after consultation with the class teacher. There was a more open structure to start, moving onto using images to scaffold the playing and discussing the mood and feeling of these. The initial setup featured 5 iPads with Orphion app, 1 Kaossilator with 5 notes setup and a floor tom with drumsticks and beaters. Observational notes were taken during when possible and shortly after. This session was held with four children and young people. There were no teachers or teaching assistant for this session.

4.2.4 Themes from Interactions with the Industrial Mentor and Stakeholder meetings

Three main themes emerged from the interactions with the industrial mentor and stakeholder meeting. These were: barriers to effective use of technology; gaps in provision; and pulling apart the instrument.

Barriers to Effective Use

Stakeholders spoke of barriers to use which included barriers to getting technology in place and ready to use, and barriers to integrating technology into practice. Barriers to getting technology in place were tightness of resources in terms of money to buy equipment, physical space to both store and to use technology, and time to gain skills with using the technology, these barriers are congruent with results in previous literature (Cevasco and Hong 2011; Clements-Cortes 2013; Hahna et al. 2012; Magee and Burland 2008; Streeter 2007). Barriers to integrating technology into practice were how to facilitate individual users and how to cater for groups. Stakeholders felt that dedicated music spaces and dedicated music and technical support staff were declining in favour of resources/physical spaces becoming multiuse. Other barriers to effective use were size of group or time of day of session. Size of group was seen to be problematic when facilitating a larger group in terms of providing enough technological tools, and complexities that come with the requisite setup and running of multiple technological tools to carry out such a session. The time of day that sessions ran played a role in whether the people involved would likely be fatigued, whether they were supported and whether they could attend at all.

Technology when improperly setup (not using the correct settings in relation to other instruments, or not matching the content of the session) or by not being ready to be used (not being charged or updated) caused disruption and thus became a barrier to participation, making it sometimes hard to judge the potential of the technology being used. '*Dedicated hardware wouldn't be charged or be able to be operated by the TA* [teaching assistant] *accompanying the pupil'* (assistant head teacher).

Gaps in Provision

The stakeholders spoke of the desire for instant access and technology that was enticing to take technology off the shelf, easy to use, and obvious how to integrate into practice.

Interaction that both leveraged skills used in the real world through our actions with tangible physical objects, and that adhered to what would be expected of an object in terms of affordances and expected sonic outcome were seen as being important. This was seen as being achieved through the form of the design of the tool, how the modes of interaction operated, and the way the tool was mapped. '*Thinking of the design of things such as the teapot.... when you hold a teapot... the way that it is constructed affords certain actions that* *naturally come as part of the design'* (industrial mentor). *'Naturalistic mappings are what we are looking at....interactions such as opening a box to change the filter on the sound for example'* (industrial mentor). This pointed to creating designs that utilise '*affordances'* (Gibson 2015) that respect and/or exploit the users natural dynamics of communication (Norman 2013, Sadri 2011) both in terms of interfaces that provide access to the necessary physical interaction, and mapping that utilise common expectation and map this to an appropriate-to-the-individual sonic output.

Tools needed to extend beyond digital feedback (such as touching a screen for example) in order to gain deeper resonance. This deeper resonance was seen as necessary to mirror the physicality and resonant capacity of traditional acoustic instruments. *'the kids need more than digital feedback...they need that deeper resonance'* (assistant head teacher).

Stakeholders spoke of a need for a flexible system using a combination of hardware and software that could be configured to suit the end user. Where flexibility was provided in the setup it aided in the responsiveness needed to create systems based on the user at the centre, and in the scenario of use. In creating tools that allow configuration to the end user, a combination of motivating sonic output, and potential for expressive output could be achieved. Fine tuning of software and hardware could then be done over time as needed to further tailor to individual needs. Hand-held portable technologies with changeable multimedia elements have previously been shown to be a successful mechanism for engaging children (Blatherwick and Cobb 2015).

Flexible technology was seen as a potential aid in 'levelling the playing field' between those participating in sessions, and that the development of a generic piece of software that could allow an existing piece of hardware (for example a joystick, which can be considered as an array of faders and buttons) to be connected was seen as a viable option to potentially address a gap in provision for this research.

Pulling Apart the Instrument

Stakeholders spoke of the problems that decoupling the interaction and sound production has with regard to cause and effect (as seen with technology such as the Soundbeam) and the importance of utilising multi-modal sensory feedback to potentially help to assist with the reinforcement of cause and effect. '*Decoupling the interaction from the sound at the end can cause issues with recognising cause and effect....the way we have got* *around this in the past is to position amps right next to the pupils to ensure that there is that instant feedback there'* (industrial mentor). This highlights the importance of having a tangibility to work against in order to provide the necessary cause and effect.

In terms of mappings, the stakeholders felt that expression vs constraint was seen as a difficult balance. This balance has to take into consideration performer freedoms (freedoms of movement and freedoms of choice) and matters of musical instrument efficiency which Jorda (2004) defines as the equation in figure 11.

$$MusicInstrumentEfficiency = \frac{MusicalOutputComplexity}{ControlInputComplexity}$$

Figure 11 - Musical Instrument Efficiency (Jorda 2004)

This balance moves on a continuum from simple to complex mappings. Simple mappings are one-to-one where one gesture controls one musical parameter, or complex - in which several gestures controls one musical parameter (convergent) or one gesture controls several musical parameters (divergent) (Rovan et al. 1997). Instruments with simple mappings could be considered to be constrained when a gesture can trigger an output but not expressively change that output, or when output is constrained to a particular set of notes or timings. Instruments that were too constrained were felt to be lacking in expression for those using them to feel fully in control or to maintain interest, for example pressing a button to trigger a sound. '*Sometimes instruments are so constrained that they don't offer the expression needed for the kids to feel fully in control'(industrial mentor)*. However, opening up more expressive potential with technology was seen to be a time-consuming process in relation to achieving outcomes with the individuals using them. This was seen as a potential problem in environments driven by outcome. This drive was seen to, at times, lead to things getting done for people resulting in a diminished learning process for individuals. '*Opening up expression means it can take longer to get outcomes, and in an environment driven by this, things can get done **for** people rather than **by** them... which is not satisfactory as a learning process' (class teacher/head of music).*

4.2.5 Themes from Sessions Using Existing Technology

Three main themes emerged from the sessions. These were: interaction styles; technology pros and cons; and the use of sonic games.

Interaction styles

Varied interaction styles were used with the iPad. These playing positions and motions were unique to each individual and were necessitated by: a combination of the individuals physical and cognitive disposition; the iPads form factor; and the Orphion interface (Figure 12). Some children favored trying to mimic playing traditional instruments such as tapping and playing percussively as if playing a bongo or playing like a piano, others tried to push the technology to see what was possible, such as pressing all the buttons they could manage until an overloaded sound could be heard, which was subsequently held for some time. Children and young people were able to hold and play notes for as long as they liked, bypassing the stamina sometimes needed with traditional instruments. This gave them the sometimes-necessary time needed to process the activity, and the ability to prolong the ephemeral nature of some instrumental interactions in order to stop the sound of their own volition. One individual moved between two notes using all fingers to tap each note in a rhythmic fashion and another circled the shapes on the screen interface of the instruments (fig 15). There was often appropriation of the tools provided such as holding of the iPad in non-typical ways to enable interaction to occur. Often times there were physical gestures such as dancing, even whilst moving around the room and not exploring the technology – they could be seen to be musicking (Small 1998).

The way the children and young people interacted with the tools provided in the sessions sometimes heralded difficulty in determining whether they were: exploring the sound to express themselves; playing and hearing the sound; performing the motion (pressing the button to press the button, or pressing the button to hear the sound); reacting to the visual feedback on the screen; simply copying others; or doing what was asked of them to please the facilitators. There is a question of the motivations behind the interactions. Were they interactions/reactions/actions?

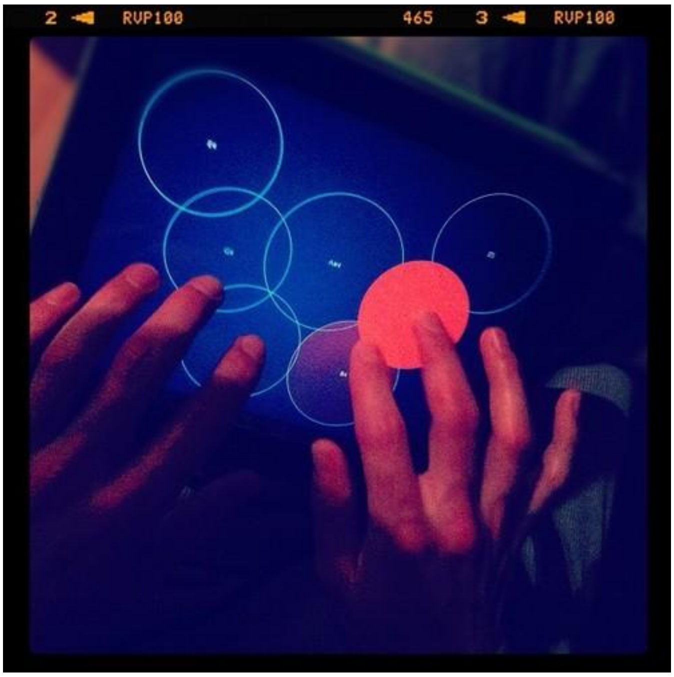

Figure 12 - Orphion app interface (SML Tumblr 2012)

Technology Pros and Cons

Apps were seen to be motivating at holding attention. '*Distraction only usually takes a minute to set in so this app* (Orphion) *has done well at holding attention*' (class teacher). The use of technology could be seen as a mediator for children who were usually not communicative at helping them to '*open up'* (industrial mentor). There were lots of smiling from individuals who were recognised as usually struggling with group situations. The sessions were seen to be providing a unique experience for the children by expanding their knowledge of music and technology.

The use of music based technological resources (such as the iPad app) were seen to: offer opportunity for physical and social skill development; allow exploration of sound; empower those using them; give those using them a voice; and provide new modes of communication. Technology such as Spotify, and having apps available on classroom iPads outside of the sessions (as occurred during this research) helped to give: the important chance to feel ownership of the instruments (akin to taking traditional instruments home to practice); the chance to practice outside of the session (thus allowing asynchronous learning); and the chance to use peer-to peer learning between the children and young people (allowing them to show others/their class what they had done/were exploring).

When the settings of the app were the same for everyone some interesting sonic soundscapes were created with a quasi-'levelling of the playing field'. This offered a cover or mask under which children and young people that might not want to be spotlighted could blend in and thus seemingly encouraged participation from all.

Technology issues meant that at times sound levels became an issue, causing startling in some of the children and young people. This was due to the sound design of the Orphion app meaning that one style of interaction would create a loud sound and another a quiet sound (depending on the amount of surface area of the body placed on the screen) so the balance had to be adjusted to mediate this by riding the volume manually. Some notes (when all iPads triggering the same notes) caused a 'beating' and feedback to occur at a bass level.

There were issues surrounding the use of iPads in that the children wanted to use the apps they liked and not the apps that were set up. Showing that careful consideration should be given to using tools that are multi-use, especially with frequent users or those that may use them for other things such as communication aids. There was also the ease of changing settings that meant that this method was employed by the facilitator to hold attention.

Sonic Games

The use of sonic games was beneficial as a framework within which to explore the instruments and engage with the children and young people present. Examples of these games were: 'follow the leader' - in which the children copied the demos of phrases in terms of timing and notes played by the facilitator; 'metaphors' - in which the sounds of storms and rain were used to dynamically explore the instruments; 'Mexican wave' – in which turns were taken in the round, first with arms, and then with each person performing a short phrase of sound and raising their hand to allow the next person to play; conductor in which one of those present was assigned (by the facilitator) to be the conductor and indicate who should play next. This slowly built up speed with everyone watching each other and the facilitator. One young person said it made them '*dizzy*'; and 'alien chat' in which the facilitator (industrial mentor) then demonstrated communication via an alien language '*chat'* via the Orphion app. The children then took it in turns in pairs to have a musical conversation. Two children, who at first were not listening to each other came to both be listening and then 'speaking' through their instrument. Using technology in this way allowed children and young people to engage with each other and be expressive without having to use language, this led to some moments where clearly both parties were having fun and were engaged.

The technology assisted in a tangible way to allow for a strong communication and connection to be achieved. A call and response activity was used to elicit the children and young people to follow the facilitator, with all the iPads featuring the same notes and all the children and young people following the same motion the levelling of the playing field was absolutely visible.

4.2.6 Analysis of Themes from Industrial Mentor and Stakeholder meetings

Barriers to effective use

The comments of the stakeholders - namely that technology could be disruptive and become a barrier echoes the findings by Magee and Burland (2008) of a 'faffiness' (ibid, p.133) that can occur when trying to make technology work within a session, highlighting the paramountcy of technology to be in a workable state by being *ready* to be used, and by being *able* to be used. In a school setting these issues are often compounded by external and uncontrollable factors such as knowledgeable assistants changing week to week or not being available which can lead to unsupported individuals or no-one knowing how to work the technology used by the individual.

Whilst literature has previously explored barriers to the use of technology (Crowe and Rio 2004; Magee and Burland 2008; Cevasco and Hong 2011; Hahna et al. 2012; Clements-Cortes 2013) this research suggests that these barriers can be placed into four categories: barriers to finding appropriate technology; barriers to setting technology up; barriers to integrating technology into practice; and barriers to using technology within the session. The above categories also interlink depending on the goals and needs of the practitioners and the individuals using the technology. Each barrier could be considered to have its own skill set and different training needs to overcome and each points to potential gaps in provision and potential ways to break down these barriers by providing technology that addresses them.

Gaps in provision

When considering gaps in provision there is the need to provide tools that both fit the needs of the stakeholders and the users at the centre of use. These gaps come in the form of explicit requirements at a meso level such as tools being easy to use, wireless, easy to set up but they also come at the micro level in terms of how the tools work when used for their intended purpose.

A design that strives to leverage commonly used interaction mechanisms or knowledge of musical instruments, might be considered as one that more prominently uses gestures that translate closely to the sonic output that occurs. This means either following the speed, direction, or amount of movement, or emulating of traditional playing gestures such as striking, swiping (this can be considered analogous to bowing a string in that two surfaces are moving against each other), or applying some form of pressure. There are clear links here between the interaction styles as demonstrated within the sessions to the literature on typology of gesture (Jensenius et al. 2010, p.12) and the literature around authenticity as a material quality of design (Hinrichsen and Bovermann 2016). The connection between the material interaction and the gesture interweave to co-construct the interaction, in which the properties of each contribute to an experience. Sound production gestures can be divided into excitation and modification gestures (Malloch et al. 2006). Excitation gestures consisting of impulsive, sustained and iterative actions and can be direct or indirect (an example of direct excitation would be hitting a drum with the hand and indirect would be hitting the drum through using a stick) and modification gestures modify the sound, such as applying pressure when using a bow. It is of use to consider how we can use the gestures of an individual as input to the musical system and what it might mean to follow traditional approaches (emulate), to utilise the bespoke interaction capabilities of the individual (translate), or utilise unique new mechanisms (innovate). There is the ability to use musical gestures that are analogous to traditional instruments, for example, a percussive strike made by the smallest tap of a finger, but to amplify that action to give the response as if a large drum had been struck heavily with a beater.

In order to move beyond digital feedback as the stakeholders suggested, we can consider utilising rich resonances. These can be thought of as both the physical/haptic feedback that occurs through interaction – whether provided by the vibrating body of an instrument or the tactile quality of graspable interaction – in other words the materiality (Hinrichsen and Bovermann 2016) and tangible feedback (Ishii and Ullmer 1997) – that comes from interacting with tools. Resonance can also refer to an experience or state entered when using a tool such as is the case with aesthetic resonance (Ellis 1995) or achieving a sense of flow (Csikszenmihalyi 2015). In practice utilising the resonant quality of the tools can provide the potential to access the resonant quality of the experience.

The stakeholder outlined a need for flexibility in creating tools in order to provide set-ups that can cater for a variety of users. This included offering flexible modes of input by providing tools that offer different modalities - in order to cater for the gestural vocabularies of the users, and the ability to map this to engaging output through the configurability in the system. Several options for creating flexible systems have been outlined within the literature review (Makey Makey, utilising Arduino, Max/MSP etc) that have potential to be combined into a workable system. Developments within music technology and the world of new interfaces for musical expression have gone some way in providing resources for creating such systems in the form of various elements of toolkits, be those sensor based hardware (I-CubeX (Mulder 1995), Phidgets (Greenberg and Fitchett 2001), or software based toolkits (JunXion (Steim 2005), Wekinator (Fiebrink and Cook 2010). However combining these takes considerable technical skill and knowledge about both computer systems and music systems, in order for users to develop their own flexible system.

The aforementioned systems are aimed at those with technical skills and developers, and this research wanted to create systems that are aimed at the music therapist and the end user that are using these systems within practice. The systems created in this research aim to solidify several elements of technology into ready-to-use configurations of hardware and software, that can be used without having to construct the system, write code, or configure many elements. There is a balance of providing a flexible system with the goal of adapting to users' needs, as well as not overwhelming the users and practitioners who are using the technology. The systems created are hoped to be accessible to those who have an interest in what technology can offer, but may not have used computers to access music-making before – or if they have it may have been using apps and basic music-making software. The systems created within this research also must take into account that there is an element of control that is given to facilitators and an element of control that is given to the central user. As such easy-to-use and appropriate mechanisms must be provided that account for this, and to ensure that this facilitated access is catered for within the interactions provided through the system. The robustness of the system is also a consideration. The final pieces of hardware have to be hardwearing due to the stresses and strains of use that may be put on them. In terms of configuring the system to the user within the software, there would often be no way to tell the user to make a specific movement as this would be unrealistic in practice, so ways to configure on-the-fly would have to be integrated that did not require this. It is hoped that this research will provide tools that work towards filling these gaps.

Pulling apart the instrument

New instruments can be considered as being formed of sonic capability, algorithmic power, and physical interfaces but can also be viewed more holistically as new ways of playing new music (Jorda 2004). These new ways of playing new music are formed of a dynamic relationship between the player and the instrument. These relationships contain within them the potential for stimulation or placation (ibid) by balancing elements of 'challenge, frustration and boredom; (ibid, p.60). Balances must be struck between the learning curve (considered as musical control input complexity/musical output complexity), performer freedom of movement (considered as the performers output potential or how they can interact) and freedom of choice (considered as what, by means of action, the player can ask the instrument to do) (ibid). Considering these elements can aid in pointing to 'what might be considered essential needs for different types of musicians' (ibid, p.60). Literature in the past has implied that 'good' instruments should: focus on the performer 'not being the instrument's slave; with the possibilities the performer has to affect the instrument's output' (ibid, p.62) by allowing 'good' and 'bad' music to be able to be played on them; or that instruments must have complex mapping strategies to feel more natural and lead to more expressive instruments (Hunt and Wanderley 2002). However, throughout this research it has been found that constraining the instruments (to produce predictable outcomes that are constrained to particular schema's of 'good' notes or with 'good' timing) and instruments that have simple one-to-one mappings (press a button to trigger a sample) have provided an access point and a level of expression that did satisfy the balances above. This can be linked to the exploration of interaction in terms of providing systems that are relative to the user by providing affordances that are appropriate and that make sense to them (Gibson 2015; Norman 2013). The ultimate aim might be considered access to expressive music-making experiences *appropriate to the individual* which takes in to consideration the above balances.

This appropriateness can be considered on two levels, the input level and how the instrument is interacted with, and what comes out of that interaction. While the central question is what is expressive for this individual? In each individual case there would be an individual answer. A more appropriate way to posit what a tool might need to offer would be to ask how can an individual access the tool? And what would they like the output to be?

Bott's (2010) suggestion of considering the individual with regard to access and/or learning needs can provide a useful tool to frame the construction of new ways of playing music and what tool might be appropriate for any given individual. When working with those who may not physically be able to develop the level of fine or gross motor skills, or strength/stamina needed to play a traditional instrument or those who may need support with the level of cognition necessary to play an instrument there is the ability to use technology to provide a continuum of support. This support could be used for developing skills over time by supporting capabilities and flexibly changing with skill level in order to maintain the balances mentioned above. Physical musical skills and cognitive musical skills can be decoupled (much like the interaction can be decoupled from the sound with technology). Musical interactions can then be broken down into constituent parts to allow for support where needed. Skills such as timing, turn taking, using expression, selecting the correct note (if playing a composed piece) etc. can be developed separately to those physical skills that are a pre-requisite to learning to play most traditional musical instruments. When considering a physical playing skill such as a string pluck, an individual may only be able to touch the string to trigger a sound, however if over time they gain the strength to pluck the string then the technology could adapt to slowly 'turn down' the amount the action is amplified via the technology. Physical skills could then be developed using technology to provide the feedback as a motivator to encourage development. Another example might be setting up a button to trigger samples or notes that automatically play in time with a song and then gradually switching control of timing to the player as they improve (although it should be noted that this would interfere with direct cause and effect in some cases).

In creating new tools that aim to balance: technology in combination with ancestry from existing instrument; and/or combine interactions that are familiar with new modes mechanisms of interaction, it may be useful to look to literature on spectator understanding and perception of skill. Such literature has shown that modelling a spectators understanding of error can be useful as a framework to help inform design (Fyans and Gurevich, 2009) and that the embodied knowledge of an instrument, can lead to significant changes in the perception of skill needed to use the instrument (Fyans and Gurevich 2011). This can be helpful to consider when thinking of those around the central user that may also be part of the musicking (Small 1998) that is happening.

4.2.7 Analysis of Themes from the Sessions

Interaction styles

Several factors affected the interactions within the sessions depending on whether an individual was focused on the tool, the sound, the others interacting, or the facilitator, alongside the individuals prior knowledge of interacting with similar tools, or with instruments that sound similar. Fels (2004) recognises four types of relationship that can occur between people and objects - 1) The person communicates with the object in a dialogue - and the result is the motivator (in this research hearing the sound, feeling the press of the button, seeing the visuals) 2) The person embodies the object - the act of control provides an emotional response (in this research exploring the sound to express themselves). 3) The object communicates to the person - as in passively watching a performance. 4) The object embodies the person – a level of proficiency with a tool is such that the user relinquished control. This research would suggest that there is an added social layer that affects peoples relationships with objects in terms of copying others and/or doing what was expected. This relationship mediates the shifting role of the tool, something which can also be seen in the work of Andersson et al. (2014), in which their tangible musical interface took the role of friend, fellow musician, and tool when used in different scenes. The tool in the case of this research could be one of fellow musician, an expressive instrument, or an interesting artefact to explore. It could also become a socially inclusive device by being used for communication or for showing compliance or co-operation.

Much in the same way digital musical instrument controllers can be considered by the degree to which they resemble traditional instrument (augmented instruments, instrument-like, instrument-inspired, or alternate controllers (Miranda and Wanderley 2006)), gestures can also be categories based on the degree of 'gesture vocabulary' (Miranda and Wanderley 2006, p.27) they share with that of traditional musical instruments. Augmented gestures may maintain the interaction style but extend the range of the gesture – or include gestures that 'unlock' more control over the sound; instrument-like gestures may maintain the same motion that would be used, mimicking the playing of a traditional instrument; instrument-inspired gestures may be likened to instrument-like gestures but with the ability to overcome the intrinsic limitations of the control mechanism of traditional instruments – such as the example given when using a small tap to trigger a large drum sound; and alternate gestures that are not modelled or inspired by acoustic interactions can offer new modes of interaction. The various gesture styles can offer support in different ways depending on the needs of the individual playing and the goals wishing to be achieved, potentially even facilitating a route into playing traditional musical instruments by developing transferable skills using technology. Within the sessions when technology was combined with acoustic instruments, the gestures used with the technology appeared to be mediated by the gestures commonly associated with the acoustic instruments that were being used at the same time. The diversity of gesture and its connection to expressive output could be utilised to address some gaps in provision.

Gestures used throughout sessions ranged from small to dramatic with the same sonic output, this meant that performances could be static or theatrical, with the same output. This can be seen as a pro or a con in that traditionally when playing an instrument, the gesture and the output are more closely linked, and the expectation might be that hitting something harder would create a bigger sound, with technology the sonic playing field can be levelled. Children and young people could express themselves as a large or as small way and be heard/not heard too loud. This might be of particular benefit in a group/ensemble playing scenario. The sonic output can effectively be scaled to suit the expressive dimensions of the user and/or the use scenario. This 'confinement to an idiom' has been viewed as a limitation in other research (Magee and Burland 2008) however throughout the sessions the use of such an confined idiom was evidenced as a useful tool.

Technology pros and cons

Technology allowed for the children to instantly copy what was being demonstrated on the iPads, this could be seen as a benefit of the technology in that it takes away the learning curve of playing an instrument both in terms of knowledge in the body i.e. muscle memory, and knowledge in the brain i.e. the myriad of cognitive processes that combine to play an instrument in order to achieve a desired musical outcome.

When considering the balance of constraining or opening up expression with technology, there is the potential to use technology to scaffold the learning process. If a traditional instrument can be considered to take 10,000 hours of practice to master (Gladwell 2008) and teachers are trying to get results with students with little time, then technology can scaffold this process by having a shallow learning curve and by providing immediate access – however this may tend to tools having less capability for expression.

In terms of levelling the playing field using technology, there is the ability to use technology to enable all to have similar levels of access to participation, and there is providing all users with the same technology and the same settings. Using the same technology with the same sounds for multiple users may help those that might not participate out of fear of doing something ‘wrong’, not being musical, or not being able to play an instrument, to do so. This might help in inclusivity of the facilitators, and others that may be present within sessions, to encourage their participation.

Using tools such as the iPad that do not come with a repertoire, or expectation of how they are played (as traditional musical instruments do) provide usefulness in encouraging interaction that is not based on expectation of what or how they are ‘normally’ played. This sentiment is echoed by others, ‘there need be no ‘right or wrong’ way to articulate sound from a keyboard, only appropriate ways for the individual’ ((Ellis and Leeuwen 2000, p.7). This can be useful for those that may be put off by the perception of traditional musical instruments and/or the types of music played on them, however it can also remove the potentially helpful existing framework of the traditional musical instrument in terms of recognisable tools, uses, and outcomes.

The use of the iPad once again offers the pro and the con, the pro is that you can change the settings, the con is that you can change the settings. The facilitator changed settings to try and maintain attention arguably foregoing a deeper connection with the sound interaction to provide a liminal pique in interest. ‘Constantly moving goalposts’ (Hunt and Wanderley 2002, p.106) created issues with continuity and expectation when considering action to sonic output with the technology. The technology in this instance is different to the traditional instrument in that traditional instruments do not change. They are predictable and rigid, which is something that some children and young people find beneficial, as change and unexpected events can be distressing for some individuals. The ability to turn the sound off with a digital musical instrument is a benefit that technology could offer in that you cannot mute a traditional instrument. However, this does then run into issues with removing control from the children and young people in independently playing or stopping the sound using their own volition.

Technological systems have to be fully tested to ensure the system works as needed and does not cause issues. This should be carried out in terms of the technology working as desired and the various technologies working together. This should be framed in how the users are likely to interact with it – this is a common practice in the music performance world when performing routines such as sound checks.

Sonic games

Sonic games helped to engage the children with the technology and with the sound. Various sonic games were used to familiarise the students with: how the technology worked - in terms of using the interfaces and the effect of this on the sonic output; to introduce musical concepts; and to encourage the development of music and communication based skills. Playing sonic games with the technology provided a framework within which to use them in practice and elucidated some of the key findings within this cycle of the research. Skills such as playing in time, following notation, or using fine or gross motor skills were recognised as potential areas for application.

4.2.8 Conclusion of Analysis

Barriers can be found in providing appropriate tech, setting it up, integrating into practice, and using within a session. Each has own sphere of issues within which gaps in provision/knowledge could be found.

Flexible systems (in terms of modes of input and content output) with interaction and appropriate feedback were seen as essential. This is formed by taking into consideration the individuals needs and wants, and the modes and mechanisms that can be provided to meet these. This includes considerations of mappings (expression and constraint), the physical form factor of the tools, and the physical interaction affordances they offer. Stimulating tools requires a delicate balance of the above which may change over time through use. These tools then form a constantly shifting relationship between the user and the tool and the user/tool coupled within the context of use which is in turn mediated by the physical space and the others within it.

Using the technology heralded various interaction styles, sometimes mimicking acoustic instruments, sometimes exploring 'new sound worlds' (Hunt et al. 2004, p.50) the output of which could be scaled to the expressive dimension of the user or to match the scenario of use, providing a ‘levelling of the playing field'. Technology was useful for a myriad of benefits outside of that of active music-making such as holding attention, and providing opportunities for physical and social skill development.

The use of iPads provided flexible tools that were sometimes unpredictable in terms of sonic output. These tools also came with a multi-use intentionality that meant that they were appropriated sometimes negatively by both the facilitator and the children and young people in order to maintain interest.

Playing sonic games with the technology provided a framework within which to use them in practice and elucidated some of the key findings within this cycle of the research. Skills such as playing in time, following notation, or using fine or gross motor skills were recognised as potential areas for application.

4.2.9 Moving Forward

This cycle was used to explore the research aims of:

- exploring how technology was incorporated into practices of music creation and sound exploration by using current technology with children and young people, gathering a group of stakeholders, and reviewing literature
- exploring issues with current music technology and usage in practice by meeting with stakeholders to gather data about technology usage
- identifying gaps in provision that can be addressed through the creation of novel musical instruments and tools, and the formation of design ideals to guide tool development

Cycle two will use the findings from cycle one in the development of bespoke tools. These include designing: for gaps in provision in providing tools that are portable, easy to use, and that can facilitate individual and group use; tangible physical interfaces that utilise commonly used interactions and provide multimodal feedback; and flexible systems that can be adapted to different users. Considerations of filling these gaps in provision and addressing barriers to access will contribute to the design of these tools. The possibility of creating a multisensory technology toolbox, that could be taken into classrooms was an outcome of discussions with stakeholders that will be explored. This exploration will include working with stakeholders from another site as an informant to the design process.

4.3 Cycle Two – Developing filterBox and squishyDrum

4.3.1 Introduction

Cycle Two of the research involved the development of two bespoke tools in the form of a filterBox and squishyDrum. The activities of this cycle relate to the research aims of working with stakeholders to:

- explore issues that stakeholders have with current music technology by meeting with stakeholders to gather data about technology usage
- create novel tools as prototypes from criteria specified by stakeholders, via design ideals created in conjunction with them, and to address gaps in provision found from the literature review

Presented here is an overview of the research activities that occurred within the cycle which are mapped to the plan, act, and reflect phases of the cycle (Figure 13). The stakeholder are identified and the research activities are outlined. The themes that emerged from this cycle through the interactions with stakeholders are presented, as developed for this thesis. These were:

- creating tools in a school setting
- user motivations
- integrating technology into practice
- goals of the use of technology
- design ideals.

The technological development of the cycle are discussed. A section is provided on 'presenting the prototypes to the stakeholder group' in order to make explicit how their input was used in the design process and their reflections on the prototypes. The themes are then analysed before a final section on 'moving forward' leads into action research cycle three.

Figure 13 - Activities of the Cycle in Phases

4.3.2 Overview of the Cycle

Two bespoke technological tools were developed using iterative input from weekly meetings with the industrial mentor (IM), and prototypes were presented to stakeholders at the stakeholder group meetings as digital probes. A stakeholder at a second site – school B - became involved after discussion with the industrial mentor. This was done in order to see how technology was being used by them and gather data that could be fed back into the development of the prototypes. The stakeholder at school B provided unique practical experience as an avid user of music technology.

4.3.3 Stakeholders and Activities

4.3.3.1 Stakeholder Group School A

- Industrial Mentor (IM)
- Class Teacher/Head of Music (CT)
- Music Therapist (MTA)
- Assistant Head Teacher (AHT)

Stakeholders School B

- Digital Music Technician (DMTB)

4.3.3.2 Meetings with Industrial Mentor (IM)

Nine meetings were held in this cycle with the IM throughout the development of the prototype tools to review the technical side of the development, as well as to discuss the wider issues pertaining the continuation of the research within the school.

4.3.3.3 Meetings with Stakeholder Group*:* 8th December 2015

This was the first meeting with the stakeholder team to discuss this research specifically. The agenda (appendix E) was to introduce the stakeholders formally to the research, give an overview of the AR methodology, get their permission to be part of the research, and show the progress made on the bespoke hardware tools. The meeting was recorded, and transcribed, and key points were created and sent by email to the stakeholders who attended and presented in person at the next stakeholder meeting (appendix F).

4.3.3.4 Meeting with Stakeholder Group: 8th February 2016

This was the second group meeting (appendix G) to state current position, changes to plans, and to feedback thematically analysed data from the previous meeting. The software was presented to the stakeholder under the name of the modular accessible musical instrument (MAMI) using a generic piece of hardware (gaming joystick) as a demonstration aid. The hardware was presented as non-functioning prototypes. The stakeholder's feedback and thoughts on the system were gathered to feed into further development iterations. There were also discussions on testing instruments, developing design principles, and the style of feedback the researcher had given to the stakeholders, as well as covering issues of ethical approval. A report was prepared and organised by key themes (appendix H), this was then emailed to the stakeholders.

4.3.3.5 Visit to Digital Music Technician at School B: 12th December 2016

A visit was organised to meet with the digital music technician working in school B. The DMTB ran music technology sessions, as well as the schools radio station, and as such was a confident user of music technology using a wide range of both software and hardware, to work with the students at the school. The visit was a chance to see what technology was used and how - as well as to ascertain what requirements the DMTB would have for new technology.

4.3.4 Themes from Interactions with the Industrial Mentor and Stakeholder Meetings

The themes presented here have been collated as part of the writing of this thesis. Five themes emerged from interactions with the industrial mentor and stakeholder meetings. These were:

- creating tools in a school setting
- user motivations
- integrating technology into practice
- goals of the use of technology
- design ideals

Creating Tools in a School Setting

Stakeholders recognised that tools would need to be authentically developed with the users at the centre to give them long-term chance of being used, and a lasting effect on pupil experience. *'For you to be able to sit and observe an authentic situation where they really are experimenting with whatever mobility they've got, and whatever cognitive function they've got, because it's much better to do it that way, because it's got a better fighting chance in the long-term of actually having an effect on pupil experience. As you say, if it's something done to them, you know, it will just kind of die off' (class teacher/head of music).* This is in line with the social model of disability in that technology can stand a better chance of adoption by the users if it is designed *with* them rather than *for* them.

It was seen to be most beneficial if the tools would remain within the school post-research. Research had been conducted in the school in the past, but the tools/prototypes were removed when the research was over. *'The point is that they're not in school anymore. Those people who've created them... have taken them away, because they were prototypes and they were first ideas, which is great, but maybe what we need to be thinking about now is how do we continue to have those things in school, because other than having a cabasa attached to a platform, that's about as far as we go' (class teacher/head of music).*

There was the idea that anything bought into school has to earn money. Earning money in terms of drawing in finance by being innovative, by engaging people to want to use, by meeting the needs of practitioners, and by physically last a long time.

User Motivations

The motivations of the user of the instruments are not always obvious and straightforward to gauge and thus it is sometimes difficult to assess the successful elements of a design. For example, some pupils get kinaesthetic feedback from the device and the interaction itself, not always from the sound so there can be ambiguity as to whether an action is done to produce the effect or because the action itself is motivating. *'they love that feedback.... it won't necessarily build the satisfaction they get from using whatever you make, won't always be related to that, sometime their attention span is only this big *makes a small gesture between hands* so if the sound is coming from behind them it won't necessarily be about playing with the sound it will be about this feels really nice in my hand...[someone was tested the other day to see if they] are touching the switch to turn the light on or touching the switch to touch a switch cus they like touching a switch and they don't care if the light is coming on*' (class teacher/head of music). Motivation may not just come from sensory feedback but resonance consisting of a combination of the feel of the device in the hand, using the device, receiving feedback from interaction and from others, and interaction with other elements such as other players, the space, physical sensations, and/or cognitive processes. This links with whether the music-making scenario is one of individual or group music-making. It is important to consider that some children and young people prefer individual play whilst others thrive when part of a bigger ensemble. *'[some children] would really go off the boil in the smaller sessions so sometimes it was only a couple of them but when it came to actually being part of a bigger ensemble that focussed them in and there was some intrinsic motivation that came of playing and being part of something. You may find that they exhaust the potential of something as a soloist but when that group dynamic comes into it really starts to excite them in a different way so maybe there is something in that*' (assistant head teacher).

Integrating Technology into Practice

Issues such as set-up time, space required, technical knowledge, or having to organise set-up may lead to tools being abandoned.

IM: It's why all electronic stuff fails in the end; it ends up in a shelf somewhere not being used, because set-up time and stuff is - like the sound beam, we always had that. Why does no one use that? Because you've got to go and set it up.
CT: Oh, the eternal question.
IM: It involves turning on a computer, it's straight away you've lost 60 per cent of the stuff
AHT: Well, people are under pressure, aren't they? Like classroom practitioners...
CT: Well, yes, it's having the space, and it's having something set up. But that's precisely - isn't that why we have someone like [media technician], though?
IM: Yes.
CT: To set up stuff ready for lessons.
IM: But, you know, people want to go, 'Right, what am I doing now? I'm going to do that. I will pull it off the shelf, I'll flick the on button', and it works.
AHT: Done.
CT: And I don't want to have to book [media technicians] time.
IM: I don't have to find [media technician], yes, or I'm doing it right now and I don't know where [media technician] is.
AHT: Plug-and-play.
IM: It needs to be plug-and-play, and these are not going to be plug and play straightaway, but that's just a massive operation to make that happen'

Technology used most often included iPads, switches, microphones (which were found to be very motivating), effects for playing with the sounds, and equipment for layering the sound. Technology was seen as growing fast with many new things available, a particular favourite seemed to be the iPad and apps available for music-making (used and recognised by several stakeholders). They offered a more manageable and portable music therapy session that doesn't necessarily require a tailored environment. '*I'm literally having to take...a couple of bags of stuff, but because of technology I can now set up something in a room.... that is still very powerful.... that doesn't depend on having a wonderful space.... I want to harness what is out there and make it very manageable and portable*' (Music therapist).

Maximising access can be provided by judging situations as they occur in practice and adapting equipment as needed to allow for different ability levels to participate regarding cognitive and physical barriers.

Goals of the Use of Technology

There were different agendas for each of the stakeholders involved, highlighting that any technology used is done so in line with the goals of those setting up its use.

> '*I will always be wearing the therapists hat, i.e. my aim will be, yes, to enhance the music making and everything that you've got down here, but it'll be on the basis of looking at that person's emotional wellbeing, their feeling of being included; all the therapeutic goals, really, and hopefully that will provide an interesting balance, because I think the problem often with projects like this is that it can be easy to lose sight slightly of the development of that person under the umbrella of - but this is a project we want - you know, we want it to work, and then sometimes you lose the individual in that. So that would be, my instinct would be to always make sure we've got that balance*' (music therapist)

The '*outcomes and end product'* (class teacher) model of working are current buzz words in the creative arts and can hamper the creative flow - there was seen to be a pull toward product led rather than process led learning. Product led learning can mean that targets are set and aimed toward rather than activities occurring and learning being the fallout from the process of the activities. To this end the performative element in similar research and projects undertaken at the school in recent years was often not seen as the most successful part of the project, in that the '*products do not always speak of the learning that's gone on internally'* (assistant head teacher). '*Last year's performances were by far and away I think the weaker part of the project; the best bit of the project came in the sensory studio when the children where discovering their selves and their musical capabilities*' (assistant head teacher).

Technology could offer the chance for self-expression, and sense of agency as well as the chance to take the journey to becoming a virtuoso. '*One thing I think I would be particularly interested in is bits of technology that enables someone not just to be engaged with music-making and sound-making but something that they learn to excel at*' (industrial mentor).

When using technology for music-making a focus on creating engagement, allowing discovery/exploration/ participation, and the chance to feel part of something were seen as an important part of this process led mode of music-making. This follows more closely with the model currently used within school where the best learning opportunities are viewed as occurring in process led moments.

> CT: '*There is a massive concern in the creative arts for education that we are all very very fixated on outcomes'*
> *AHT: 'right product led rather than process led'*
> CT: '*That it's got to be, you know, being engaged, discovering, exploring, and in fact you know the arts award training that our staff have had here, is about simply participating and being part of something'*
> AHT: '*It's how we work though isn't it? For the best part, some of the best learning opportunities are in the process led moments, and not in the product which doesn't actually speak of the learning that has gone on internally does it?'*

Fixating on how things move towards an end product can exclude people and create anxiety that can ruin the process and shut down much needed playfulness. '*if we want to widen participation then people need to feel confident about it doesn't matter how it ends up, I need to just get my hands in there... I just need to get my head and my heart anchored into this process*' (class teacher/head of music).

Design Ideals

> *'They'll understand the sensitivity, they'll understand the sense of subtlety, in terms of volume levels, style, even bending notes and stuff, but they may not be able to ever master the fingering that will make them excel at an instrument......but that doesn't mean with help setting up the instrument appropriately, they can't excel at the level they are able to, and that's the power of that' (music therapist).*

Throughout the interactions with the stakeholders the process of requirements capture was undertaken to create some design ideals. There was an overall feeling of moving away from the flat black screen paradigm that was felt hard to manipulate, impersonal, not tactile with a low level of feedback, and lacking in the sensory properties of an acoustic/traditional instrument (industrial mentor). The following design ideals developed from discussion with stakeholders that focus on moving forward from the above issues. These ideals pertained to the requirements for setting up the technology, the way the technology would work in practice, how users might interact and what they might expect, and how to share the tools developed.

There was the goal for the tools to be easy to set-up to be used by an individual, with a focus on tools where *'form affirms function such as the opening and closing of a box to control a filter*' (industrial mentor). This links into the literature around affordances (Gibson 2015), tangible interfaces (Fishkin 2004), and materiality in design (Hinrichsen and Bovermann 2016). A focus on tangible objects that are nice to hold and feel, '*perhaps finished in wood with a nice varnish like a traditional stringed instrument of quality, instantly suggesting that they are akin to an instrument'* (industrial mentor), are wireless and can belong to someone to take home. Preferably some local sensory feedback to give resonance.

> *'One of the things to bear in mind is that one of the reasons pupils like particular instruments, it's about the resonance aspect, and they're getting that sensory feedback. So, I think you're looking at other ways, and if they're not going to get a resonance feedback from the instruments that you're generating then what other kinds of feedback might there be? I think that's an aspect that it would be good if it's not lost, it's still alive in the conversation about the developments, because that is huge things that*

people get either from singing or from playing an instrument or an acoustic' (class teacher/head of music).

There should be a focus on accessibility, not dependent on finger dexterity that offers the user control over the creative process. There should be a focus on tools that enabling multiple people to play cohesively so that group playing can be facilitated.

On a practical level, there should be the ability to attach the instruments to stands, clamps and arms and to provide wires if batteries are likely to run out, and the ability to 'hide' the controls. '*What I have discovered over the years is the ease with which some of our children can end up more interested in the controls than the actual sounds*' (music therapist).

In terms of the creation of the tools, an open source philosophy was seen as being important. This would allow others to access, contribute, and augment the developments from the research, with designs and plans freely available online. Easy to build developments that are aimed at the semi-techie (by providing all the resources to recreate) could be taken and adapted/appropriated by the coder providing the potential to increase the longevity of the project – and a mechanism for what is developed within this research to carry on after the project ends.

'Ultimately the goal is a standalone instrument' (industrial mentor) but initially the MAMI software (computer) would act as a bridge to allow flexibility, with ability to upload different sounds, and configure settings to suit users. Plug-and-play solutions were considered the ideal (assistant head teacher) but require lots of development often leading to a high cost (industrial mentor).

4.3.5 Technological Development

4.3.5.1 Hardware development

Two unique bespoke instruments were developed for this cycle based on identifying the need with the industrial mentor of providing hand-held tools, offering input modalities that might suit different types of needs and uses – the filterBox and the squishyDrum (initially called pressure drum). The filterBox was an attempt to condense elements of interactions akin to those used with traditional acoustic instruments into a smaller form factor, and to do so in a constrained way by locking the output to specified notes from selectable scales scale. The mapping of the filterBox was as such to explore the ability to control sound via many-to-one mappings by using fine motor control. The squishyDrum was an attempt to create a tool that could be hand-held or used on a surface that allowed interaction in the form of pressure on the surface or tapping on the outer shell. This interaction was aimed at a move away from focusing on fine motor skill and finger dexterity to providing a surface to which pressure could be applied. The initial prototyping process and iterations can be seen in the form of six blog posts that followed the process week by week (appendix I). Several iterations of the designs occurred both in terms of form factor and technology used to realise the final designs. The prototypes were used as digital probes (Hutchinson et al. 2003) and aimed to turn the requirements of the stakeholders into a tangible technological output. The design decisions for the tools initially stemmed from incorporating successful elements of previous work undertaken by the author and with the school. Other decisions stemmed from the actions that occurred throughout cycle one as well as discussions with the stakeholders, and discussions with the IM throughout this cycle.

Initially it was felt important to offer the user the chance to take the journey to becoming a virtuoso with a technology-based instruments, by having scope for improvement over time. This was of particular interest from an orchestral standpoint and to allow for maximum capability for expression, growth of self-esteem, and the feeling of ownership and intimacy with the tools. The final tool design focussed on providing hardware that allowed for different modes of interaction. The designs in this way have the potential to provide this journey – depending on their configuration with the software component.

The shape, texture, and feel, of the tools were seen as important to provide a feeling of quality within the material construction. Feedback from the tools, in terms of high fidelity sounds, were considered vital. The combination of both was needed in order to create a multi-sensory experience. Resonant (either from haptic feedback or vibrational feedback from natural resonances of vibrating acoustic bodies) and sensory feedback were felt to be important for creating enticing tools. Plug-and-play solutions were the ideal goals but as recognised in cycle one this would require significant development so whilst the end goal was to create self-contained units, the tools developed in this cycle used the computer as the bridge. '*That's why these are really cheap and really makeable, and if they plug into a computer it's so much easier. But yes, it's not ideal. Ideally, they would have their own speaker on and make their own noise and vibrate themselves and be self-contained and just have an on and an off button, and that is the end goal, but I'm getting there, realistically*' (Industrial mentor). Thinking around form, function, aesthetic considerations, and interactions that adhere to expectation (i.e. squeeze something harder to make it louder) were paramount.

filterBox. The aim with the filterBox (Figure 14) was to create something that when held would allow access to two valve style buttons and a force sensitive resistor, as well as facilitate the opening and closing of the lid to access a light dependent resistor. The elements could then be used in conjunction with each other and separately in an ergonomic way. Buttons were used to enable more functionality and provide tactile feedback. These match the valve style to mimic an interaction with an instrument such as a trumpet. The force sensitive resistors (FSR) were installed to be a continuous controller, which could be pressed to achieve effects. This allows for the mimicking of other instruments such as fretting a guitar and give expression through fingertip movement and pressure. The mapping of the FSR could then be connected to something like the amplitude of the sound so when pressed harder the sound would be louder, following what might naturally be expected from an interaction of that style. A light dependent resistor (LDR) also worked as a mechanism for continuous control to, for example, control a filter or control the mute of a trumpet, or change the sound or volume. Placing the LDR in the front edge at the top of the main unit and, where the lid closes, allowed the movement of opening and closing the lid to control a connected parameter. Fine movement can then be used in order to achieve effects such as vibrato/tremolo/filtering. A parallel can also be drawn between something like scratching (DJ style) and the opening and closing of the lid.

Figure 14 - filterBox

squishyDrum. The squishyDrum (Figure 15) (previously named pressure box) features a deformable surface, like a tambourine/small drum but with a malleable skin that could be pushed into to create or manipulate sound. Initially an array of piezos arranged around the bottom of the circular wooden box was used to create eight pressure points. The box was then filled with foam and topped with a soft tactile yet spongy material such as neoprene. The final design featured three round force sensitive resistors alongside two piezos with a skin made of thick silicon.

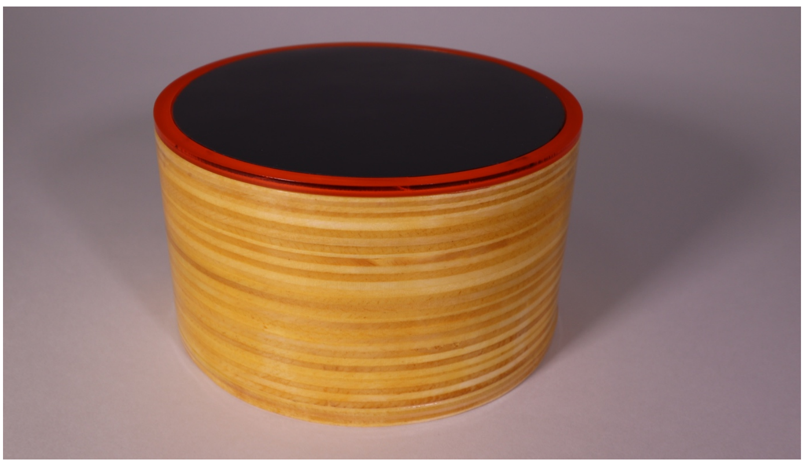

Figure 15 - squishyDrum

4.3.5.2 Software development

The software element, as described in this paragraph, was developed by the industrial mentor. This was named the modular accessible musical instrument (MAMI) and aimed to allow connection of bespoke instruments as well as commercially available instruments and equipment to the MAMI software, thus allow for routing of the signal (sensor information coming from the equipment and instruments) to musical parameters. The MAMI software was developed to provide a modular system that could be adapted to any piece of hardware connected to it. The combination of bespoke hardware and modular software was used to provide a flexible system in order to respond to individual's needs, as a mechanism to provide instruments that could rapidly be put together dependent on these needs. The initial software as developed by the industrial mentor focussed on providing an input mechanism to allow multiple pieces of hardware to be connected to it via common connection and communication protocols (Figure 16). The user interface was designed in Max/MSP and aimed to give the user an easy mechanism to build instruments using external hardware in the form of MIDI inputs, computer peripherals (human interface devices), OSC controllers and/or serial devices (serial device added in Figure 18). It provides a system to connect multiple devices and specify the amount of buttons (any form of triggering mechanism such as a switch) or faders (any form of continuous controller such as the x and y of a joystick) they consist of. A newly created button input (Figure 16) could be set to mirror the hardware, be momentary, toggle on/off, or be timed (with changeable time) (Figure 22). It could also be set to a threshold or have the range reversed. The fader (Figure 20) can mirror the input, be smoothed (by changeable amount), or reversed. The input can then be remapped in terms of input to output and a hit area can be set (Figure 23). The outputs of the devices could also be viewed (Figure 21).

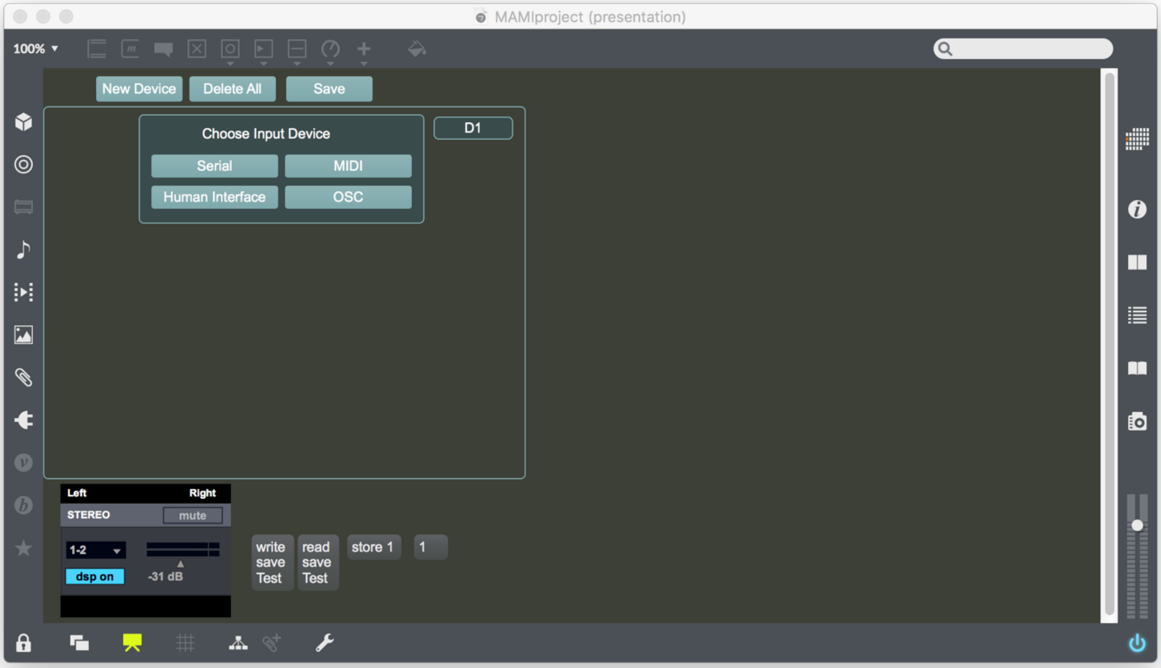

Figure 16 - Basic MAMI Main Screen

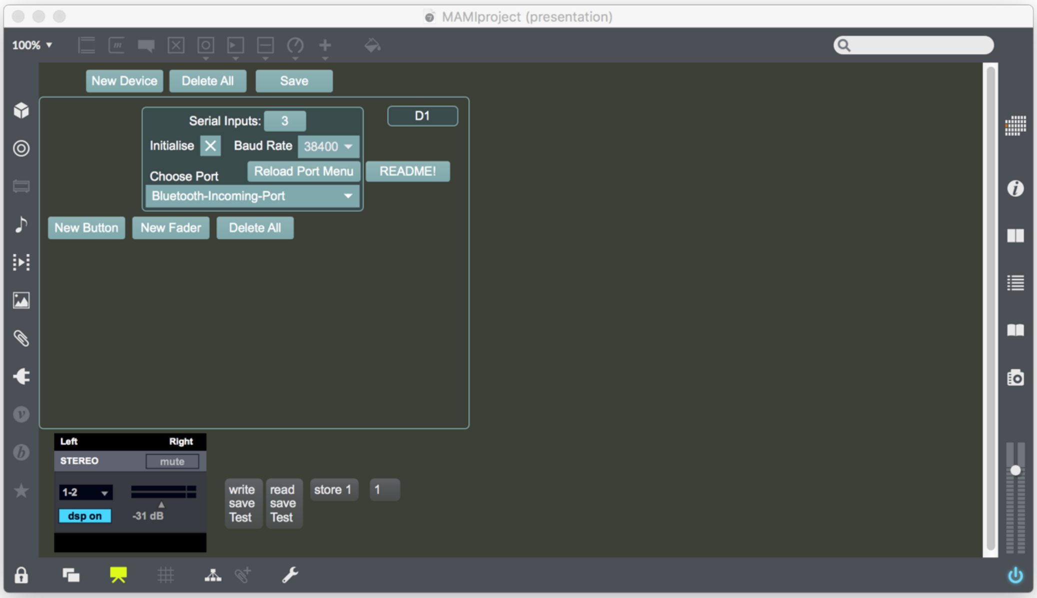

Figure 17 - with an added serial piece of hardware

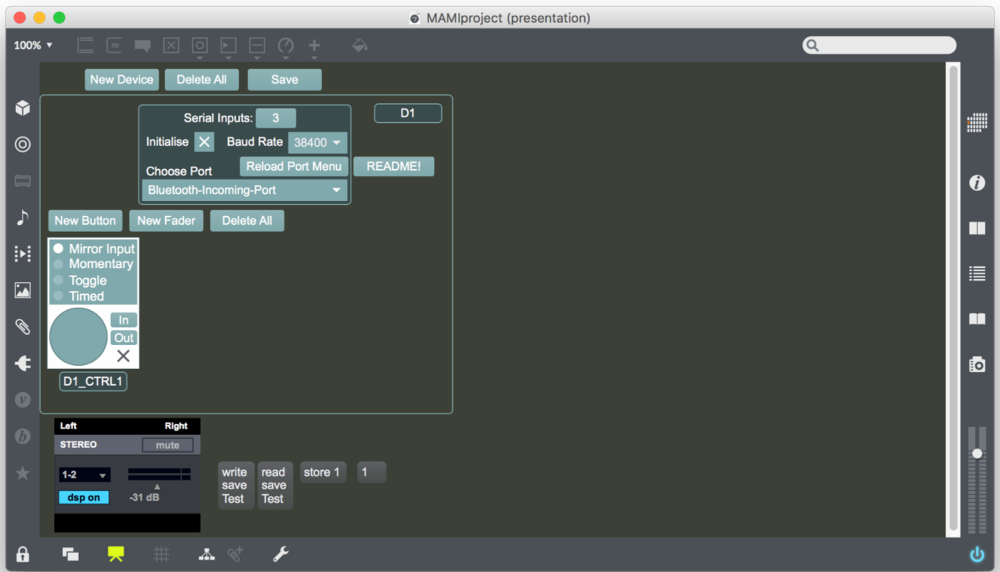

Figure 18 - adding a button to MAMI

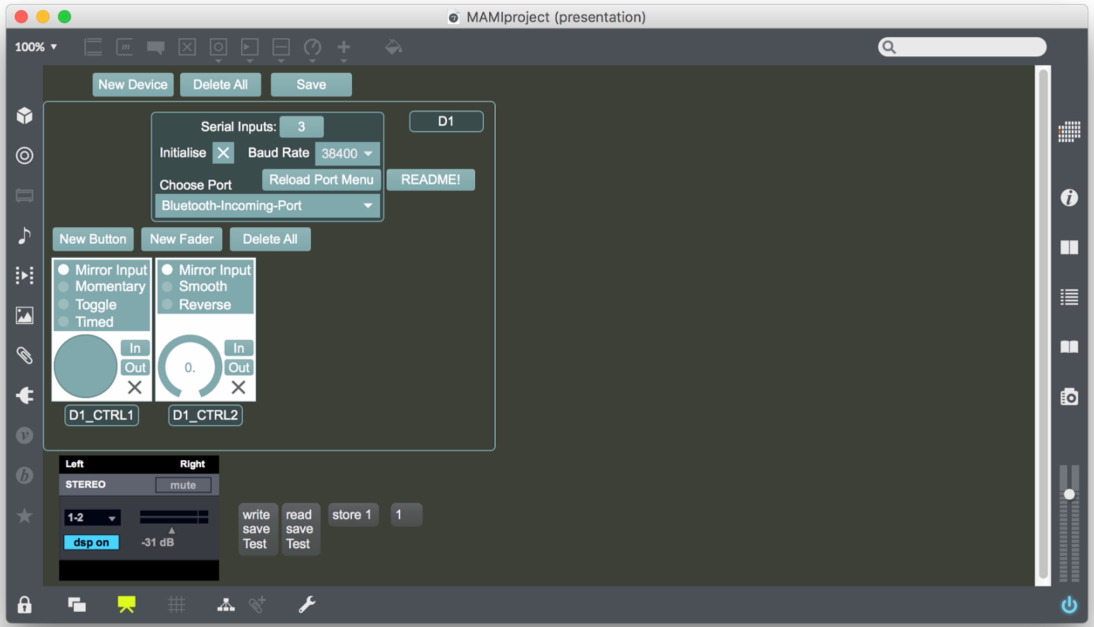

Figure 20 - adding a fader to MAMI

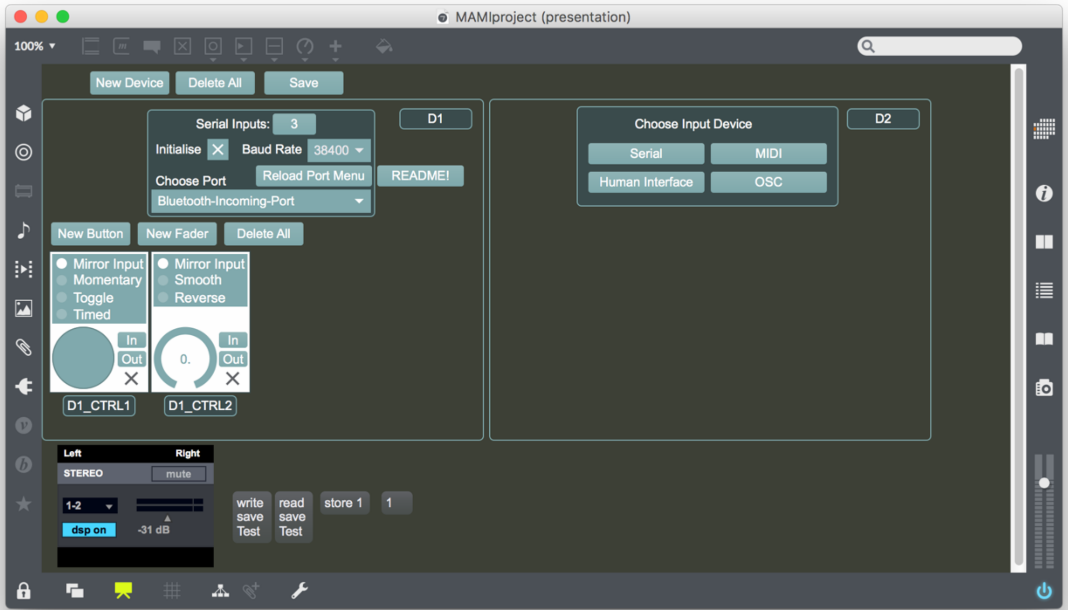

Figure 19 - adding a second device

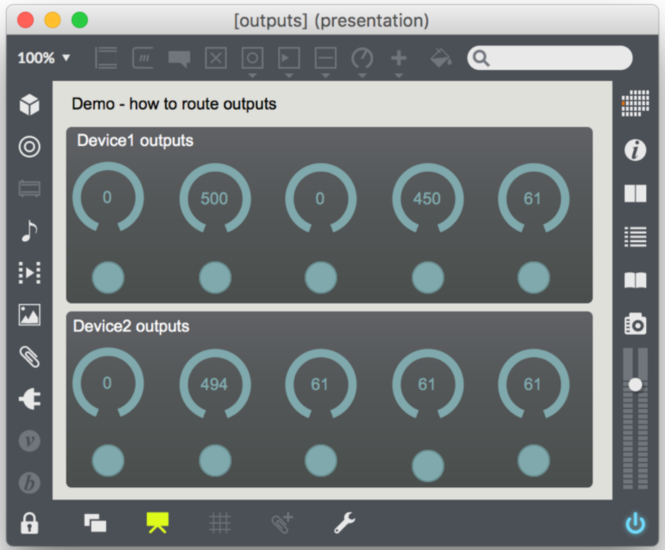

Figure 21 - displaying the device outputs

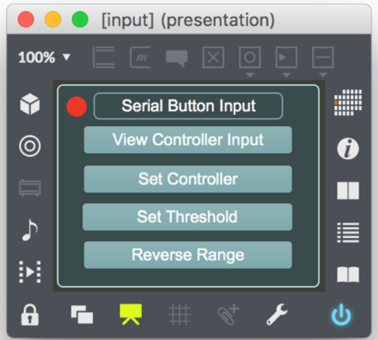

Figure 22 - controls for button input

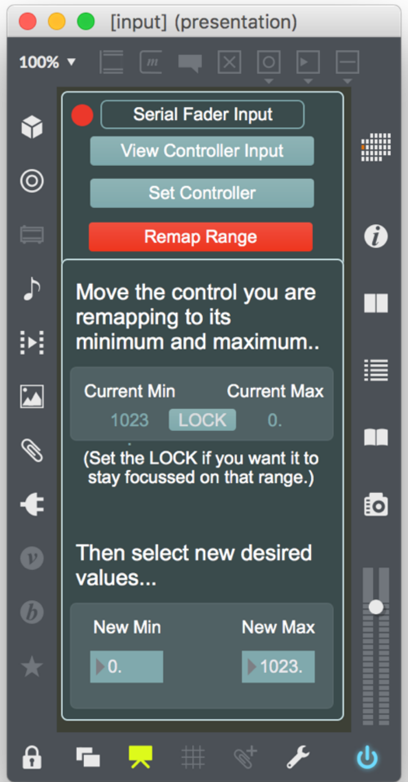

Figure 23 - controls for fader input

4.3.6 Presenting the Prototypes to the Stakeholder Group

The hardware tool prototypes (filterBox and squishyDrum) were presented at the first stakeholder group meetings as digital probes. Both tools had the form factor of the final product however the finish was of a much lower quality. The filterBox was functioning in a rudimentary form (with a bespoke demo patch) and the squishyDrum was presented as a non-functioning probe. They were seen as exciting and as offering flexibility and functionality not as easily achieved with acoustic instruments. **'***It is dead exciting. It is really, really exciting'* (assistant head teacher). *'You could have several different guitars (all with different tunings), but as an instrument they might take home...they can't retune it themselves...... there might not be someone to do that so that's why we are looking at making bespoke instruments, to fill those gaps and give them proper instruments*' (industrial mentor). The filterBox was seen as tailored more towards right handers and it was seen as important to look at the capabilities of the children to establish where the design should go (squeezing the filter box to create sound and physical difficulty with that). This included setting things up to enable instant access. The handheld designs were exciting and allowed for a feeling of ownership when in use. *'I love the size of these things. They're just so ownable, as in, you know, it's mine for the moment'* (music therapist). These could potentially form an 'orchestra in a box' that could be taken home by the children. '*It's like a little taiko drum. It reminds me of like a mini taiko drum. Boom, boom, boom, boom. Yes, it's ace*' (assistant head teacher).

The MAMI software was presented at the second stakeholder group meeting and was seen to offer a potential solution in its modular design. The software was often seen as a sticking point with the creation of hardware, and so a system that could be adapted to various pieces of hardware was the idea presented to the stakeholders. '*We get to this point of we have to build some software for it and its always a massive and time consuming job and we thought well actually this is probably a problem that lots of people face and maybe the one of the best thing we can do it create a modular bit of software that can be adaptable to any bit of hardware*' (industrial mentor). Most hardware instruments are fader and button based. The aim of the software would be to allow users to map a variety of hardware as inputs to a musical output (such as scales, notes, filters, samples) (industrial mentor). A plug and play hardware and software system was seen to be a solid outcome for this research. '*Just be able to see a cool bit of hardware and buy it or borrow it or get an old one and plug it in to something and to start making music straight away without having to program stuff will be a useful thing*' (industrial mentor). The modular aspect offers the ability to transfer tools between users – with something adaptable being viewed as the best outcome for the school in terms of being used, not left in a cupboard, and being a resource for multiple users. '*I feel the aim is to be able to sit down with a new student and be able to spend 15 mins setting up new instrument hardware and software, the sort of thing that would have taken weeks before*' (industrial mentor).

4.3.7 Analysis of Themes

Creating Tools in a School Setting

Stakeholders wanted a user-centric process for tools to be authentically developed and further to this tools that could stay in the setting. Literature suggested designing within the context in a participatory way would allow for a more authentic usage scenario to be achieved (Druin and Druin 1999; Frauenberger et al. 2012; Grierson and Kiefer 2013; Hutchinson et al. 2003), and that having tools to use in the same way as an acoustic instrument (to take home and to develop practice with outside of research time) would provide the most opportunities for engagement and use (Malloch and Wanderley 2007). Developing with users at the centre, and within the context, did create a more authentic usage scenario however it was at times hard to reconcile the needs of the stakeholders with the resources available. The logistical management necessary with regard to developing technology and working within a school setting meant that development was often times halted by factors from either facet. These issues may have been alleviated by utilising designing *with* and *for* users at discrete stages in development as the ongoing development cycles did not have a formal structure which led to some unrealistic goals.

User Motivations

The motivation to use a tool for active music-making comes from interaction with the tool itself (Hinrichsen and Bovermann 2016), and feedback from the interaction (Evans 2005), alongside socio-contextual factors (group or individual use) (Burland and Magee 2014). User motivations are varied and sometimes difficult to ascertain which was evidenced in the sessions that ran in cycle one of this research.

The use of feedback is a crucial mechanism to encourage motivation to use a tool. This feedback is formed of loops which can be local to the device (where interaction with the device is the central feedback loop), as part of the use of the wider musical system (where interaction with the sound is the central feedback loop), or as part of the social experience (where interaction with others is the central feedback loop) – these loops are fluid and can be traversed dependent on the focus of the individual at the centre, their meaning-making and interaction with the tool, the sound, and the others present. In this way, couplings are made between the tool, the user, and the environment in various configurations in the ways explored through our human-technology relations (Ihde 1990, p.72). This can be thought of as a performance ecosystem constituted of the performer, the instrument, and the environment (Waters 2007) in which each component can in itself have its own ecosystem of components that contribute the overarching use of a tool for active music-making.

In effect the tool criss-crosses through stages of examination - to enquiry - to use as a tool (Dourish 2004), in which the object withdraws (as in Heidegger's Hammer -1978, p.69) – through to utilisation in communication with others. These tool states are dependent of the focus of the user. These meaning-making interactions are mediated by the lifeworld and body schema of the individual, as well as being changeable in the ways encapsulated in Blumer's three propositions of symbolic interactionalism.

If the ecosystem of the tool as a music-making device can be considered as constituted of: the tool itself; the feedback loops of the tool in use; and the context within which the tool is used, then each of these elements can provide starting points for design. A requirement to consider local feedback on the tool, musical feedback from the system, and social interdependencies of the tools connected, can be leveraged against the potential needs and performance dimensions of the users as starting points for designs.

Integrating Technology into Practice

Technology such as iPads (Knight 2013), switches, and microphones were seen to be manageable by being portable, familiar, and user friendly and thus used more than more specialist equipment such as the Soundbeam (Magee and Burland 2008). This highlights the need for tools and systems created to both be portable, and to minimise the need for specialist knowledge and technical expertise in set-up and use – especially important for allowing flexibility to change setting and adapt the system when it is in use in response to the user's needs.

Tools are abandoned because they exceed the resources that are/or can be allocated to them. These resources can be tangible, abstract, or ephemeral: tangible in terms of space to store, time to set-up, or money to buy; abstract in terms of how to select tools, how to set-up technology, or how to integrate it into practice; or ephemeral in the case of abandonment during sessions due to issues with set-up or malfunctions or lack of knowledge around technology use in real-time. The 'in-the-moment' nature of the interactions that music therapists and clients have means that any tools that are utilised must be reliable, understandable, and workable in order to not turn from tool to barrier. This is an area where technology has incurred criticism by being seen to be detracting from, or intrusive into, the client/therapist relationship (Hahna et al. 2012) with elements that can be disorientating (Whitehead-Pleaux et al. 2011, p.4) from the added level of abstraction that technology brings or technology that can be distracting to the clients.

Goals of the Use of Technology

The use of technology is inter-connected with the goals wishing to be achieved by its use. Different types of goals were elucidated depending on whether the focus was from the perspective of the practitioner (teacher/music therapist) or the user at the centre. Goals fell into categories as suggested by literature in terms of physical goals (Moraiti et al. 2015)(such as those around strengthening movement and rehabilitation), musical goals (such as playing in time), and personal goals (such as achieving a sense of agency). This research also recognises the importance of social goals (being a part of something) that is strongly interlinked with previous literature in developing communication (Crowe and Rio 2004) and focussed participation (Andersson and Cappelen 2013; Misje 2013; Swingler 1998).

When considering the drive to assess, evaluate and validate tools using empirical methods, which have historically been part of the world of HCI, and further to this the world of NIME (O'Modhrain 2011; Barbosa et al. 2015), there is perhaps the idea that goals are needed in order to create success criteria to allow assessment and validation of tools created. This research would suggest that it is in the process of use, with a focus on playful participation, that assessment can be made on the successfulness of tools and not the products that come out of the interactions or any metrics that can be held against them. It is tricky to try and assess tools when there must be a metric to assess against, often the metrics sit within a specific academic/practical field – it is the view of this research that metrics can not only be subjective and changeable by practitioner but they can stifle creativity and playfulness in some cases. The nebulous nature of evaluation is recognised in the research of Shimy (2015). Shimy and others (Stowell et al. 2008) acknowledging that the task-based quantitative techniques of classical HCI research are not able to be used with the hard-to-quantify aspects of musical performance, and thus a move towards experience-based approaches and user-driven design, congruent with Third-wave HCI (Bodker 2006), is necessary.

Design Ideals

Stakeholders wanted a move away from screen based interaction towards a set of tools that would utilise some of the qualities that were enchanting about traditional instruments. The industrial mentor in particular discussed the use of hand-held tangible controllers that utilised modes of interaction that could be considered akin to those of acoustic instruments, or that had the physical properties of musical instruments in the way they felt to hold and use. This move towards tangible tools that can include both the acoustic ancestry of traditional instruments combined with the flexibility and multi-use opportunities of technology can provide engaging tools (Harrison et al. 2019) which provide a rich interaction experience. A move toward tangible tools 'could reveal the conceptual metaphors of the clients, address their tactile/kinaesthetic hyposensitivity, and act as diagnostic and performance tools to gauge their capabilities' (Kirwan et al. 2015, p.1). It has been suggested that 'GUIs fall short of embracing the richness of human senses and skills people have developed through a lifetime of interaction with the physical world. Our attempt is to change "painted bits" into "tangible bits" by taking advantage of multiple senses and the multi-modality of human interactions with the real world.....[and] the use of graspable objects and ambient media will lead us to a much richer multi-sensory experience of digital information' (Ishii and Ullmer 1997, p.7/8). This can be seen as a necessary move for those that simply cannot interact with touchscreen interfaces or for those that need the deeper resonance of tactile feedback and an interface to grasp against.

In order to address the gaps in provision already explored within this research any tool created should focus on ease of set-up and use (Magee 2006) with 'instant music, subtlety later' (Cook 2001) still being a helpful adage.

4.3.8 Conclusion of Analysis

Long-term use of tools can be affected by the availability and authenticity of developed tools. These tools need to be innovative, engaging, meet needs, and be robust. Engagement with tools come from feedback loops in which the tool, the output, or the social dimension can be the focus.

Opportunities for meaning-making in terms exploring an interface, experiencing a sense of cause and effect, entering a flow state, or communication and interaction with others etc., are mediated by each of these foci. These potential states of engagement are further mediated by the individuals users underlying phenomenology. Consider these varying elements within this ecosystem can be leveraged when designing new tools. An example can be provided here by considering a fictitious user. The user utilises a joystick for mobility (electric wheelchair), has a charismatic relationship with the music therapist that includes banter with them, and is an Eminem fan. The MAMI system is used to provide them the ability to trigger samples from 'The Real Slim Shady' by Eminem through moving the joystick. The joystick is not their focus (as they are used to using this mechanism), this then leaves them free to switch between focusing on the enjoyment of hearing music they like (which has been added through the functionality of the MAMI system), and the ability to use this mechanism to commune with the music therapist who can play against what they are triggering.

Tools can become barriers or be abandoned due to exceeding the tangible, abstract, or ephemeral resources that can be allocated to them, consequently there should be a drive to create tools that minimise use of these resources. Tools can be subject to the goals wishing to be achieved with them. These can be linked to musical, physical, personal, or social goals. Goals can necessitate evaluation and assessment against metrics that may be subjective and dependent on field of study, this can incur difficulties due to the nebulous nature of evaluation. Tangible tools that feature multi-sensory properties provide opportunity for rich interaction experiences. Combining elements of acoustic ancestry with technological flexibility could lead to tools that address some of the gaps in provision experienced by stakeholders.

4.3.9 Moving forward

This cycle was used to explore the research aims of:

- exploring issues that stakeholders have with current music technology by gathering data from stakeholders
- creating novel musical tools from criteria specified by stakeholders and to address gaps in provision found from the literature review by developing prototype designs incorporating ideals gathered from stakeholders, and from the previous cycle

This cycle was used to ascertained requirements of music technology as expressed by the stakeholders, and observed from cycle one, and to translate these into technological solutions. To this end two novel pieces of hardware were created to work alongside a software component named the modular accessible musical instrument or MAMI, as developed by the industrial mentor.

The requirements of a technology toolkit, as deemed to be a useful outcome of the research, were specified by the industrial mentor as requiring the inclusion of:

- Three hardware tools – filterBox/squishyDrum/(and an as-yet-undeveloped joystick based tool)
- Connecting software – the MAMI software
- Supporting resources – as needed to recreate and use the above including manuals for use, hardware Wiki page (how to make the above tools), usage scenarios, code, and CAD files

For the research to move forward there was the perceived need from the stakeholders to make tools that could be given to practitioners. This was partly due to the failure of the researcher being able to create, run, and document sessions, and develop technology concurrently. It was suggested that tools could be developed in close connection with a practitioner, and through this process the needs of the person at the centre could potentially be better be met. From a technical perspective, this meant that the success of the tools could be measured by the efficacy of the functionality of the tool, as deemed appropriate by the practitioner, and the development of features and functionality would be those that helped the practitioner to deliver their goals. The benefits of using a practitioner in close collaboration in development would be:

- they would aid in selecting children and young people to participate and developing assessment outcomes
- the practitioner would have a baseline knowledge of the individuals they work with, as well as how they usually incorporate technology
- the practitioner would have access to the peripheral logistics surrounding any usage of the tools - such as access to space/clients/time slots

Cycle two utilised the stakeholder activities from two sites and outcomes from cycle one to develop two bespoke tools. Cycle three explores the addition of stakeholders from two more sites and the development of a joystick based tool called the Noodler. The Noodlers design was informed by interactions with these stakeholders and was developed in close conjunction with the music therapist at school A.

4.4 Cycle Three – The Noodler

4.4.1 Introduction

The previous cycle was used to explore the creation of bespoke hardware and software informed by stakeholder's input – the cycle focussed on considering the children and young people at the centre of the research, as well as the issues that practitioners, and those surrounding the individual, have with technology. Key aspects explored included the incorporation of technology into practice, and what could be considered successful in terms of technology. When questions of validating the instruments still were not well-defined thorough discussions with the IM there was an identified need to reach out to practitioners. Initially the research started with the assumption that instruments would be made for individuals, or instruments that could be tailored to individuals, thus creating personal instruments that were bespoke to the needs of that individual. These would use design approaches informed by phenomenological understanding. However, after discussion with the industrial mentor, supervisors, and other stakeholders, it was concluded that if the research moved into the direction of creating technology that worked for practitioners, there might be more chance of technology being created that would provide effective functionality for both the central user and the practitioner, in order to aid in active music-making.

The analogy of the tennis match was used. In the beginning the research was focusing on the player and their connection with the racket in the experiential first-hand domain of interaction with tools, but as time moved on it the research became more about the tennis coach by extrapolating out requirements to ensure that the right type of tool (or racket) was provided. This allowed a 'zooming out' to occur in order to see the tool as embedded within a bigger context, in recognition that music-making in the settings, and with the users involved in this research, often constitute the messy real world scenario described in the third-wave of HCI (Bodker 2006) - involving many agents in the process of musicking (Small 1998). This meant including input from more stakeholders, observing their practice closely, and integrating the tools into practice, in order to inform and reform the design. Something that is unique to this research. The triangular scope did not start wide and zoom in as is often the case with research but started wide and zoomed out further in an effort to accomplish a more holistic design philosophy. The inclusion of more contributary voices allowed the wider typology of the tool situation, in context, to feature as an influence on the design of the tools, which could be used by a variety of users and for varying use cases.

This focal shift from the individual's perspective to providing effective tools in context meant there was a push for future cycles of the action research process to work with key stakeholders such as music therapists more closely, and to use their expertise to determine a more solid idea of the requirements of instruments in terms of assessment criteria and outcome indicators. This allowed for more solid grounding when assessing the efficacy and effectiveness of technology developed and also permitted resources to be developed with the foundation of practical use at the centre of the development. Issues surrounding technological success can be seen from dual perspectives (Figure 24).

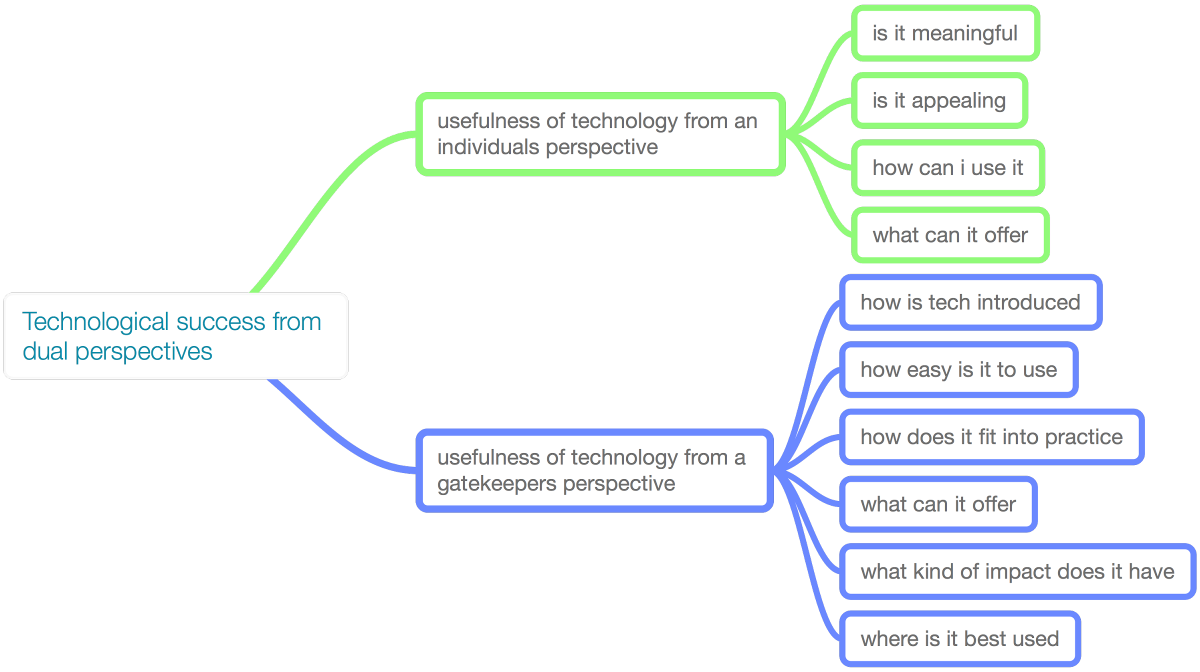

Figure 24 - Technology success from dual perspective

Cycle three details the development of the Noodler in close collaboration the music therapist working at school A, as well as interaction with a music therapist and a music technology subject co-ordinator at school C, and a music therapist and a community musician at a day centre. The activities of this cycle relate to the research aims of:

- exploring the issues that stakeholders have with current music technology by meeting with stakeholders to gather data about technology usage, and observing stakeholders as practitioners to identify where technology could help

- creating novel prototype tools that match criteria as specified by stakeholders, by reviewing gaps in provision, creating design ideals in conjunction with stakeholders
- assessing the effectiveness of these novel tools with a view to improving practices by iteratively developing prototype tools through practical use and working with stakeholder to ascertain success criteria

The stakeholders involved are listed and the main activities in the cycle have been placed in the diagram below (Figure 25). Following this is an overview of each of the stakeholders and their practice, featuring a description of a typical session conducted by them as observed by the researcher. An overview is given of the sessions conducted in school A and the two children that were involved. The themes that emerged from the interactions with the stakeholders, and from the session, are discussed separately. Themes that emerged from the stakeholder interactions were:

- technology as part of the scenario
- areas of application
- technology currently used
- barriers to technology being used
- assessing technology usage
- client interaction
- design ideals

Themes that emerged from the sessions were:

- interactions at the micro, meso, and macro for child one
- issues, and latent informers

There then follows a section on the technological hardware and software developments of the Noodler, and a discussion of its development before an analysis of the themes is presented. Also presented as part of this cycle are eighteen design considerations that form a contribution of knowledge from this research (section 4.4.10), and which went on to inform the creation of the final toolkit. A final section on 'moving forward' then leads into action research cycle four.

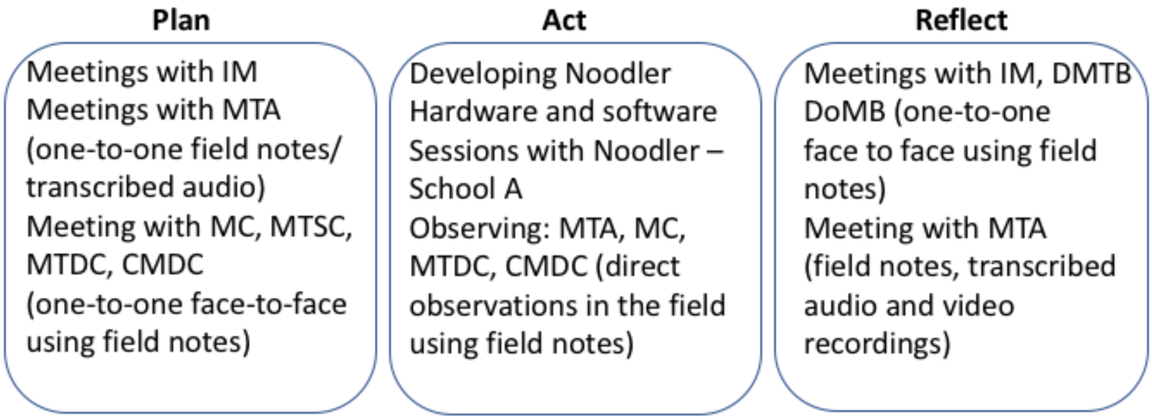

Figure 25 - Activities of the Cycle in Phases

4.4.2 Overview of the Cycle

A third bespoke tool (the Noodler) was developed during this cycle in close connection with stakeholders at four sites. The addition of: the director of music at school B; a musician (who used technology very little) and music technologist at school C; and a community musician and music therapist at a day centre, were included to gain different usage scenarios and perspectives on use of technology, as well as to review the prototypes. Sessions were held with two children at school using the tool developed in this cycle.

4.4.3 Stakeholders and Activities

4.4.3.1 Stakeholders School A

- Industrial Mentor (IM)
- Music Therapist (MTA)
- Child One (CO)
- Child Two (CT)

Stakeholders School B

- Director of Music (DoMB)
- Digital Music Technician (DMTB)

Stakeholders School C

- Musician (MC)
- Music Technologist (MTSC)

Stakeholders Day Centre

- Music Therapist (MTDC)
- Community Musician (CMDC)

4.4.3.2 Meetings with Industrial Mentor

Eleven meetings were held during cycle three. These meetings were used as a sounding board for the technical development of the Noodler and the integration with it into the MAMI system.

4.4.3.3 Meetings with Music Therapist School A (MTA)

Bio: MTA completed their music therapist training in 2002 and received a post graduate diploma in Music Therapy (Dip.Mus.Th.). They practiced as Music Therapist and Arts Therapy Consultant at school A, where they worked primarily with children and young people between the ages of four and nineteen with a variety of special needs. They lecture in the U.K and internationally, and offer training in multi-sensory learning techniques and arts therapy principles of practice. They integrate their skills and experience as composer, performer, recording artist, communicator and music therapist into their practice.
MTA is well established within the school giving the research an advantage at being slotted into the school schedule. The collaborative development with MTA included discussing technology whilst not in session, selecting which areas of practice could be improved with technology, and implementation of the technology within the setting. Fourteen one-to-one meetings ran from May 2017 (before the end of the school term) recommencing at the start of September 2017 (the beginning of the school year) through to July 2018. Throughout these meeting the tools were being developed. MTA gravitated toward the Noodler out of the three tools presented initially thus this was the tool that was taken forward to use within sessions.

MTA thought that the Noodler would be a helpful to motivate people to control movement (improving fine motor skills) and use to be able to use a tool independently (using serious sounds and tailoring to movement to provide significant and powerful experiences in this setting). From the meetings with music therapist in school A there was some gathering of initial technical specifications for the system, looking at how the Noodler could be useful in a variety of situations and for a variety of users. The music therapist identified particular children and young people who might benefit from trying the Noodler. The tool and the sonic output were discussed throughout the meetings and sessions iteratively in development of the final sonic output of the Noodler and the features and functionality that the software side of the Noodler offered. After six meetings, the developed technology began being used in practice within sessions that were part of MTA's schedule and a further eight meetings were held for the iterative development of the Noodler.

Example session

Presented here is an example of an observed session prior to commencing the use of any technology developed within this research. The session was entitled 'The Forest Never Sleeps'. In the session, the music therapist brought his trolley housing lots of sensory stimulating objects into the classroom. On the trolley were all manner of sound and light-based artefacts and interactive toys. The trolley also housed some speakers and an iPad to control the speakers, a microphone, and an amp - which has various effects available. For this particular session, the music therapist brought in some fake grass with which he covered a large area of the floor, allowing the children to lay on it together. There were various props that were used in connection with the sonic soundscape that was played as a backdrop. The music therapist then played the guitar and sang, or played the melodica over this. The sonic backdrop changed over time moving through phases of bird song, wind through trees, and storm, dynamically build up and down throughout. The lyrical mantra was sung as follows... 'the forest never sleeps, its calling every day, listen to its music, makes you want to play'. The music therapist would then sing lyrics that matched the soundscape such as - 'the tweeting of the birds, happy in the trees, listen to their music, makes you want to play' or 'the howling of the wind, rushing through the trees, listen to them rustling, makes you want to play', for each section there are physical sensory props that are handed out. These include plush birds that tweet when pressed, rain sticks, and thunder drums. Feathers and nesting materials are also used as tactile props. The music therapist would often incorporate the names of the children into the song and would move around the room playing and connecting with the children present as well as controlling the giving out of the props.

4.4.3.4 Meeting with Director of Music and Digital Music Technician School B

A meeting was held with both stakeholders together at school B. This agenda of this meeting (appendix J) was to gain more information in order to form the final kit and to gather feedback about the prototypes.

4.4.3.5 Meeting with Music Technologist (MTSC) School C

Bio: MTSC was the subject coordinator of Media and Music Technology SEND School teaching music across primary and senior phases. They worked daily with pupils with MLD and SLD. They were the lead of an initiative to increase pupils' access to appropriate musical (and media related) technologies aiming at further enabling pupils with the means to communicate. This included nurturing and facilitation of *artistic expression*, using technology *if* appropriate and purposeful to do so. They practiced as a 1:1 communication worker supporting young people with ASC, and Learning Facilitator of a provision for pupils with emotional and behavioural difficulties (EBD) prior to beginning Initial Teacher Training, where they spent a number of years as Year 4 class teacher (trained via the graduate teacher programme) before beginning work in a specialist provision for pupils with EBD. At the time if their involvement with this research they held the placement as a teacher of Music and Media (SEND). A phone conversation, three meetings, and one session were observation.

Example session

Around eight young people with mild learning difficulties sat in an arc focussed on the interactive whiteboard. A series of boxes containing different percussion instruments were laid out in front of them on the floor. The MTSC had a giant die that would be rolled by the young people in turn. The number on the die represented a genre of music of which a related music video would be played representative of that genre. After the student had rolled the die they would chose an instrument to distribute to play alongside the music in the video.

4.4.3.6 Meeting with Musician School C (MC)

Bio: Their approach involves the whole class, using music as a tool for social integration and engagement. A musician and composer who has spent over 25 years working with various participants, communities, abilities and ages. They strongly believed that music in a workshop setting is about responding to what the participants and pupils give back to them. They studied music at the Guildhall School of Music and Drama and at City University and worked as a music leader for various national and international Orchestras and music organisations. A meeting and observation of three sessions occurred throughout a morning with MC.

Example session

The children sat in a circle and the musician used the keyboard to play and sing. Instruments such as tambourines and boom sticks were handed out from the music room in which the activity took place. There was also the use of a large drum that the children gathered around to feel the resonance of. A large big mac button was passed around and used to trigger a sample that said 'Hello [musician's name]' as part of a high five song at the start of the session.

4.4.3.7 Meeting with Music Therapist Day Centre (MTDC)

Bio: The music therapist studied music at City University, London and the Guildhall School of Music and Drama, then completed postgraduate studies in music education at the University of Alicante, Spain. After working as a music teacher in Spain and the UK, they retrained as a music therapist at Nordoff Robbins. Their music therapy experience includes setting up several music therapy pilot projects in the Dorset/Hampshire area with diverse client groups including traumatised refugees and asylum seekers; children and adults with physical and learning disabilities; older adults with dementia; and children with early trauma and attachment disorders, who are looked after by the local authority. The music therapist was collaborating with two research projects based at Bournemouth University – this research and another, looking into how group music therapy can help asylum seekers with integration and settlement. They had been working for Nordoff Robbins since 2017. Two meetings (one of which was a final kit meeting with the community musician) and one observation of a session occurred with this music therapist.

Example session

The music therapist used a percussive equipment on a trolley alongside playing keyboard and guitar. Everyone (around 20 clients) sat around in a circle. The session consisted of a song that moved with the vibe of the group and called on each individual to play a part when indicated by the music therapist. The individuals were given time to respond. Two people in wheelchairs played a cymbal with a beater and the chimes. A couple of people had horns which they engaged with each other as the brass section, most others had tambourines and one person had a whoopy whistle which provided some funny moments.

4.4.3.8 Meeting with Community Musician Day Centre (CMDC)

Two meetings (one for the final kit discussion with the music therapist) and an observation of a session occurred.

Example session

Around 30 clients sat around in a circle. The community musician gave everyone a choice of instruments to play – they had been working with this group for a few weeks and so had some ideas of what they liked to play. There were percussive instruments such as drums, bang tubes and chimes. The music therapist played the guitar and one client played the electronic organ. The session consisted of singing in the round, turn taking and choosing songs for the community musician to play as a backdrop for the other percussion based activities.

4.4.3.9 Sessions at School A

Two children used the Noodler as part of the music therapy group sessions within their respective classes. Child one used the Noodler for thirteen sessions and one performance and child two used the Noodler for six sessions. Some audio/visual footage was taken during some of the sessions when particularly successful technology usage had occurred, sometimes what was seen could not be filmed again so there were several extraordinary moments that only remain in field notes and memory.

Child One School A

Bio: 'This pupil is 17 years old and has a diagnosis of autism spectrum disorder. [They are] non-verbal other than about 10 learned words which are only usually spoken in repetition. [They are] able to use a symbol to indicate a need, for example 'toilet' symbol on the door. [They] need sensory stimulation and moves continually, 'flapping' hands or running around the room with high knees, and is usually moving [their] head from side to side. [They] love 'flappies' and will flick them continually to keep [them] calm. [They are] unsure how to regulate [their] emotions. [They] love music and will relax and listen to music at times, and loves any activities involving music such as sherbourne, tacpac or sensology' (class teacher).

The aims of music therapy with this student were to prepare for life after school through developing independence and capability of choice. Working within the sessions was structured to accommodate for this. There was a focus on creating awareness of cause and effect through the pleasure of music, and perhaps then moving into the next step to understand timing. The justification for the use of technology over acoustic instruments in the case of child one case was offered by the music therapist:

> *'Many on the Autistic Spectrum are 'tactile defensive' - find all sorts of textures and objects uncomfortable, and would rather not 'take the risk' of even trying. So for* [child one] *the value of 'technology' is that one simple object overcomes this limitation. Once* [they] *can become familiar and comfortable with the simple hand held object, this will give* [them] *access to all possible sounds, 'bypassing' as it were the textures, shapes, objects that would be the source of* [their] *resistance to exploring them'* (Music Therapist School A).

Child one also performed with the Noodler at the school Christmas concert in a church hall for 300 people. Appendix C features an overview of this activity alongside comments as made by the music therapist on analysing the footage from the performance.

Child Two School A

BIOGRAPHICAL INFORMATION REQUESTED BUT NOT RECEIVED

The justification below was offered by the music therapist for the use of technology over acoustic instruments in the case of child two:

> *'Technology simply gives* [them] *access to sound and music that very little else could, given the limitations imposed on* [them] *by* [their] *condition, the weakness in* [their] *limbs, hands, fingers etc, and of course the fact that* [they] *has to 'live' pretty much all day, in a wheel chair'* (Music therapist school A).

4.4.3.10 Final Kit Meetings

Final meetings were undertaken with two of the five recipients of the toolkit (school B and the day centre) to present the elements of the toolkit, gather responses about them, talk about other potential elements (which due to time constraints did not occur), discuss success criteria, and think about case studies of use (agenda can be seen in appendix J). Some of these points were not applicable as kit assessment became outside of the scope of this research due to time constraints.

4.4.4 Themes from Interaction with the Industrial Mentor and Stakeholder Meetings

Eight themes emerged from interactions with the industrial mentor and stakeholder meetings. These were: technology as 'part of the scenario'; areas of application; technology currently used; barriers to technology usage; removing fear as a barrier; assessing technology usage; client interaction; and design ideals.

Within these meetings prototypes of the tools in developments – in terms of the hardware – were shown to the stakeholders as probes which then led to new findings and iterations of designs.

Technology as 'Part of the Scenario'

Where technology is used it is '*part of the scenario*' (music therapist school A) however the main goal of music therapy is about communication and relationship.

> '*Technology is simply part of the music making so it would be very rare that say all that happened was a child was sitting on the Musii and that was it or the only thing that was happening that was it or somebody was playing the Theramini. Once a child or student has grasped the potential, knows how they want to work with an instrument, then my job is to turn that into something meaningful by joining in. So, it's always supporting the ultimate goal, which is we are doing something together, this is about communication and a relationship, it's not just come in here and have half an hour or fun, I hope that it will be fun but the aims behind music therapy are communication, enabling a child to communicate when they can't or don't want to use words. Learn about the value in relationship, a lot of our children live incredibly isolated lives, where self is absolutely central to everything, so to encourage some of our children to relate to another person in an appropriate way, is a big thing, and music-making is, as we know, a most wonderful way of doing that, and with this technology that I am describing those can become tools in this process*' (music therapist school A).

Technology should only ever be used in its rightful place and not ever allowed to dominate - especially in SEN settings where children can get fascinated by knobs, dials, faders etc. and not with the sound they are making. '*Tech is full of fascinating elements that may not have to do with its purpose. Some time ago I bought a sampled piano in and children fixated with the volume control, weren't focusing on enjoying the piano as the instrument'* (music therapist school A). Technology should support the music therapist to empower the children and young people. A basic principle of music therapy is that everything is accessible, the only rules are that we don't harm each other or the instruments, and the therapist can create the structure. Technology has to fit this principle. '*Last thing you want to do in the world of therapy, is set up a situation where you are telling someone no or don't or do it this way*' (music therapist school A). Technological is used to '*reward or enhance*' (music therapist school A) the music therapists' practice.

Areas of Application

Two areas of application were mentioned – one based on providing physical provision i.e. to turn tiny movements into big sounds, and the other to support learning needs i.e. to encourage the development of fine motor skills for those with no physical barriers. '*Children and young people can sometimes have difficulty achieving fine motor control, often when there is no physical barrier*' (music therapist school A), as can be seen in developmental disorders such as Autism. These fine motor skills are fundamental when interacting with objects in the world and form the basis of independence. Exploration of small hand-held instruments may provide a motivating tool to encourage development of fine motor skills. These skills can then be utilised in other areas of interaction.

Technology could help by being a motivating tool in both areas of application to '*enable those who don't normally join in'* (community musician) and used to encourage movement and flexion of limbs with links to goals of physical development/therapy. The use of technology should be about enabling people, '*not disabled or differently abled but enabled'* (community musician).

There is not a 'one-size fits all' approach but individualised needs that have to be catered for, this can include exploring styles, scales, genres, as well as more specifics - such as the use of atonal music for those who may find timed movement difficult, or exploring selected frequencies for those that have patches of deafness, or difficulty in processing some frequencies.

Technology Currently Used

Examples of technology currently used and the pros and cons of these were explored with the stakeholders. The iPad, the Musii, the Theramini, and the Soundbeam were mentioned.

The iPad which was used for its apps or for its sound production capability. '*I suppose that I would have to say the most powerful single piece of tech in the room is the iPad because there is just so much now accessible on it in terms of generating sounds and soundscapes....what I don't mean is handing out the iPad to a child and saying that's yours you do this ... it would be either go to one of hundreds of apps I now have got that are about soundscapes or rhythms or the visualscapes that are highly motivating because they generate colour and shape and it would be through the whole system* (of speakers)' (music therapist school A). For sound production the iPad was used to play music from apps, personal libraries or specific apps like YouTube. '*That's just straight forward playing albums that I've got or my own music through a system and saying we are going to use that as a canvas and join in'* (music therapist school A). The iPad was used with different age groups and apps such as Keez and Bebot used to record, playback, and loop audio (community musician day centre).

There was discussion of the Musii, '*extraordinary invention.... the beauty is I can control the sound, the scale, the volume from a wireless tablet so the youngsters aren't getting fixated with the control, their task is to sit, lie, roll over the cones, and they will create sound and generate music. Wonderful on many levels, it's very physical and some of our children have to be physical when they are making music, its intriguing and quite mysterious at times, the sounds are powerful and grown up sounds, you can bring in drum beats and take them out. So that is an example of tech at its absolute best in a music therapy setting, enabling a child, motivating visual, and powerful, but nothing on it that will cause the obsessive behaviour*' (music therapist school A).

The Theramini, '*although there are controls on this I, as the therapist, do the controlling, and then as you know, the generation of music is all about the aerial that senses proximity so the child or student's way of music is all about not touching, which is extraordinary thing to be able to say to somebody this is one musical instrument that you play by not touching and if you do it won't work. If you think about that its great as it saves any battles of no don't do that. Again, don't need the 'don't and no', and again powerful* *sounds, and I can control effects on it, pitch correction, and volume, and it's got a nice range of presets*' (music therapist school A).

The Soundbeam was mentioned in all of the settings, which was seen as being difficult to use and set up for those who are not musically trained. Playing the Soundbeam was seen as an abstract concept with cause and effect that was not obvious.

Other technologies mentioned were the use of loops within digital audio workstations such as Ableton Live and Magix Music Maker, and the recording of sessions using the computer. A PA system and microphone were mentioned as being used with positive effects. Switch based technologies like the big mac were used as a vocal recorder and playback mechanism, or as a mechanism to allow inclusion in sections of the session.

Barriers to Technology Being Used

Whilst there was technology available in the research sites visited in this cycle there was no space to store, or time to learn how to incorporate technology. Things that required batteries were seen as being 'faffy' and prone to not working. Other perceived barriers were cost, training time, and size of technology. Portable tools that could '*connect to any smart board'* were seen as a benefit (digital music technician school B).

Class size had an effect on whether technology was seen to be useful. Engaging the whole class, and being able to keep the engagement was seen as compounded by the use of technology. This included having a class of 20 students with '*not enough technology to go around and that kids would be waiting for the technology*' (music technologist school C). Being able to cater for all the students and their specific needs in sessions was a key feature to establishing engagement and one that was seen as not easily attained with technology. One stakeholder spoke of '*rolling in the percussion trolley*' (music technologist school C) and seeing the disengagement from the students. Logistical problems were the quick turnaround between classes often spanning across several physical locations within the research sites.

When considering the barriers of training**,** music classes were often facilitated by those with no music therapy training, or specialist music practitioners in post. There was the idea that music therapists were '*becoming a luxury*' (music technologist school C) and increasingly teachers were becoming the music leaders within schools and sessions. There were also issues faced by those trained or considered the '*techie*' one when attempting to pass on knowledge to others, in that this would have to be facilitated, or they would be asked to be the facilitator. There was recognition that a lot of times staff, who were not musicians, would be facilitating the use of technology and that any examples of use of technology should be done with emphasis on the ease of use. In terms of technology working for the therapist – '*taking the fear out is a big thing*' (music therapist day centre).

Assessing Technology Usage

In assessing the instruments there was a focus on process led practice with activity following the lead of the process. Aims would come out of music and interaction (music therapist day centre and community musician day centre). In terms of success criteria for assessment of the success of any musical interventions, having fun and smiling were considered good signifiers. On a deeper level technology could be deemed successful by contributing to skill development such as timing and dynamics.

Client Interaction

Skills and experience should be able to be taken into account both in terms of current ability and previous experience when creating systems with the user at the centre. Considerations of physical ability such as limited grasp and reach, eye movement, breathing, vocalising, and stomping were examples given. What was important was using the client's ability to provide them with an opportunity to engage and assert their autonomy. If clients have had musical experience, this should be leveraged as they may need support with only part of the music-making experience. An example given was of a former blues guitarist who had experienced a stroke - by using musical knowledge already held, in combination with current muscle movement or previous muscle memory, a new instrument could be created that both supported current experience whilst providing mechanisms to overcome acquired disabling barriers.

There may be a varied level of perception by individuals leading to heterogeneous awareness of cause and effect. Some clients may be overstimulated and others may be under stimulated, a multisensory approach should be considered to enhance effectiveness of interaction if needed. There may be the need to appeal to all senses for some clients with PMLD and not in a simplistic manner. The community musician stated that '*repetition bears* *fruit*' when working with some clients, particularly those with PMLD, this meant using the same exercises and providing choices within that framework.

Physiological connections were valued when practicing music therapy. Gestures such as eye contact and breathing were used throughout sessions, especially in the case of clients with PMLD with physiological connection being a key aspect of ascertaining the wellbeing of the client. At the core of the interaction should be intimacy, even mirroring the type of intimate interaction between a mother and baby, in which mimicking and echoing movement and expression are used.

The '*sound of music is not important, the sound of people expressing themselves through music is the important connection*' (community musician). '*Everybody wants to communicate*', '*The music doesn't have to be therapeutic or musical, it is a musical echo from intensive interaction'* (community musician). The therapist spoke of '*stepping back and letting the client speak*' (music therapist day centre) to achieve a sense of agency in terms of musical voice**.** Stating that the less they do, the more the other person does. This included giving the autonomy to change sounds, and not making assumptions on tastes of clients.

There was an expression of the social importance of being able to play together. '*Facilitating the chance to make sounds and make choices in a group activity is beautiful'* (music therapist school A).

Design Ideals

'*Grown-up sounds'* (music therapist school A) that were *'aesthetically pleasing'* (industrial mentor) with '*rich sonic feedback'* (industrial mentor) were seen as a priority. A self-contained and portable wireless instrument was the ideal with control via a separate interface. In terms of usability - instruments created '*must be easy to use*' and '*easy to set up'* (music therapist day centre, and school A). Traditional instruments were seen as a combination of '*tactile stuff'* (digital music technician school C) which had appeal in terms of design aesthetic (the feel of the wood, the sensation of the interaction with the instrument).

Set instruments with limited purpose were seen as potentially easier to use. Specific technology requirements included being able to plug into an amplifier, be easy to clean, linking to an iPad, a bank of presets of sounds as a necessity, as well as something set up upon initially turning the system on. Presets were seen as important to facilitate instant access and should include samples that are common for storytelling, with the ability to add own samples which would then allow use *'from nursery to adult'* (director of music school B). An initial pool of three palettes of scales featuring: '*a major scale, sound effects, and a middle-eastern scale (all in perfect pitch)*' would be a minimum starting point (music therapist and community musician day centre). Universal access was seen as important with the need for technology to be motivating and provide resonance. Multi-modal ways of interacting would allow different populations to access the technology in different ways as some children might be touch averse etc, but there should also be consideration to potential sensory overload with conditions such as epilepsy. Multiple instruments, that encourage the awareness of joining together, were seen as the ideal (with the therapist as the glue). Favoured aspects of the prototypes were the portability, smallness, enticing material (wooden), and the tactility.

4.4.5 Themes from Sessions with the Noodler

Below are themes that emerged from the use of the Noodler by the children at School A. These themes have been developed through ethnographic methods of observation and analysis with some input from the music therapist as indicated. The findings of these sessions are presented for each child separately to highlight what emerged from each user and usage scenario. For child one the themes of: interactions at micro, meso, and macro level emerged. For child two the themes of: interactions; issues; and latent informers emerged.

The Noodler was setup and facilitated by the researcher, whilst being embedded in sessions that were ran by the music therapist. Both children used the Noodler only as part of these group sessions or for a few minutes prior to the sessions officially starting. The Noodler was connected to the researchers laptop, into the MAMI software and the Noodler patch, and then the output was routed through a Saffire 6 USB Audio Interface into an amplifier, which was placed as close to the user as possible.

4.4.5.1 Child One in Session with the Noodler

Interactions at Micro, Meso, and Macro

The way the child explored the device can be split into micro, meso, and macro level interactions. The micro level relates to the user and the tool and the connection between them, the meso level pertains to the interaction between the child and tool with the music therapist and/or the environment within which they are present, and the macro level reaches out beyond the child and tool interacting in a particular space and time into the bigger picture in terms of the child developing through the use of the tools.

Micro Level Interaction

At the micro level the child explored the device and was very interested in it, carefully focusing on it and pulling it close to their face, pressing all the buttons, and stroking the material. They would demonstrate interactions such as pressing the button or moving the joystick with one finger at a time or retriggering one note with the same motion repetitively. The inherent form factor of the Noodler meant that there was some difficulty at times to move between the joystick and the buttons. This was due to the child playing with their index finger whilst holding the device in the opposite hand.

After several sessions, the music therapist suggested there be a few minutes to show the child any new sounds that had been added to the Noodler's canon prior to the session starting to help orientate the child on how the Noodler worked. The music therapist stated that '*there was a marked difference in* [child's name] *approach after having a few minutes at the start of the session compared to going straight in*' (music therapist). This highlighted the need to give the child the chance to hear what they were controlling. There were multiple indications that the child was enjoying the interaction with the Noodler: the way they held and examined it; the rocking of their body; the big smiles; the look of being lost in thought whilst playing. The child at one point expressed clearly that they didn't want the Noodler to be taken away by pulling the device out of reach sharply. These interactions involve inability to locate the intention as previously discussed, in whether the interaction was for the interaction with the tool, or for the sound creation that comes with the interaction.

For some sessions, it was more obvious that the technology was not appropriate. One particular session child one was sleeping on arrival and in a '*despondent mood'* (teaching assistant stated). The child played with the Noodler as an object but showed no sign of the triggering interactions as they had done in previous sessions - even with the Noodler was set to trigger their favourite song. When the Noodler was removed, the child did the actions for the song and seemed to have an uplift in his mood which clearly indicated that the technology was not appropriate for that child at that time.

Meso Level Interactions

At the meso level the music therapist thought the child connected the cause and effect, knew that they were creating the sound, and were actively into it. In one specific session, when the child was instructed by the music therapist to play, they responded by alternating between pressing each of the buttons with an index finger rhythmically, they would then stop after a short while before resuming when instructed again by the music therapist. This might suggest that while the cause and effect of the interaction and sound may or may not be there, there was definitely a cause and effect relationship established between what the music therapist wanted and what the child did. This might suggest that in finding a motivating tool (such as the Noodler) work could be done to develop some understanding of cause and effect, or of expectation and connection with another person, solely through the inherent properties of a motivating object.

Macro Level Interactions

At the macro level there were clear connections with play, and the potential to use the Noodler to engage individuals in developmental domains. Thomas and Harding (2011) outline five domains that have the potential to be developed through play: physical, cognitive, emotional, social, and spiritual. Research has previously shown that using music technology has been used in several of these developmental domains already (Clements-Cortes 2013; Magee and Burland 2008). Hutt's taxonomy (1981) specifies three categories of types of playful behaviour that could lead to development of the individual within these domains. These include activities that involve epistemic play (in terms of using curiosity to learn about their environment), ludic play (using imagination and fantasy) and games with rules (in learning about placing themselves in the world and their social interaction with others). In using the Noodler, both in terms of exploring the tool itself as well as the sound that is created, epistemic play and curiosity were demonstrated by the child. The Noodler provided the opportunity for ludic play in terms of role play (by using sound samples relating stories) and the use imagination – by allowing the child to express themselves through the varied responses they could make with the Noodler. The Noodler was used to explore games with rules by providing a tool to explore things such as turn taking, following the conductor, or playing alongside others, in order to develop social interactions, and potentially enhance the learning of one's place in the world.

4.4.5.2 Child Two in Sessions with the Noodler

Interactions

Micro level interactions saw child two exploring the device using one hand, trying a range of modes and positions to activate the buttons and move the joystick. They manipulated the Noodler around and also used other parts of their body such as their mouth, and teeth to move the joystick, before settling into holding it as it was designed to be typically held, and using a thumb to move the joystick back and forth to trigger the samples. The child began saying hello into the end of the Noodler as if it were a microphone.

Meso level interactions saw the child creating a new game of throwing the Noodler to see if the researcher would catch it, the researcher would then respond with a happy face or a sad face if they missed the catch. Sometimes the sound would trigger as it hit the floor, and this seemed to be exciting for the child. This shows that appropriation led to engaging interaction but also highlighted the need for robust tools.

Issues

Various issues were manifested through the use of the technology in the settings. These related to how the technology was physically setup and the effect this had on being able to control the sound. An example was an amplifier being set up next to a child the therapist had selected as a potential participant that instantly showed aversion to the Noodler, meaning that the Noodler was subsequently passed around to see who else might like to play (being wireless was useful in this instance). Child two was therefore sitting around two metres from the amp with no way to reposition either the amp or child two, both due to the space being full, and power sockets being inaccessible. This set up meant that cause and effect could have been lost. To mediate this the sound level was increased. The sounds used were those of the train track and whistle noises, which at times could be quite harsh. Another child in the class was sound sensitive and could not exit as the door was blocked, the door to outside was accessible but it was a very cold day. This meant that there was a bit of an impasse and highlights the importance of knowing who is going to be attending the session, and what their sensitivity and sensory needs might be. Some children require direct and loud interaction and stimulation and others can be overwhelmed by overly loud and direct stimulation. This is a key issue when working with groups in this setting. There should be provision to minimise discomfort for individuals as needed (ear defenders for example, or a quieter place within which to still participate) whilst also maximising the opportunity to facilitate individuals that may need stronger stimuli. This issue also related to the type of sound that was used, in that the samples and MIDI notes and drums were triggered with a set velocity. This is an issue inherent to digital musical instruments, and the decoupling of input and output, in that there isn't the ability to control the volume with the energy put into the system, as is the case with acoustic instruments, unless it is programmed in. In the case of the sessions, there was some riding of the volume button to mediate this and to make the volume of the playback of triggered notes or samples fit the dynamic of the rest of the music. This 'manual volume riding' was particularly used in a session where an acoustic drum was played and built up to a loud crescendo to allow the Noodler to be heard but not at excessive volume.

In some sessions the backing track played through speakers by the music therapist matched the samples on the Noodler meaning they became drowned out. It was difficult to distinguish the Noodler from the track unless the 'wrong' section was triggered in which case it sounded dissonant and confusing. This shows that there should be careful selection of sounds that are used as background and sounds that are used with the technology, otherwise there could be issues with sounds blending in too well or appearing to be sonically disruptive.

Time of day was identified as a factor affecting success, in terms of participant fatigue as well as the types of previous activity they had been involved in. Child two had swimming prior to one session and was very fatigued, not wanting to use the Noodler and throwing it onto the floor and saying '*no more*' at the start of the session. This shows that the use of technology or the type of activity that requires the full attention of the child should be carefully positioned within that child's day to ensure the best chance of success. Though interestingly, when asked to perform a solo for the class with the Noodler by the music therapist the child obliged, handing the Noodler back once the solo had finished. This is concurrent with the statement by the assistant head teacher that some children will be motivated by a group setting, or it could mean that the child could potentially be responding to the music therapists request because they are motivated to please that person.

Latent Informers

The researcher was informed of child two's favourite song (Mamma Mia) by the teaching assistant, and so programmed samples from this into the Noodler. This showed the importance of gaining input from these *latent informers* that surround the child and know them best. Child two seemed much more interested in the Noodler when these sounds were programmed in. They used their hand to push the Noodler button onto their mouth to trigger the sample quickly. The starting notes of the song were mapped to the Noodler buttons with the Mamma Mia chorus segmented and mapped to the joystick directions of up, down, left, and right. There became a significant interplay between the therapist, and the child as they used the Noodler buttons to trigger the starting notes of Mamma Mia. The therapist would copy the sound and the child would press the buttons to trigger them. This led to hysterical laughter by the child, the TA commented that she had never seen her laugh like that, and all the staff seemed transfixed. The child was asked about their favourite songs and, with help from the TA, which were then incorporated into the Noodler for further sessions.

4.4.6 Technological Development

4.4.6.1 Hardware Development

The Noodler (Figure 26) is a repurposed Nintendo Wiichuck that carries within it the functionality of two buttons, one accelerometer, and an X/Y joystick. The Noodler is connected by a short cable to a transmitter box which then sends the data from the on-board sensors to a receiver plugged into the USB on the host computer. The cable effectively makes the Noodler wireless to the computer but allows the bulk of the weight of the battery and micro-processor to be offloaded from the hand. The main component is off-the-shelf and can be plugged into the connector housed within the transmitter box. The software that receives the data is an adjunct to the basic MAMI software. The transmitter uses a 9v battery for power. The first prototype of the Noodler featured the addition of a retrofitted scroll wheel on the side of the handheld part, however this was subsequently abandoned in further units to allow for replacements to be purchasable off-the-shelf.

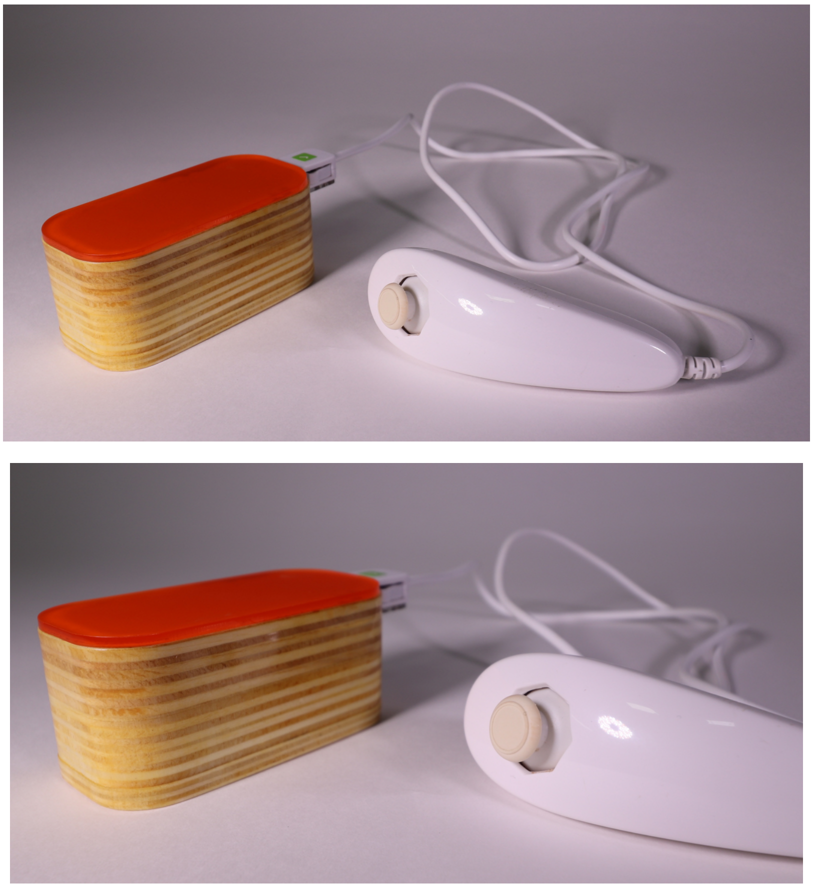

Figure 26 - Noodler Hardware

4.4.6.2 Noodler Software Development

The Noodler software patch (Figure 27) is a standalone patch that utilises the basic MAMI software to stream data to it. The patch allows the joystick and buttons to be used to trigger up to 16 samples or notes when entering coloured trigger zones. The trigger zones can be drawn in and saved or loaded from presets. Figure 28 shows four example layouts:

- Four trigger zones on the hard left, right, up and down of the joystick
- Two trigger zones on the up and down of the joystick
- Six trigger zones to be navigated by the joystick
- Six trigger lines each with nine trigger zones mimicking the layout of a guitar fretboard

The black areas show a '*point of rest'* (Magee 2014a, p.88) within which the user can opt to stop the sound. There are 2 modes: MIDI note triggering, or sample triggering. MIDI note triggering enables the selection of notes that are triggered by assigning a note to a colour or to a button, or by constraining trigger zones to a scale. Note selection can be saved and loaded back in. The instrument can be selected (from 128 choices) as can the octave (-2 octaves to +4 octaves). Also selectable are MIDI instruments from the general MIDI standard or MIDI drums. There is the ability to select if the note stays on whilst the target dot stays within a trigger zone or whether the triggered note has a set duration - which is also changeable. There is a pan dial to allow the MIDI output to be panned to the left or right.

Sample triggering allows the coloured trigger zones to activate a sample. A folder of samples can be selected from those supplies or the user can upload their own by dragging and dropping or reading in via pop-up dialog box. These can then be assigned to the different colours of the trigger zones. Samples triggered by the buttons can also be changed. The sample can then be set to play to the end or stop as soon as the trigger zone is left. The output from the sample triggered can be panned to the left, right, or stereo to enable sound separation for two speakers if the Noodler is being used alongside another tool in the toolkit.

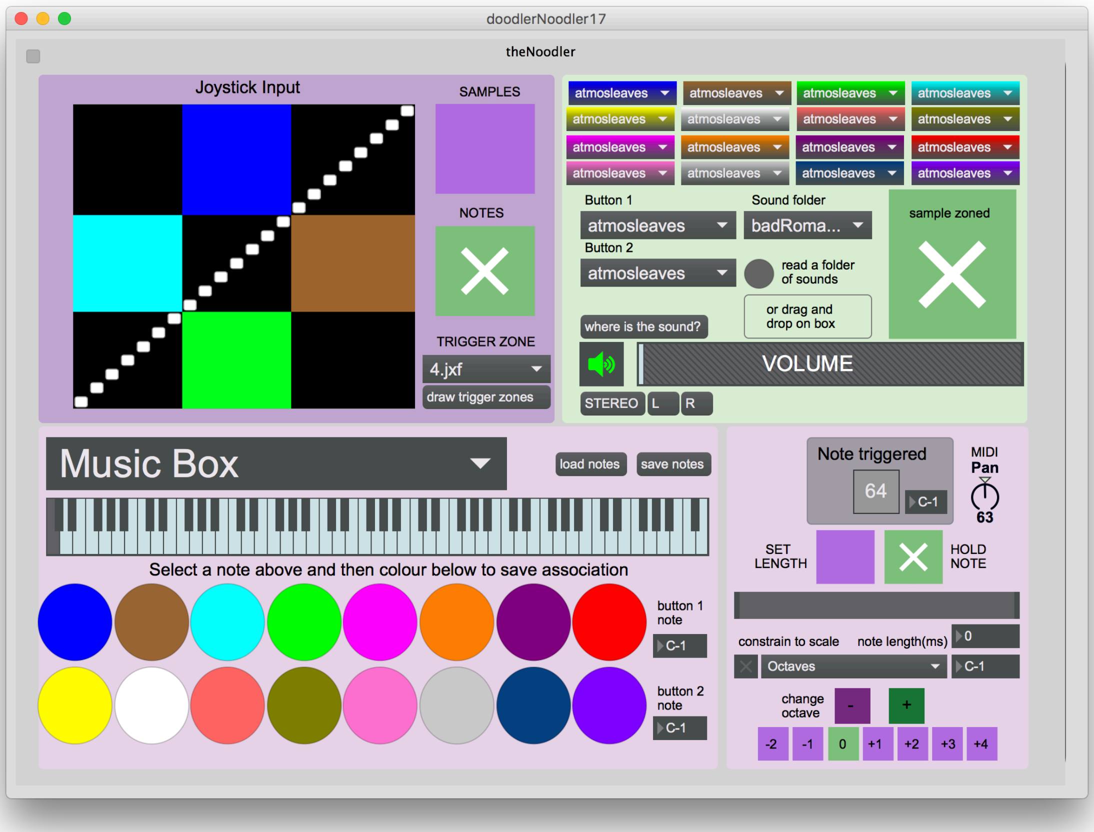

Figure 27 - Noodler Patch

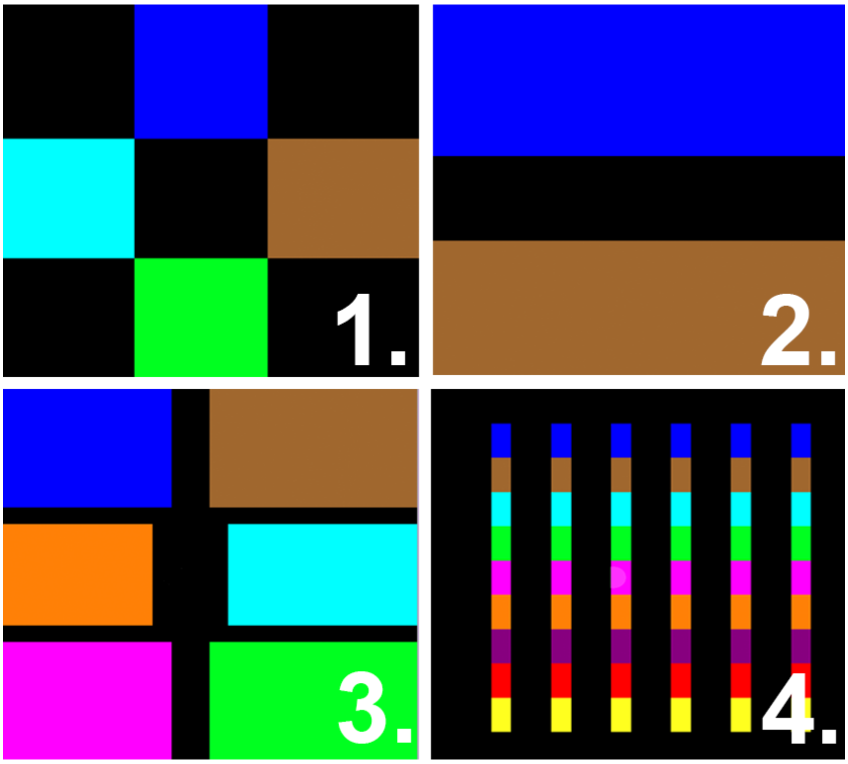

Figure 28 - Four Example Trigger Zone Layouts

4.4.7 Development Discussion

High fidelity and appropriate (in terms of content) sounds were seen as important, as was being able to change the sounds quickly, and have the sounds at the right volume level. In terms of sounds used, with both children the MIDI instrument of music box was used or the taiko drums. The rest of the time there were four samples split into the four main directions (up, down, left, right) of the joystick and over the two buttons.

The graphical user interface (GUI) was sometimes difficult to navigate, this was partially alleviated by the development of the ability to control the settings using the iPad

Technology being used to 'change the goal posts' has being discussed within this research, however it was exemplified in the sessions, in that it was tempting to change settings to 'fill the gaps' between the sections where the Noodler was played. The researcher asked whether the Noodler should be set to trigger something between the songs originally specified by the music therapist (non-pitched percussion based to allow it to fit), but the music therapist thought this would cause confusion for the user. As the Noodler was not used for every song in the session, there was the choice to either turn down the volume or remove the device from the child. The issues with turning down the volume was a potential disconnect between cause and effect. This might lead to the child thinking that it the device was broken or that it didn't work for them. A common problem in this context is one of 'learned helplessness'(Koegal and Mentis 1985) in that the child no longer believes that they have the ability to achieve the outcome, or have any control, so they effectively 'give up'. Not only might the volume being turned down confuse the child, but it would in effect be opposite to what they were expecting, which again could be a problem in those children that prefer and are motivated by repetition and predictability in feedback. The Noodler however, was changed when used throughout the session entitled 'The forest never sleeps'. The triggered sounds were chosen to match the sections of the song and of the physical props that were circulating the room. When thinking of concerns of having to carry resources, the Noodler in this case replaced several other physical props. The Noodler did not fully embody all of the sensory qualities of the props, in that there was no change in its physical sensory properties as experienced with other physical props, so this was a limitation. For some this could be beneficial, such as those that prefer predictable interaction and may not want the constant changing of objects.

Technical problems meant that the Noodler joystick failed to spring back to central position, this could highlight a problem with moisture ingress. The ability to swap out the main Noodler component (for another off the shelf Wiichuck) was useful both in terms of fixing technical problems, as well as having a readily available cheap component that could belong to each user to minimise health and safety and cross contamination issues.

The flexibility of the system was at the forefront through the requests of the music therapist. This meant that sounds could be removed and changed on-the-fly provided that they were in the bank of sounds already added to the system. This feature was useful when a sound effect did not fit within the scenario. At times integrating new sound was difficult, if for example, sounds were requested close to the start of the session as each sample requires preparation to add to the system (top and tailing and ensuring good looping/sound levels etc).

The use of the Noodler was featured at the start of the session when the music therapist would spotlight the child using the device. This would then garner applause from the classmates in the style of letting the soloist have the spotlight. This was helpful to reinforce the cause and effect and let all present focus on what the child was playing with the Noodler.

By the end of the sessions the Noodler usage had become sound effects based. This was due to the types of songs that were being used in the sessions, which primarily focussed on the children choosing their favourite song to play over the music from the therapists speakers, and to be able to be heard in this mix. The music therapist felt that starting with recognisable sound effects and moving toward more musical aspects would be more effective when the children gained more awareness of how the Noodler worked. Small sections of songs were used as samples and triggered over the top of the songs played by the music therapist. This was in an attempt to simplify the sonic output with the aim of providing a stronger cause and effect bond. Examples of used songs were London's burning, Daft Punks 'Get Lucky', and sound effects from the Peppa Pig theme. Motivating sounds were used as a mechanism for initially using the Noodler and exploring the device. This mode of introduction and initial exploration was useful in the context however, this has to be balanced with issues around obsessive and compulsive behaviour, or behaviour that is not seen as desirable in terms of physical movement. Several times during the research there were thoughts about instruments that could tie into some of the stimulation-based behaviours (such as flapping) that some of the children would display – if these were desirable - perhaps suggesting an avenue of future research.

The ability to work in session and then iteratively change the programming to address issues as they arose was very useful. An example of this was the addition of the functionality to trigger a sample to play to the end or to leave the trigger zone and have the sample stop, which fixed the problem of creating cacophonous sound in some scenarios. This addition opened up potential avenues for exploring the cognition of an individual in terms of musical development and evidencing knowledge of cause and effect, and also allowed the child to explore a playful element of interaction.

The researcher was permitted by the music therapist to be autonomous in setting up the technology and following suggestions of others. This was helpful to allow the research to move organically in terms of the way the technology was used, and the sonic output, but it bears thinking about the point made by the music therapist of not saying 'no' and 'don't'. In constructing specific gestures to trigger sound with the Noodler there then would be a situation where there would be a 'right' way to play the instrument. This would be a step back toward the rigidity set in the realm of the traditional acoustic instrument. While this could provide a mechanism to positively challenge some to move toward goals of developing fine control, or nuanced particular movement, it might obfuscate others. Again, this was about forming a balance between expression and constraint and between open field versus specifically tailored interaction to allow the individual to flourish.

In some respects, the full potential of the Noodler was not explored, in terms of the data that the device has available (accelerometer, buttons, and x/y joystick), but the system did provide a tool that worked in context at the time, to provide what the music therapist required. There is future potential to expand and extend the complexity of the sonic output by changing the software end of the Noodler, as the Noodler in the end, provided only limited note triggering and sample triggering functionality.

4.4.8 Analysis of Themes

Technology as 'Part of the Scenario'

Technology should be considered as a part of the music-making experience and as such should support the ultimate goal of the practitioner. Technology can be used to reward or enhance what they do and should not just being used for technologies sake (Magee 2011). Accessible tools are ones that are open to being used however the user wants to use them and do not dominate. Domination can come from technological elements being distracting - some individuals will be drawn to screens and controls (Hunt et al. 2004) - or from overstimulation (Frid 2019). Contraindications and benefits of the use of technology can centre around the practitioner or the individual (Partesotti et al. 2018). Considering how the tools sits within the practice and where the potential benefits or contraindications lie has an effect on the design of the tools. The design of new tools has to take into account the context that they will be used within in relation to both the practitioner and the user at the centre, and how these two combine into cohesive music-making scenarios that are two way in nature.

Areas of Application

Two areas of application we evident within this research – however both involved physical provision. These physical provision were translating small/atypical physical movement for those with physical disabilities into usable input gestures; and gaining control over physical movement such as fine motor skills for those with developmental disorders such as Autism. This highlights a potential need to rethink how users' needs are categorised. Evaluating need in the past has focussed on distinguishing access needs and learning needs but as evidenced in this research both areas of application were access needs, with one stemming from a learning need. This reductive categorisation of target user groups into those with motor (physical) disabilities and those with cognitive difficulties (Jense and Leeuw 2015; Frid 2018) is not helpful for developing tools. Instead a turn toward the social model of disability is needed in terms of providing tools that aim towards embodiment and away from impairment (Shakespeare and Watson 2002) by considering users' needs as interlinking physical and cognitive requirements, and thus mapping users capabilities to desired musical outcomes, in effect mapping the mode of input to the sonic output as suggested by Doherty et al. (2001). Focussing on the control characteristics of the user, as echoed by others when designing DMIs 'we should start by considering the body language of the performer' (Jack et al. 2017, p.1).

Areas of application can vary depending on factors of goals of use whether to provide access to the individual using the tool, in order to allow expressive interaction, or to facilitate development of skills such as realisation of cause and effect. This can be linked to using technology to provide a means to translate movement into sound (where the tool withdraws, in the phenomenological sense (Heidegger 1978, p.69), and the expression becomes the focus) and using technology to provide a focal point to interact with sound (where the tool is present as a means to work with/against and development of fine motor skills are the focus). This can be exemplified in two fictitious example users and use cases. One is a child with a physical disability that restricts finger movement to a one centimetre span that can be utilised to provide expressive control of several musical notes via a joystick. In use, the joystick withdraws, as the child embodies the tool to express themselves through the sonic output. The second is a child with Autism where fine motor skills prove to be difficult. In this case the notes are provided on the same span however the tool is worked with and against by the child in order to control the triggering of the notes. The tool remains the same (a joystick with a centimetre span triggering notes), the interaction remains the same (both people move the joystick to trigger the same notes) however, the focus changes.

It can be beneficial to think of a specific child when designing the functionality of the instrument, akin to the use of personas in the world of HCI (in which fictitious users are created that exemplify typical traits of real-life counterparts), to allow for designs that have a basis in real world issues that can then translate to other users. Considerations such as interactions using minimalistic movements, and how this can be translated into a musical language for an individual to be able to communicate and interact are useful when designing technological systems. Technology provides unique opportunities to traverse both the means to an expressive embodied output and the means to the development of skill attributes, in a motivating way.

Technology Currently Used

Technologies that was packaged as instantly usable and self-contained - such as the iPad - and those with separate control and interface elements - such as the Musii and the Theramini - were favoured. This separation meant that settings could be changed by the practitioner and any potentially distracting elements (such as screens and controls) could be hidden - an issue which has been highlighted in literature (Grierson and Kiefer 2013).

The troubles with the Soundbeam revolved around its difficulty in use, and the abstract nature of using an invisible beam to realise cause and effect (Andersson et al. 2014). Although there are clear advantages to technologies such as the Soundbeam in terms of allowing variability in range (from 25 centimetres – 6 metres) and sonic output, which can offer tailorability to the gestural dimensions of the individual user (Swingler and Brockhouse 2009).

More common use technologies such as the PA and microphone, and switches such as the BigMac allowed users to add own content thus giving a method of inclusion in session and showing the importance of appropriation as a route to ownership and authorship (Zappi and McPherson 2018). This customisability and in some cases appropriation is a key aspect when considering traditional musical instruments, in which the instrument is set-up with the nuanced idiosyncratic detail that each musician stamps onto them, which is an important part of ownership. A benefit of the digital musical instruments is the ability to add an infinite number of sound palettes which can include user-created content in order to create tools that are personalised for musical expression (Robertson and Bertelli 2014). This is of particular importance when considering the range of users and scenarios of use within the this research.

Barriers to Technology Being Used

Barriers as stated in the literature were still present in practice. Namely space to store, time to learn how to incorporate, lack of training, technology being faffy and unreliable, cost, and fear of use. An additional barrier appeared to be the size of the group - with facilitating multiple users in a session with technology being seen as not logistically possible. There was also the fact of moving locations of sessions and rapid turnaround of the practitioners day. Specialists and location for them to practice were felt to be decreasing alongside the squeezing of resources due to budget restrictions. These all had an impact on incorporating anything new, or outside of the tools. The percussion trolley occupying this resource space seemed to reign supreme in nearly every session attended as part of the research. Perhaps it is within this space that the gap in provision is more evident – a gap for something that is portable, but offers interaction beyond mainly non-pitched percussion resources. How can access to active music-making be given those that cannot access the percussion trolley to enable them to participate, and in such a way that easily slots into practice – especially if this practice is losing resources such as space and specialist staff? A report conducted in 2015 (Welch et al. 2015) found that 80% of special educational needs schools employed a specialist music teacher, a figure that was of much higher proportion to two decades earlier, and 4/5 of schools had a dedicated music room. These figures appear to suggest that provision is still available in schools despite what was stated by the stakeholders involved in this research.

The barrier of the 'the group setting' can be considered a sub category which potentially traverses all of the categories as stated in the 'barriers to effective use' section of cycle one. What was highlighted was that the practice of music-making within the sites and sessions attended throughout this research revealed an 'all or nothing' integration of technology in terms of supplying all of those in the group with technology, as was the case with handing out the percussion instruments, else it was potentially seen as an extra drain on resources to set up technology for individual users. These scenarios of group use or individual use, could potentially inform the design of tools in that they must focus on easily integrating into practice (by being quick to use and easy to customise to users) and/or that multiple tools could be setup to facilitate multiple users at the same time.

The prototype tools presented were not seen as instruments but more as controllers. This might be down to the material quality (Schindler and Hinrichsen 2007) of the prototypes as presented in that they did not feel like instruments, or look like any other instruments and as such did not conform to any of the mental models (O'Modhrain 2011). Therefore users did not have the same expectation for them to be instruments. This was seen as a pro in that '*staff might be less afraid to use them'* (community musician day centre) due to a perception of less room for error. The prototypes being unfamiliar tools was seen as potentially useful for creating new mental pathways, as there would be no preconception of how tools should be used (something which has been discussed in cycle two). Fear can be elevated by the use of technology (will it work?), however fear of playing things wrong can be alleviated with technology (I know it will sound good). Technology must work to remove the practitioners fear of use whilst at the same time provide a mechanism to reduce fear of playing incorrectly for the user. Perhaps there is space within the creation of new tools to break down several layers of barrier (in terms of both access to music-making and socio-cultural issues), in that technology has the potential to provide oppressed communities with access to music-making, but its use may also aid in diminishing of some of the cultural elitism that exists around the playing of traditional musical instruments (Crooke 2018) by providing new tools, repertoires etc. These elitisms can be seen when considering the different attitudes people express when being asked to run a music workshop versus being asked to run something like an art workshop, the latter tends to be more acceptable to undertake as a novice, whilst the former seems to strike fear. Technology based tools can alleviate fear of playing the 'wrong' thing and lower anxieties around initial access by providing tools that scaffold users with the music-making process.

Assessing Technology Usage

As discussed in cycle one, assessment is a difficult matter when dealing with success of new tools being created for music-making. In this cycle an effort was made to find out how new tools might fit into the assessment schedule within the sites of the research. Again more difficulties were faced. These were: the need to remain process based as specified by the stakeholders (with assessable metrics coming out of music-making activities); lack of standardised curriculum (one school used three curriculums); and curriculums which did not appear to utilise the full capacity of music as interconnected to other subject and developments domains - despite music being an everyday practice within the sites visited during the research. Stakeholders specified that external frameworks (such as Sounds of Intent), and pathways to accreditation would be difficult to integrate due to time constraints. This was consistent with an implied gap in accreditation provision (Bott and Westrup 2012; Welch et al. 2015). Independent of the framework used to document the progress of the users, success criteria can be categorised based on goals around increasing wellbeing (whether this be physical or cognitive or combinations of both) or on skill acquisition (which traditionally might be connected to playing a musical instrument to become virtuosic). Within this research process led learning was carried out in both sections of free and explorative play, but there is opportunity to utilise structured assessment of skill acquisition (when thinking of developing musical skills). Much in the same way that a traditional instrument might be learnt from formal lessons combined with practice and exploration.

Client Interaction

Client interaction was seen as involving: utilisation of physical ability; level of current and/or acquired skills; and awareness of feedback. It was seen as imperative to ascertain the levels of each and to not make assumptions, in order to provide tools that work for the individual. Particularly with determining levels of cause and effect which is a crucial determinant as to whether DMIs can potentially work (Magee and Burland 2008). These tools can then provide important opportunities to allow the connection needed, through interaction, for the music therapy process.

Design Ideals

Design ideals involved what the tools should look, feel, and operate like, the type of interaction that is afforded, and the feedback that is being produced (sonic or otherwise). Considerations of sonic output centred around such concerns as: the aesthetical limitations of MIDI (Cappelen and Andersson 2012); and equipping tools with a range of sound 'palettes' of preset scales/timbres that enable instant access, being seen as a priority. The idea of 'instant music, subtlety later' (Cook 2009, p.218) was crucial in terms of instant response to both user interaction (Hunt and Kirk 2000; Wanderley and Depalle 2004) and practitioner setup. This can be considered to be a balance of achieving 'a low entry fee' (Wessel and Wright 2001, p.12) against achieving 'no ceiling on virtuosity' (ibid p.12) due to the need for the tools to be multiuse, and therefore flexible, but also multiuser with both facilitators/practitioners and central users. Tools being easy to set up and use, such as being limited in purpose, can have benefits in providing 'tighter constraints [which] may paradoxically lead to a richer performer experience' (Zappi and McPherson (2018, p.1) thus enabling the 'emergence of personal practices and preferences in neurodiverse groups of children and young people' (Wright and Dooley 2019, p.162).

The drive for self-contained and portable tools lends itself to the use of tools that are wireless - with wires being potentially problematic in the setting (Magee and Burland 2008) due to distracting qualities, the restrictions they cause in movement (Streeter et al. 2012), the health and safety risk they may pose, and/or the fragility of cables in reducing robustness (Grierson and Kiefer 2013). However going wireless can bring issues such as loss of connection and extra complexity in set up (Ward et al. 2017).

An interesting desire for some of the stakeholders was that tools be compatible both with one another and with current technologies such as iPads, amplifiers, and traditional instruments, in order for them to be fully usable them as tools for the given scenarios that the practitioners worked within. In being flexible in terms of adaption of the input, the mappings and the output, tools could be created to suit the client. This also included peripheral practicalities such as tools being easy to clean, and aesthetic considerations such as tools being made of enticing material that provides a desirable tactility alongside multisensory accessibility.

4.4.9 Conclusion of Analysis

Methods of integration should consider the user and the practitioner in a holistic context. Technology as used in the music-making process is to provide support with concern to suitability for purpose. Areas of application can be found by considering the needs of the users. These needs are often a mixture of physical and cognitive needs and as such tools created should consider both as control characteristics of the user. These needs can change the focus of the tool in the interaction, and as should be considered in order to create suitable technology systems. Packages of instantly accessible technology that provide good quality interaction, allow for tailorability, are portable, and reveal/conceal (Kiran 2015) ways of setting up the tools by enabling/constraining (ibid) how tools work are beneficial. The combination of the above allows for appropriation and customisation to better suit the end users and/or the usage scenario. Barriers to usage include barriers as suggested in previous cycles, alongside the addition of potential subcategory of 'the group setting' in which technology must aim to work within the resource space that is currently inhibited by the percussion trolley. This might involve making tools that facilitate ease of use and customisation and/or multiuser scenarios. Fear can be a barrier to technology usage but can also alleviate fear in terms of providing tools that reduce perceived room for error.

Assessing technology is difficult if not aligned to existing frameworks within each setting. This highlights a gap in accreditation provision. Client interaction comprises of physical ability, skill level, and awareness of cause and effect, each of which should not be assumed, and should be ascertained to provide useful tools.

Flexible tactile tools, formed of changeable inputs and outputs, that feature a selection of presets, with instant access potential, are necessary – these can be considered as assemblages of balances such as: being wired/wireless; constrained/opened up in terms of expression; made of natural material combined with electronics; stand-alone or connectable via the computer as a bridge. Interactions with these tools occur at the micro, meso, and macro level. Each of which can be used to inform the design of tools and each of which can potentially utilise playful behaviour in various categories, to contribute to development within several domains.

Any tools created have to consider the context within which they will be used to ensure that there is minimised risk harm being caused through their use. The inclusion of design features and functionality that allow for the comfort of the users and those around them remain of central importance. At times this will mean not using the tools at all. Latent informers are important providers of helpful information that can guide the construction and use of successful tools. Integrating tools can bring up challenging design problems - these challenges often present the chance to design some functionality to help mediate them. Developing changeable tools means that they will be changed, this can both help to provide a one-tool-for-all in terms of: usage throughout a session, and in matching sonic output to user needs, but also means that there is no consistency to the output, which some users might find confusing.

4.4.10 Design Considerations

Presented below are 18 design considerations for instruments for users with complex needs in SEN settings. These considerations have developed from literature reviews, practice based work by the researcher and via reports of similar work. Much like Perry Cook's (2001) design principles some are human/artistic and some are technical, or in different terms some relate to the instrument, some to the user and others relate to the context of use. They begin with a focus on the design of the instrument itself, move out into the design of the system and then into designing for the context of use.

1. **Consider each layer of the system** – There is commonly a modular 3-part description to DMIs. Moog (1984) identified 'the sound generator, the interface between the musician and the sound generator, and the tactile and visual reality of the instrument that makes a musician feel good when using it' (p.214), Pressing (1990); the control interface, the processor, and the output, and Hunt et al (2004) the interface, abstract, and synthesis mapping layers. Think of the separate elements that create a modular system, where each element can be enhanced, replaced (Farrimond et al 2011), adapted, modified, or automated depending on the need of the musician. This enables a tailoring to an individual's specific needs and capabilities, both in terms of how they can interact with the system (sensor inputs, gestural capability, or other ways the individual can provide energy to the system), and what the system provides back (feedback mechanism and also content of that mechanism). Making interactions meaningful with mapping between the player's control of the instrument and the sound produced being one of the most dominant issues in the creation of new musical interfaces (Fels 2004) and each layer of a system allows for meaning to be added and also allows for the system to provide support where needed in a flexible way.

2. Decoupling the action and sound production – In DMIs the excitation-sonification relationship is broken. This can lead to opportunities but can also create problems. The dislocation of excitation and sonification is exciting (Paine 2009), in that any small movement can be used to produce large sonic changes but can also cause problems with cause and effect for some users as dislocation of action and reaction can be an abstract concept for some. Feedback is often provided separately from where the excitation occurred and, if not delivered in a way that can be accessed by the user, can render gestures meaningless. According to the stakeholders at school A to mitigate this feedback should be placed close to creation of sound, either embedded or with an amplifier, for example, touching to the musician's seat for vibration [personal communication].

3. Expression vs Constraint – How much expression is offered can affect how engaging the instrument is depending on the user. 'The one-for-one (mapping) scheme may be inspired by a wish on the part of the instrument designer to make the instrument 'easy to play', but it is a debatable point whether this simplicity is in fact a desirable thing, or whether this results in an instrument lacking in expressive capability' (Kirk et al. 2002, p.1023). Mappings which are not one-to-one are more engaging for users (Hunt and Kirk 2000) however 'good musical instruments must strike the right balance between challenge, frustration and boredom' (Jorda 2005, p.174). Rich experiences tend not to come from devices that are too simple, however devices that are too complex can 'alienate the user before their richness can be extracted' (Jorda 2004) so there needs to be a balance between both elements that suit the musician playing. In a SEN setting expression vs constraint are better expressed as scalability and configurability, used to provide a system that suits the individual's needs and is empowering vs overpowering. Scalability and configurability can be provided at the interface level by using flexible modular input mechanisms, by dynamic interfaces that can be configured to the user's abilities to create potentially complex and expressive musical gesture from simple inputs, and/or at the content level by being able to map these inputs to meaningful content. There is an important balance to strike here as teachers at school A said that 'opening up expression means it takes longer to get outcomes and in an environment driven by outcomes things can get done for people which can lead to an unsatisfactory learning experience [personal communication]. Instruments should be able to scale in content to suit the user's ability and allow for improvement over time. Making things configurable and scalable to the individuals using them is paramount in this context as there is no typical user.

4. **Continuum of Control** – Johnston et al (2009) identify three modes of interaction characterising the musicians approach to virtual instruments. Each offer different levels of control over the system; Instrumental: where the musician prioritises detailed control, ornamental: where the musician surrenders detailed control to allow for the software to transform the sound, and conversational: a two-way conversation between the musician and the virtual instrument that shapes the musical direction the musician takes. In the SEN setting there needs to be a continuum of control. This continuum of computer control vs human control of the system can be used to scaffold the capabilities of the individual and provide support when needed whilst allowing maximum control of the instrument. For example, consider playing a melody; a switch (which is a very common assistive technology tool) could be used to scroll through a melody note by note, or a movement in and out of an ultrasonic beam, such as those featured on the Soundbeam (Williams 1989), could provide the same potential but the musician has to successfully select the right zone to break on the beam, both these musicians are being supported to different degrees to achieve the same outcome. Systems can support those with different levels of needs to play together.

5. Natural Interaction (when I move you move) – This principle relates to matching the gesture of excitation to the sonification in a way that makes sense to the player. 'A direct relationship is established between the physical gesture, the nature of the stimuli and the perceived outcome. The resulting awareness is multifaceted and has been at the core of musical performance for centuries' (Paine 2009, p.142). The gesture used has to have an intuitive result from the sound; e.g. you can hit a snare drum in a multitude of ways and produce a variety of sounds and dynamics. The sound should genuinely express the nature of the movement in a 'symbiotic' relationship (Hewitt 2014) i.e. if you push harder the sound is louder; what a player might naturally expect from an interaction of that where the form and function link with the shape of the design style. Instruments that offer and interaction that mimics traditional instruments (for example using valve style buttons for recreating a trumpet valve) can offer an experience close to the traditional instrument, giving a sense of familiarity to the user as to what is expected from the interaction. Another important add-on is the ability to stop all the sound. Hewitt (2014) suggests that being able to make no sound without having to withdraw from the motion-sensing field – like stopping a bow on a cello string without lifting it up is of high importance. Gesture to sonification should be tailored to the individual and their range of movement or capability allows mapping of an interaction that is natural to that individual.

6. Form should inspire interaction – Acoustic instruments are naturally pleasing to look at and feel. They are enjoyable artefacts with history to them and are formed from natural materials. Tactile materials with a shape, texture, feel, smell and feedback can draw users in and stimulate all the senses. Instruments designed with new materiality and form provide new opportunities to inspire interaction and allow configuration of the instrument to suit the individual's preference and need, both in terms of look and feel. Some CYP may be averse to touching certain textures and others may have favourite colours and textures that can be used to encourage engagement. One of the criticisms of the Skoog was that it was very child-like in appearance, something that has been rectified with the Skoog 2.0 (Skoog 2016).

7. Robust/Durable/Stable – 'Construction can never be solid enough, especially when it is to be used by children' (Jensensius and Voldsund 2012, p.303). Designs should be as robust as possible to ensure they have the durability to cope with the context they will be used in. There is also a need for the instruments and any accompanying software to be as stable as possible. If there are malfunctions, then this can be discouraging for the users and those around them and may lead to technologies being abandoned.

8. **Respect the feedback loop –** Interaction between the person and the instrument typically takes place through the aural and visual feedback loop with the performer making decisions in real-time on that basis (Pressing 1990). For users with complex needs these channels of feedback may be impaired, therefore feedback should be provided in a way that make sense to the user allowing access and resonance with the instrument. Within stakeholder meetings tactile/haptic and vibration feedback were identified as important to reinforce cause and effect. Light and visuals were also found to provide structure and stimulate responses. As well as the feedback from playing the instrument there should be adequate feedback for the navigation of the instruments configuration. To allow for navigation feedback should be visual, audible, and/or tactile allowing for scalability to physical, cognitive, and sensory ability (Farrimond et al. 2011).

9. **Make it meaningful to those involved –** This means creating technology that allows for the user to add their own content/samples and give input for how the instrument works in a customisable way, thus having some ownership over the instrument design, and not only making it work based on individual needs in terms of their cognitive/sensory/motor skills but also making it carry meaning for them in terms of content. One of the criticisms of some previous DMI's specifically aimed at the SEN market is that their sound palettes are impersonal and lacking in sophistication (Streeter 2007). This can be negated by leaving the sound palette open enabling users to add their own sounds that carry meaning for the individuals using them.

10. **If you can add a microphone- do it –** Use of voice is very important in an SEN context. It can provide an avenue for exploring self-experience, communication and relational possibilities (Anderson and Cappelen 2013). A microphone can provide access to allow for those that cannot interact with a system in any other way. Stakeholders school A said that voice and voice manipulation were a good avenue for engagement for some CYP that would otherwise be unable to physically interact with a system, and also allows for addition of sampled sounds from the environment to be input into the system [personal communication].

11. Think of sound quality – Make the sound quality high. The overriding use of the MIDI protocol and the general MIDI sound range in the past has left a lot to be desired with the type of sounds offered and the inherent lack of expressive potential offered. The 'lack of subtlety has meant that timbres can wear thin' (Hunt et al 2004, p.52). Hewitt (2014) suggests that ideally there should be an option to be polyphonic – played with multiple movements simultaneously. The music technologist from school C also suggests this is useful for building up rich sonic soundscapes by layering triggered sounds [personal communication]. The quality of onboard sound and the quality and option for outboard sound is important as sound may be amplified through a PA system or via amps or monitors or headphones. The ability to adjust sound levels to suit the user is important as some CYP may be very sensitive to sound and others may have hearing impairments. Localising the sound by placing amps or monitors close to the player is common practice within the school setting to reinforce cause and effect.

12. Facilitate choice/ offer consistency – Instruments in the main are set up by the musician playing them, in the school context this is not the case. Rather, there is a tendency for those facilitating the musician or the session to choose the setup of the technology both in terms of how gestures are captured and the musical output of the system. When decisions are made for people, this leads to two problems; relinquished choice of both interaction style and output received, and potential for moving of the goalposts or in other words programmability is a curse (Cook 2001). Within the context of musicians with complex needs there can be a tendency of involuntarily relinquished choice meaning that things are often chosen for people instead of with them. Enabling users to select for themselves, if they can, the level and type of control they have should be paramount. Hunt et al speak of the dangers of configurable instruments in that the "goalposts are constantly being moved" (Hunt et al 2000, p.364). They say traditional instruments do not change character from one session to the next and musicians undergo a process of learning to configure their instrument. Changing goalposts can mean that some users never have the chance to get to grips with their instrument, this can be particularly damaging if their needs mean that predictability is a strong motivator. There could also be the danger of learned helplessness with users not feeling like they have control over the system or feeling like it is their fault that the instrument is responding differently. Hunt et al suggest perhaps setting up an instrument with the same configuration for each particular situation (Hunt et al. 2000). This can be made more difficult if the particular situation changes often as can be the case in the school setting with different locations and staff being used to facilitate sessions on a pragmatic basis. A built-in system to recall configurations would help with this.

13. **Participatory design –** The head of music at school A says that creating with the user provides a more authentic picture. The industrial mentor adds that this is important to establish where the design should go and highlights issues that may not be obvious to the digital musical instrument designer [personal communication]. Only the users and those who work closely with them will best know their needs in terms of interacting with an instrument. Working in a participatory way can allow for rapidly working out kinks and problems with any designs. A designer cannot possibly guess at how a neurodiverse users will respond to a particular design - which may have taken hours of work, so participatory design also means a reduction in wasted time.

14. **Small, cheap and easy to use –** Barry Farrimond describes the first instrument he designed for users with complex needs and how it was only revealed to be big, expensive, and hard to use upon its maiden voyage of use (Farrimond 2016). Typically, in a school there is limited space and budgets, both in terms of time spent by staff training to use the technology and money available to buy technology (Hahna et 2012). Having things that are off-the-shelf/affordable, easy to programme with minimal set-up needed, that can be made compact are paramount (Hewitt 2014; Farrimond et al. 2011). Expense and need for insider knowledge lead to tools being abandoned (Streeter 2007). Plug-and-play is the ideal in terms of allowing the system to work within the context as ease of use is currently a barrier to technology usage. Gallin and Sirguy (2011) give six points that impacted on the design process of their plug-and-play system that can be useful to consider; '1) the technical side must be transparent to the user; 2) the design is focused on the way the interface will be used; 3) the accessible parameters are the only "visible" setting parameters; 4) it imposes a wide compatibility with existing OS, softwares, MIDI devices and other hardware interfaces; 5) it requires different levels of use: ready-to-use; internal parameter access via the editor; and Max programming; 6) it requires compatibility with other communication protocols' (p.437). These points cover several important areas that allow these systems to work in context and with other systems already in place whilst not overwhelming those facilitating the use of the

system. Once the system is up and running technology can be adapted to the situation by adapting equipment as needed in practice, and allowing equipment to work alongside other equipment. The more familiarity that can be provided as part of the design the better as then users won't be so fearful of using the technology, for example allow switches that are already used in the school to be plugged into the designed modular instrument. This allows for components to be added as user's familiarity with the system grows. To enhance ease of use, remove unnecessary complexity like jargon, convolution, big manuals, and hard configuration should be avoided (Farrimond et al. 2011) and any terminology or language used should be familiar to the user. Designs should be easy to use physically (for example jack sockets and connectors can be hard to pull apart) in making sure the system is suitable for the amount of strength the user is capable of. Instruments should also be able to be mounted, with standard mounting fixtures and arms, to enable easy positioning.

15. Wires are not awesome – Instruments that are wireless enable easier sharing and cut down on health and safety issues, they also mean that there can be a distance between the computer at the centre of the sound processing and where the action is. The music therapy space is best kept clear of electrical leads and this is especially important with users that are unable to reach a computer or their equipment prevents them from easily accessing wired devices. Some equipment vital to some CYP or wheel chairs do not easily travel over wires and for others having the computer and its screen nearby can provide distractions. However, there is danger of adding complexity to the system and opportunities for technical failure by making things wireless.

16. Think of the whole context – Designing a DMI in itself is a challenge but when this design process is placed in a school setting it can be even more challenging. There is a need to find out how best to communicate with those involved and how to disseminate what you are creating. The school environment may restrict what can be done, with the time of day and year affecting the ability to access the users. Very often instruments designed are not accessible or configured by the target users directly but by those facilitating access. There may be several practitioners involved in the use of the technology; from music leaders to music therapists, to teachers and teaching assistants all with various goals. Sessions could focus on 'education in music, education through music, music therapy, or music as a leisure activity' (Farrimond et al 2011, p.11) with goals to play as an ensemble, to feel a sense of intimacy with an instrument (Fels 2004), to provide a therapeutic or educational experience, or playing for fun. There is a need for user friendly systems that understand requirements and attitudes of facilitators in order to be inviting to use (Streeter 2007). Often DMIs developed for the school setting are taken away when the research finishes, "leaving something behind is preferable as is keeping the tech neutral with no brand, open source and widely available" (Nagler 2011). If DMIs are taken away there in no opportunity to practice with the instrument removing the chance to progress.

17. Providing educational context for use – One of the larger problems, certainly for the uptake of technology within the area of music therapy, is incorporating technology into practice (Crowe and Rio 2004; Magee 2006) and having confidence with doing so (Streeter 2007). Cevasco and Hong (2011) suggest giving provision to providing examples of how to incorporate technology into practice with better training on how to enhance music making with technology to make it less daunting. Linking with requirements of the curriculum, learning outcomes, or other curriculum subject areas can also be useful at showing the spectrum of how the technology can be put into practice. Frameworks such as the Sounds of Intent (Welch et al. 2009) have made progress in this area. This can create a context for use especially if linked into teaching schemes. If teachers and facilitators cannot see how the technology can be put into practice they may leave it on the shelf.

18. Tech and do you even need it? – Technology should be unique to an individual's needs (Nagler 2011). and not just be used as 'technology for technologies sake' (Magee 2011, p.151). Farrimond et al (2011) identifies that a key issue to consider when determining musical possibilities for individual musicians is to try and distinguish between access needs and learning needs. For physical barriers, the emphasis of provision should aim to maximize individual physical abilities and for cognitive barriers, an emphasis on tools that adapt to the individual's cognitive level should be paramount. The technology should primarily meet the creative preference of the musician (ibid). Stakeholders from school A say technology can also be combined with acoustic instruments by using this interplay to encourage motivation, interaction, and engagement [personal communication].

4.4.11 Moving Forward

This cycle was used to explore the research aims of:

- exploring the issues that stakeholders have with current music technology by meeting with stakeholders to gather data about technology usage, and observing stakeholders as practitioners to identify where technology could help
- creating novel prototype tools that match criteria as specified by stakeholders, by reviewing gaps in provision, creating design ideals in conjunction with stakeholders
- assessing the effectiveness of these novel tools with a view to improving practices by iteratively developing prototype tools through practical use and working with stakeholder to ascertain success criteria

This cycle documented the close collaboration that occurred with practitioners in the field to both develop the Noodler, and to gain input into requirements for the formation of the final toolkit. Observations of sessions ran by the practitioners were conducted to give a grounding of how instruments were used in sessions, how the sessions were run, and design ideals that could feed forward into the final form of the MAMI Tech Toolkit. Information gathered from these interactions and observations informed the development of the Noodler as well as the software element of the MAMI tech toolkit.

A set of 18 design considerations were also presented. These were published at the end of action research cycle two (Ward et al. 2017) and revisited for this thesis (section 4.4.10).

One thing that was apparent throughout this cycle was the need for a standalone tool that did not need a separate computer and had an on-board speaker. This idea will be explored in the next cycle of this research in which the development of the final tool (the touchBox) is outlined, and the tools are turned into a cohesive kit before being taken back to the philosophical underpinnings that they emerged from.

4.5 Cycle Four - Developing touchBox and finalising the MAMI Tech Toolkit

4.5.1 Introduction

The previous cycle detailed the collaborative work undertaken with stakeholders to realise the specifications for the Noodler and move toward the final form of the MAMI tech toolkit, as well as the presentation of a set of eighteen design considerations (section 4.4.10) that form a contribution to knowledge from this research. This cycle presents the final addition to the toolkit – touchBox alongside the final developments of the software. There was no direct interaction with stakeholders in the final cycle of this research as the main aim of the cycle was to translate all of the findings gathered into the final MAMI Tech Toolkit, and accompanying thesis, as per the requirements of both the industrial mentor and sponsoring organisation, and the EngD qualification. This cycle was also used to reflect on the tools and their relation to the philosophical underpinning that they emerged from in order to analyse that tool with regard to the overarching research aims. The activities of this cycle relate to the aims of:

- creating novel tools that match criteria as specified by stakeholders, and address issues as found in literature
- assessing the effectiveness of these novel tools with a view to improving practices by analysing created tools against informing philosophical underpinnings and design considerations

The main activities of the cycle are provided below (Figure 29) followed by an overview of the cycle. The technological developments of the hardware and software are discussed, the system architecture is outlined, and iPad connectivity is discussed. After which the final kit specification is laid out in terms of kit contents. The components of the kit are then analysed through the 'tool as probe' mechanism, in order to explore the connection between the stakeholders requirements and the created tool, and the created tool to the informing philosophies from which they emerged. There is then an analysis of the MAMI

Tech Toolkit and composite parts against the design considerations that emerged from this research. A final section is provided on moving forward.

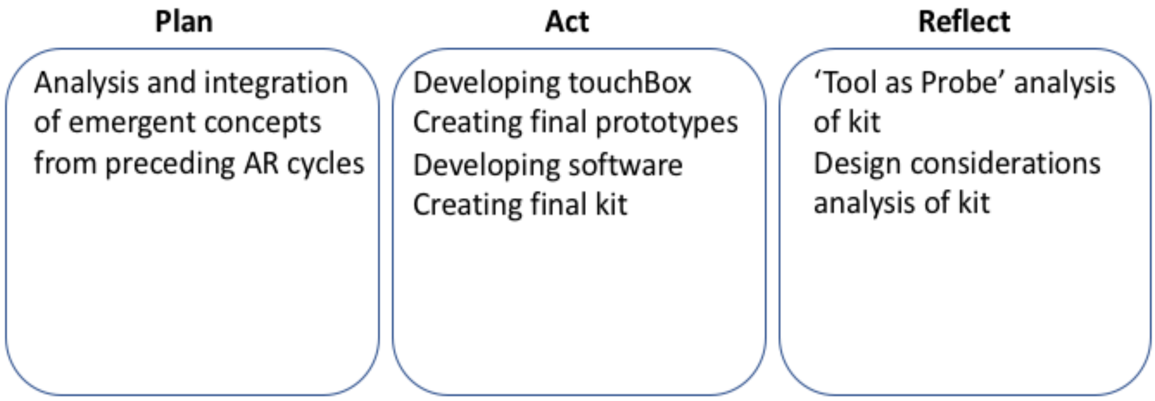

Figure 29 - Activities of the Cycle in Phases

4.5.2 Overview of the Cycle

A fourth bespoke tool (the touchBox) was developed during this cycle. Further to this was the development of all of the tools into a cohesive kit (the MAMI Tech Toolkit). Software to accompany the filterBox and squishyDrum was developed, alongside an overall software application. Resources for use were developed - such as a manual - and iPad connectivity was integrated.

4.5.3 Technological Development

4.5.3.1 Hardware Development

From the feedback gathered from the stakeholders it was clear that there was a need for a tool that was stand-alone and did not need to connect to a computer. The touchBox was developed to meet this demand (Figure 30, 31). This type of tool was aimed at being easy to set-up out-of-the-box. The touchBox features an on-board mono speaker, and buttons and dials to allow for adjustment of the sound. There is an LCD screen for visual feedback of the settings, and eight connectable trigger pads which plug into the front of the device. In touchBox the buttons control: the type (timbre) of sound (featuring square, triangle, sample, sine, and saw waveforms); the octave of the notes (plus or minus 2 octaves); the scale (major, minor, akebono, pygmy, equinox, sapphire, gypsy, silver spring, integral, dorian, golden arcadia, pentatonic major, pentatonic minor, and blues); and the tonic note of the scale (A, A#, B, C, C#, D, D#, E, F, F#, G, G#). The dials control of the volume and note decay (allowing for short sharp notes or long notes). Up to eight pads can be connected using the 3.5mm jack sockets along the front of the device. Each pad triggers a different note in ascending order from left to right, in the selected scale starting from the selected tonic note. The touch pads are connected with extendable and retractable cords to allow for easy storage and ease of adjustment to the required length. The box when initially turned on, loads an A major scale, starting with the note A below middle C, and with a square wave timbre. Many buttons and dials were tested to find those that had the aesthetical qualities laid out by the stakeholders both in terms of feeling nice to use, and providing adequate feedback to the user, or maintaining a utility in the form itself. The dial covers and button size/shape were chosen to allow for use by feel, as well as being coloured differently to be easier to distinguish for those with visual impairments. Sockets are provided to allow for use with headphones, a 1/4in output socket to allow connection to an amp, and a toggle switch to turn off the on-board speaker. Internally the touchBox has a Teensy 3.2 micro-processor with Teensy audio adapter board to handle the processing of the sensor input and audio synthesis. The code (appendix K) featured on the touchBox is modified code from two other sources (Bartlett 2018 and Cool 2017).

Figure 30 - touchBox

Figure 31 - touchBox Sockets and Example with Four Pads

4.5.3.2 Software development

For the finalisation of the toolkit, the MAMI software created in Max/MSP by the industrial mentor was used and extended. The final software application runs on both Mac and Windows operating systems and features the functionality to connect the tools in the toolkit, and to open separate applications relating to each tool in the kit. The software for the Noodler has been detailed in section 4.4.6.2. The software applications for the filterBox and the squishyDrum are detailed below:

filterBox software

The software application (Figure 32) used in conjunction with the filterBox hardware is based on a patch developed by the industrial mentor, and allows for selection of a VST instrument, turning sound on/off, controlling volume, selecting the channel for the sound output (L, R and Stereo – to allow for two instruments to have discrete audio channels with one computer), and selection of the musical scale (from 16 choices). VST instruments provided are done so at the request of stakeholders who wanted grown-up sounds and rich sonic output. Instruments included are Crystal, Dexed, helm, Kairatune, Obxd, Sinnah, Synth1, TripleCheese, Massive (demo) – access to the graphical user interface controls of the selected instrument is also provided for those wanting to explore each VST fully. There are

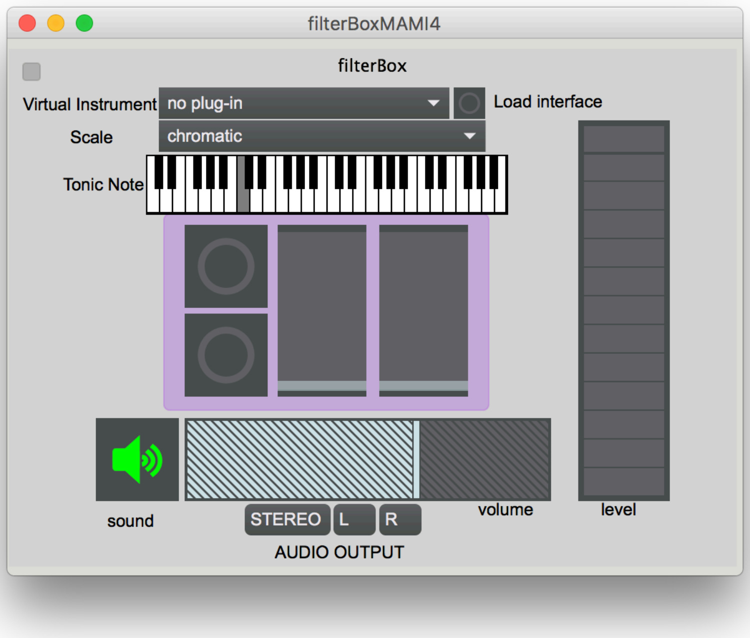

Figure 32 - filterBox Interface

also icons that visually show the interaction with the buttons, pressure strip, and the light sensor, as well as the levels of the sound and the master volume level. The buttons on the hardware control the notes which can be moved up with one button and down with the other, through the selected scale. The pressure strip controls the volume of the notes, and the light sensor control the filter on the notes.

squishyDrum software

There are two software applications that work with squishyDrum. squishyShaker (Figure 33) which allows for the selection of digital objects to be used as shaker style items. This uses the PeRColate collection of Max/MSP objects by Trueman and Dubois (2006) - https://github.com/Cycling74/percolate. The pressing of the pads then determined the amplitude of the sound and the number of objects in the 'digital shaker'. Also selectable are the pitch of the sound, the channel for the output of the sound (left, right, or stereo), the volume, and an icon to turn the sound off.

The second software app, named Simple Sample (Figure 34), allows for 3 samples to be triggered by pressing the pressure sensors, or by pressing the on-screen button. This was to allow the person working with the person using the squishyDrum the opportunity to mirror the action of the user and vica-versa. The ability to record from microphone was added to respond to stakeholder demand. This feature allows three samples to be recorded via a connected microphone or inbuilt computer microphone, and triggered by pressing the pressure sensors. The gain of the recording microphone can be changed as can the volume of the sample and recording output. In this way, an added functionality of being able to trigger a

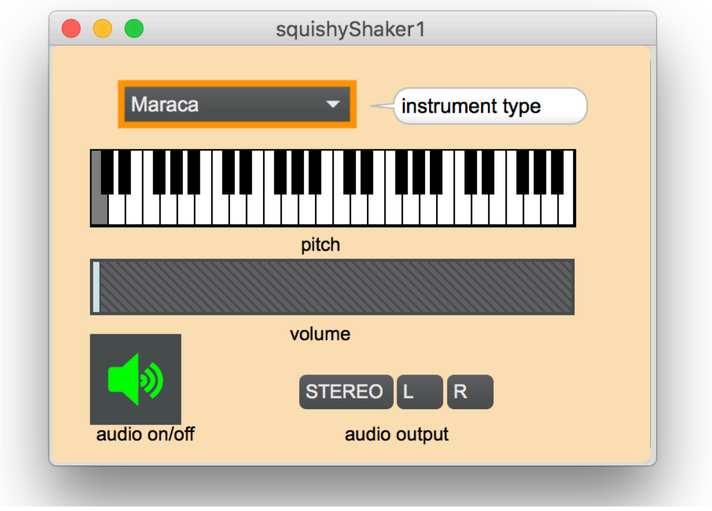

Figure 33 - squishyShaker

sample and a recording from the microphone at the same time can be achieved. Sample folders can be dragged and dropped (using either a single folder or a folder or folders) or read in via the click of a button to open a dialog box. A toggle was added to switch between the sample playing to the end or retriggering upon repressing the pressure pad to allow for sonic layering to be achieved. The folder where the audio recordings are stored can also be selected.

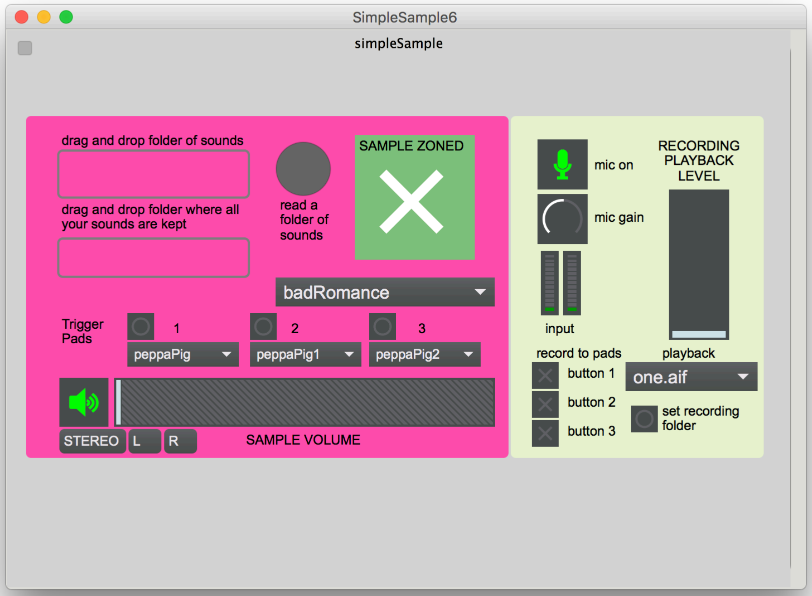

Figure 34 – Simple Sample

Final MAMI Tech Toolkit Software Application

The MAMI Tech Toolkit software application (Figure 35) was developed to work on both Mac and Windows operating systems. The main window features functionality to connect a single tool or all of the tools within the kit. As well as controls to turn the audio driver off/on, check the audio driver set-up (via a separate pop-up), and to see connected devices outputs (also via a pop-up window). An image of each tool is provided within the application and when clicked the software application for that tool opens in a new window.

Figure 35 - MAMI Tech Toolkit 2.0 Application Interface

4.5.3.3 System Architecture

The controllers in the kit (apart from the touchBox) all have the same internal architecture (Figure 36) featuring an Arduino board (Pro Mini for the transmitter side and Nano for the receiver side connected to a USB port via micro USB cable), an NRF24L01 2.4GHZ wireless radio transceiver module, plus various sensors.

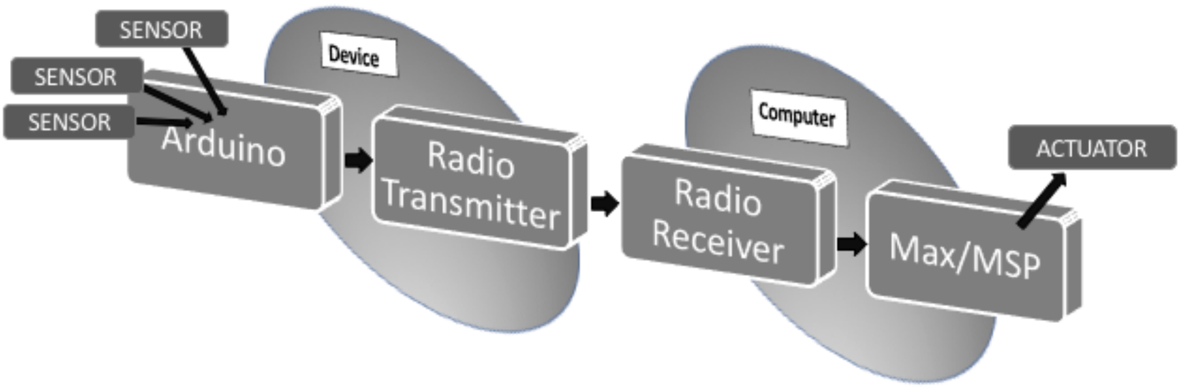

Figure 36 - Tool/Computer Transmission System

4.5.3.4 Bill of Materials for Each Tool in the Kit

A table is provided in appendix L that details each element of the kit and the components that are contained within it.

4.5.3.5 iPad connectivity

A feature often requested was iPad connectivity, this led to the inclusion of the ability to use the Mira app. The Mira app allows mirroring of the graphical user interface from the Max/MSP software on the computer to the iPad, which in turn means the iPad can be used as a controller for the settings. The Mira app (at a cost of £9.99) manages the connection between the iPad and Max/MSP software. The settings can then be controlled away from the computer, effectively removing the need to touch the computer during the interaction. This can be useful for some clients who might find the computer a highly interesting thing which can be a distraction, and also removes the need for the therapist to physically sit at a computer which could become a barrier to interaction. The music therapist or the client can use the iPad to configure the sound of the instrument in a wireless way in an attempt to permit a smoother integration the technology into session structure. An iPad is also a much more familiar and enticing control unit when considering changing settings, with more direct access to enable quick changing of the setup.

4.5.3.6 Whose Code Is It?

Each item in the kit is an assemblage of many different pieces of code. The table in appendix M outlines the code that is running on the Arduino inside the hardware tools. Each tool is then broken down to show the other components of code that have been put together within the main code. Any separate header tabs that are called within the main code are also broken down in the same manner (if the code used is not part of the vanilla Arduino download). The code running on the Arduinos within the hardware tools and receivers is presented first followed by a breakdown of the code used within each patcher of the software. The first entry of this table details the elements of the industrial mentors MAMI software which have been utilised within the MAMI Tech Toolkit software. All of the code is available in the GitHub repository located on the following link https://github.com/asha-blue/MAMI-Tech-Toolkit-Final-Edition.

4.5.4 Development Discussion

In developing the final kit there was a drive to create an easy to use system, with all tools streaming to one receiver box, this technical implementation did not happen. This was later seen as a benefit in that the kit in its final form could be split with different elements being used separately as needed, increasing the flexibility of the kit.

There was a lot of time spent on avenues of technological development that didn't work out – these included using lithium batteries. The use of which would have allowed for longer battery life, easier charging, and the addition of power hungry components such as vibration motors. It was deemed too dangerous to use lithium-based batteries due to the explosive risk that they could pose.

In terms of wireless communication there was the attempt to use Bluetooth to allow interfaces to connect without the need for a receiver, however Bluetooth 2.0 was very flaky (both in connecting and maintaining signal, and in losing data packets). BLE was not able to be integrated into the Max/MSP environment, thus the reason for choosing to use the NFR radio system. The NFR radios proved to be very robust at handling the data sending and receiving, with low latency, low data loss, and good efficiency in terms of battery use.
Much more development could have been done to achieve a more user-friendly graphical user interface for the applications created. This could have included making the navigation more user friendly, giving feedback from interactions, making functionality more obvious, and giving the user more information (such as hovering over a control to learn what it does). Time simply ran out and the toolkit had to be packaged to be distributed to the stakeholders.

The final software application creation took time in order to enable it to work on both Macintosh and Windows operating system. There was also time spent on developing documents such as a manual for use (appendix N) and a welcome to the kit in which an overview of the kit was given (appendix B). There was not enough time for full and robust testing of the software, which could potentially lead to problems with use.

Some functionality could not be translated to the iPad controller via the Mira application, these include the ability to save and load settings that utilised a pop-up dialog box on the computer as Mira did not support this functionality – this leaves room for development of proprietary software to handle this connection to increase functionality to truly replicate what can be controlled when using the main computer that the software is running on.

Given more time there could have been implementations of audio/visual feedback about the state of the device such as power level, on/off lights, successful connection lights to cover some of the basics of what can be consider a ‘good’ system, in providing feedback to the user, however these were not able to be implemented due to time restrictions.

Some Wii nunchucks didn’t work the same as the original nunchuck used to calibrate the system. This meant that several were purchased and the data streaming from them was different. This is an inherent problem with the availability of technology in terms of branded and non-branded components as clone components were purchased for the kits to save cost.

Another issue was the unused potential for creating more complex instruments at a mapping level. There were many streams of data coming from the tools, but these were not utilised to their full potential. This was about time, resources, and skill set in that the researcher spent time enabling the system to function on a basic level and because of this did not fully explore the sonic possibilities of each individual tool.

MAMI is available online for those wishing to use it with their own developments but in its current state, the sonic output or musical devices side of the software remains to be developed. There is potential for future work on the sonic output side of the development, and it is hoped that in creating the online resources associated with the toolkit that there will be some development by third-parties and that the research will have some longevity and be continued through others adaptations and additions.

Max/MSP would often crash meaning that everything would have to be reloaded and reconnected, which at times proved to overwhelm the time left to use the device. It would take a long time to create the set up correctly and as such a stand-alone application was developed, this also meant that the users would not have to download a whole application to operate the software but it did mean that the whole Max/MSP application was bundled into the application built for the research, this led to a hefty file size which could have been reduced with further slim-lining of what was included into the compiled application, but once again time was against the ability to slim-down the application.

There was potential to add audio feedback when pressing the buttons of the touchBox, to inform the user of the selections they were making as there was sometimes the expectation that the buttons were part of the music-making when they only change settings

The aim initially was to be able to make any piece/use an existing piece of hardware, connect to MAMI, and then map the inputs on the device to sonic output within MAMI. This turned out to be a much larger undertaking than initially conceptualised and so the final kit features a MAMI that is tailored to the components of the kit. The application, built on top of the vanilla MAMI developed by the industrial mentor, meant that users could load it up and connect tools from the toolkit in an easier way, however it also meant that the application was locked to the toolkit and own devices could not be added. This had to be the case to allow the hardware developed to connect and work with the sonic output as mapped when considering the stakeholders and their requests for ease-of-use and instant access. In the end this became a compromise between providing a flexible system that is completely in the hands of the user to providing a locked system that provides functionality that was requested by the stakeholders.

4.5.5 The Final MAMI Tech Toolkit

Figure 37 - The MAMI Tech Toolkit in its case

The final kit (Figure 37) contained all the elements needed to use the instruments with a standard computer (table 7). A test was completed on an a laptop at school A (Toshiba Satellite Pro C660-1LR from 2011) to ensure that most modern computers would run the software and allow all the instruments to be used, this was conducted with the knowledge that schools often have equipment that is not state of the art. There was a need to create something as a containable package that could travel with the music therapist or around the school, and as such the kit was presented in a metal flight case complete with inner padding.

Item	**Description**	**Power**	**Uses**
Noodler	Wii chuck controller with on-board accelerometer, x/y joystick, and 2 buttons, detachable sender unit with built-in battery compartment	9v battery	Set trigger zones by drawing, trigger midi notes of samples, select the notes and the samples triggered by which colour, choose a folder of samples
Noodler Receiver	Receiver box with detachable USB cable	USB powered from computer	Receive data from Noodler wirelessly
filterBox	Hinged lidded filterBox unit with on-board force sensitive resistor, 2 buttons, and light dependent resistor and built in battery compartment	9v battery	Move up and down notes in a scale, change amplitude and filter amount on notes using selected virtual instrument
filterBox Receiver	Receiver box with detachable USB cable	USB powered from computer	Receive data from filterBox wirelessly

squishyDrum	squishyDrum unit with 3 force sensitive resistors, 2 piezo discs and built-in battery compartment	9v battery	Trigger sound synthesis of shaker sounds change number of objects and amplitude. Trigger recorded of stored samples
squishyDrum Receiver	Receiver box with detachable USB cable	USB powered from computer	Receive data from squishyDrum wirelessly
touchBox	Stand-alone box with 8 jack sockets for input, 2 dials, 5 buttons, built-in LCD display, internal speaker, headphone and ¼ in jack socket for output, toggle switch (between internal speaker and 1/4in output)	2xAA batteries	Trigger notes with selectable waveform, scale, tonic note, octave select, volume, note decay length
touchBox pads x 8	Detachable capacitive touch copper pads with 3mm jack tipped 1m retractable cables	n/a	Connect to touchBox to access touchBox functionality
USB Drive	MAMI Tech Toolkit software application, e-copy of instruction manual. Driver software for USB	USB powered from computer	Software for setting up and using musical output of Noodler, filterBox, and squishyDrum, and for instruction on

	receivers, and Bonjour software.		configuring the touchBox. Instructions on installing drivers to allow Mira functionality in Windows and connection of receivers
Instruction Manual (appendix N)	Booklet featuring description of the software and instructions on set up	n/a	Physical copy of the instruction manual
Kit contents sheet	Laminated list of kit components with space for name and date if removing items	n/a	Physical copy for checking kit contents and location
Welcome to the Kit (appendix B)	Description of the hardware tools in the kit	n/a	Physical copy of details of hardware in kit

Table 4 - Components in the MAMI Tech Toolkit

4.5.6 'Tool as Probe' Analysis

The tools developed throughout the research were used as technology probes. The *'tool as probe'* mechanism was used to elicit requirements from the stakeholders through an iterative design process. The final elements of the kit are presented with concrete connections between the requirements of the stakeholders and the features and functionality of the tools and system made explicit.

Prototypes of the tools were presented to stakeholders throughout interactions with them. These prototype tools were used as 'technology probes' (Hutchinson et al 2003) in order to iteratively provide physical manifestations of the stakeholders requirements, and were used in order to both gain their feedback, and engage them to think of next design steps (Hutchinson et al 2003). Each element of the kit is analysed below to cement how the requirements specified by the stakeholders are manifest in the features and the functionality embedded within the kit.

filterBox – Stakeholder Requirements to Final Design Analysis

Description of Element of Kit	Requirements as informed by 'tool as probe' to design
filterBox features: • hinged-lid • on-board force sensitive resistor • 2 buttons • light dependent resistor • built in 9V battery compartment • separate USB receiver • accompanying software	• tangible hand-held tool • enabling interaction styles akin to those used with traditional instruments • potential to explore sound using fine-motor control • direct translation of gesture in to sound (i.e. squeeze harder to make louder). Ability to move up and down common scales • high fidelity and motivating to user sounds

Figure 38 - filterBox

The filterBox (Figure 38) is oval-shaped hand-held tool with a hinged lid. The surface has an acrylic lacquered high-gloss finish on laminated softwood with acrylic facia plates with integrated high quality sensors. The use of these materials and finishes was to done so in order to suggest a quality and robustness and to invoke a familiarity of material analogous to those used in acoustic instruments such as an acoustic guitar.

The final look of the tool aimed to give the look, smell, feel, and overall sense of 'instrumentliness' which can be considered to be formed of a combination of both the material the tool is created from and the gestural vocabulary it utilises.

The smooth-action hinge is the same style as that used on an upright piano key cover and can be opened and closed to increase/decrease the light to the LDR altering a filter on the sound. Using a commonly used interaction (the opening of a hinge) the lid mechanism aimed provide a resistive mechanism for the user to work against in order to explore the sonic properties of the filterBox. The changing filter cut-off provided a familiar connection between the energy input via movement to match the sonic output, whilst also using expectation by maintaining common projected outcomes of interaction with objects/sounds (for example what a sound being put in a box would sound like) as the lid was closed. This mechanism also provided interaction opportunities that were analogous to those found in both in traditional instruments - such as playing a trumpet with a mute – or in more contemporary music practices – such as scratching like a DJ. The position of the lid can be used to interpret how much light is being let in both by sight and by feel. The hinged mechanism provides a physical constraint and an instrumental resistance to work against that can be used to facilitate an embodied sense of sound to movement. The light dependent resistor could be controlled by other means such as a finger or hand placed over it. Covering the surface of the filterBox results in a sonic reduction giving the impression of hiding the box or making it quiet and giving it a quasi-other quality by perhaps encouraging an anthropomorphic quality.

A force sensitive resistor sits around the 'waist' of the tool and must be pressed for the notes as selected by the buttons to be triggered. The FSR is positioned as such that if the tool is held in the hand, then the resistor will always be pressed slightly. The force sensitive resistor reacts in a similar way to the LDR in that the harder the strip is pressed the higher the amplitude of the sound. Again leveraging a commonly expected outcome to a commonly used interaction, with energy in and energy out being balanced as such that you press the strip harder and the sound gets louder. Two mini push button switches are provided to move notes up and down through a scale. These buttons were chosen to draw on acoustic ancestries by being physically analogous to valve mechanism, such as those used for discrete control of note changes on, for example, trumpets.

Many-to-one complex mappings are employed as a strategy to achieve a low threshold, high ceiling (Myers et al. 2000) access to the tool, in which instant access and initial ease of use is balanced with the chance to achieve a nuanced and sophisticated control of sound, and more technical exploration over time. Complex physical manipulation (for example pressing the note up button, undulated pressing on the force sensitive resistor and slowly opening the lid will herald different results to rapidly pressing the scale up button and statically pressing the FSR) can then be navigated as the potential of the tool is explored by the user. The sounds used were constrained to selectable scales in order to scaffold the interaction between the user and the tool, by removing dissonance, and to allow the tool to be in-tune with both other tools in the kit, and/or any other music-making means. In this constraint the tool fosters a sense of inclusivity (Wright and Dooley 2019), and an involving nature (Kiran 2015) by removing the sense or worry of playing it wrong.

The use of VST software provides nuanced control over 'grown-up' sounds. The set-up of the software form a series of constraints that the user must navigate in order to explore the sound gamut available (Wright and Dooley 2019; Magnusson 2010). This requires navigation using fine-motor skills, and the tool worked against and through, to achieve a blurring between the subject and object into enmeshment (Evens 2005) or the facilitation of embodied interaction (Ihde 1990). The filterBox software provides the opportunity to select a range of VST instruments and access the graphical user interfaces of each –opening up the opportunities for endless augmentation of the sound to suit the user. This mechanism allows the user to delve deeper into augmenting the sound whilst still providing easily selectable presets. Several VST instruments were selectable (and settings within them accessible) to give the user access to a choice of high fidelity sounds that were motivational to use and highly customisable. Through revealing hierarchical levels of control of the settings as needed/wanted by the user there was an attempt to enable and support the users without overwhelming them.

squishyDrum – Stakeholder Requirements to Final Design Analysis

Description of Element of Kit	**Requirements as informed by 'tool as probe' to design**

squishyDrum features: • 3 force sensitive resistors • 2 piezo discs • built-in 9V battery compartment • separate USB receiver • accompanying software	• wireless tool that could be hand-held or placed on a lap or surface • move away from fine motor control. Malleable surface to which bodily pressure could be applied • the ability to hit like a drum • ability to record own samples and play back

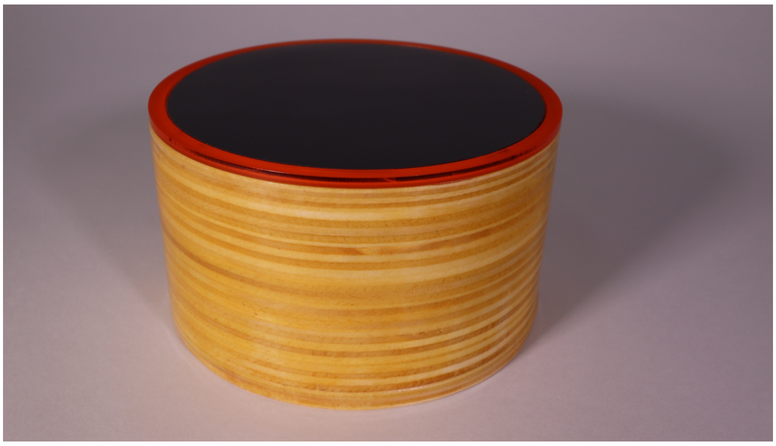

Figure 39 - squishyDrum

The squishyDrum (Figure 39) is a round tool with a 150mm diameter which fosters being held in the hands or placed on a lap/or surface and uses materials that match that of the filterBox. On the top there is a 3mm thick silicon skin. The materials used are done so to evokes a sense of robustness. The main interaction mode for the squishyDrum is applying pressure on the silicon surface under which there are three force sensitive resistors. Small amounts of pressure can be used to trigger sounds thus magnifying gestures of the users. There are also two piezo discs inside to allow for tapping on the drum. The size and shape of the squishyDrum do evoke an acoustic drum. There is the ability to hit the drum with a stick or hand through the use of piezo discs within the tool. The use of physical modelling within the sound synthesis allows a rich interaction.

Two software apps are provided to be used with the squishyDrum – squishyShaker and Simple Sample (as described in section 4.5.3.2). The amount of effort exerted on the surface directly correlates to the intensity of the sound with the added element of having to press two of the force sensitive resistors in tandem to trigger the sound within the squishyShaker app, to encourage exploration of the surface to discover and coax out the sound. The physical construction of the squishyDrum meant that it could be leant on in order to trigger sound thus giving the ability to hold the sound for as long as desired, something which is almost exclusive of digital musical instruments (save for some drone instruments that afford this type of sound however still need energy input from a user to sustain). This self-sustain has potential to enable the user to engage on a deeper level than with acoustic instruments by providing time to process the sound as there is the ability of technology to extend/shorten interaction. On one side the note can be extended until the user wants it to stop, and on the other side the note may stop when the user stops pressing and as such a continued interaction is needed, both mechanisms are tailorable to the user's needs and the goals of the sonic exploration but highlight this extending/shortening ability. The squishyDrum allows sounds to be recorded and played back, magnifying the users voice, and enabling them to hear themselves, as well as giving some ownership, involvement, and autonomy in the creation of triggered content.

The Noodler - Stakeholder Requirements to Final Design Analysis

Description of Element of Kit	**Requirements as informed by 'tool as probe' to design**
The Noodler features: • removable Wiichuck controller • on-board accelerometer • x/y joystick • 2 buttons • built-in 9V battery compartment • separate USB receiver • accompanying software	• tangible hand-held wireless multi-modal device. • customisable ability to trigger sounds. 'Drawable' trigger zone templates to allow individual user mappings of gesture to sonification. • ability to add user media in order to create motivating interaction. • provision of commonly used presets in the form of a variety of instruments/scales/sound effects to allow instant access. • use of familiar input devices (joystick and buttons).

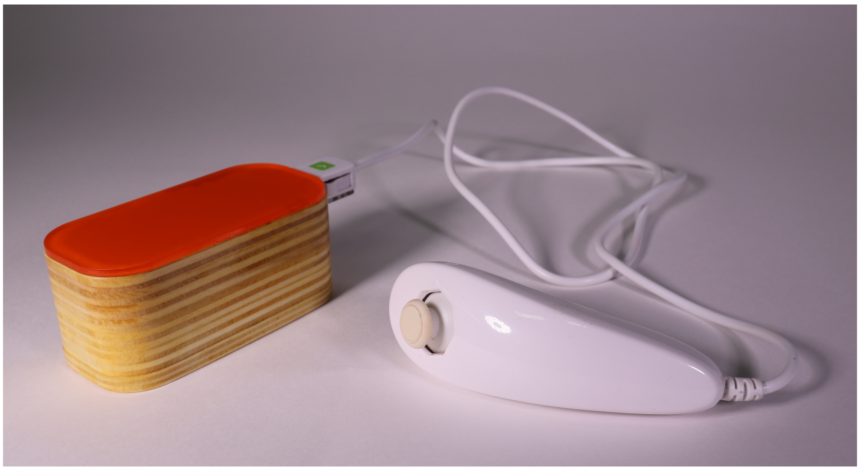

Figure 40 - The Noodler

The Noodler (Figure 40) is a recognisable tool both in being a joystick and a controller for the popular computer console the Wii, which builds on commonly used interaction within the user group (that of controlling things with a joystick). The Noodler leverages these existing skills to provide access to triggering notes and samples. The compact, lightweight form factor of the Noodler means it can be moved around easily. The joystick and buttons can be accessed with the thumb and fingers but also by holding the Noodler and pushing them onto a surface in order to trigger sounds. This enables it to be used against different body parts/against tables to activate the sonic output.

The ability to change both sonic content and triggering gestures means the tool can be tailored to the individual from the bottom up, which would suggest that there would be an inherent ability for that tool to become easier to embody. By allowing the user to select from samples provided or the ability to add their own, they could appropriate the system to suit their tastes, leading to the chance to motivate engaged use. Discussion of the Noodler in use in sessions/performances can be found in appendix C and section 4.4.5.

The familiar mechanism of drawing (with the mouse) is used to draw in trigger zones with different coloured pens and enables trigger zones (up to 16) to be set-up by. These designed trigger zones allow for tailoring the Noodler and the affordances it can offer to specific users. A dot is provided as an on-screen visual representation of the position of the Noodler within the trigger zone in order to give users some visual feedback to the effect of their actions and establish cause and effect by ensuring explicit visual mapping between sites of interaction and sonic generation. The Noodler sacrifices complex mappings, in order to facilitate ease-of-use as a triggering tool.

Within the software the state of the system can be seen from a variety of graphical user interface components using a blend of windows, icons, menus, and pointers (Dam 1997), as well as musically analogous elements - such as an onscreen musical keyboards, graphical faders, and knobs in order to provide a system that made sense to the user. More time to iterate over this process would have been helpful in order to involve the users in creating an interface that better matched their need's, as at times the current interface may alienate some users – both by being difficult to interpret (describing functionality in a simple manner without using jargon whilst retaining an accurate description of said functionality is a challenge), or by having inaccessible usability qualities (icons that are too small, writing to describe functionality for those that cannot read) which could form barriers to some users. The addition of iPad integration via the Mira app was used to help alleviate this in some areas.

touchBox - Stakeholder Requirements to Final Design Analysis

Description of Element of Kit	**Requirements as informed by 'tool as probe' to design**
touchBox features: • stand-alone box with 8 jack sockets • 8 capacitive touch copper pads (each with 3mm jack tipped 1m retractable cables) • 2 dials • 5 buttons • built-in LCD display • internal speaker, headphone and ¼ in jack socket for output, toggle switch (between internal speaker and ¼ in output) • 2xAA battery compartment	• self-contained unit with on-board speaker. Turn on and play. • light touch to activate. • polyphonic • headphone socket. • screen display. • operate by touch alone. • trigger notes with selectable waveform, scale, tonic note, octave select, volume, note decay length.

Figure 41 - touchBox

The touchBox (Figure 41) comprises of the main unit in which all of the electronics, mechanisms for changing settings, and the speaker are housed, alongside eight detachable pads that match the materials and design aesthetic as used in the filterBox and squishyDrum. The pads are hand-held size and can be held, placed on a surface, or mounted. The pads require a light touch on a copper conductive plate to trigger and stay activated until the touch is removed. This provides accessibility for those who can only apply very small amounts of pressure and gives the user the opportunity to control the sound beyond that of triggering a sonic event in that the user can also choose when the sound stops. This gives the users a chance to rest and take in the sound giving sometimes vital processing time needed to truly realise cause and effect. The amount of pads can be selected and moved into position to suit the user. The movability of the pads encourage appropriation by giving the users some autonomy in the set-up of their own instrument. This appropriating is common in other musical instruments where each player has their own unique set-up.

Each button and knob has a different style of casing for the different controls that are offered and are also different colours. These design decisions provide the ability for the user to develop a relationship with the tool by touch alone, which then enables the tool to withdraw in order to forefront the relationship of the practitioner with the central user. Through the tangibility of the tool and the single use/single function mode of interaction that the mechanisms of input (buttons and knobs) offer there was an attempt to enable the chance of familiarity to be developed through the use of the tool. The use of tangible interface components helps to address the issue of technology being seen as a barrier to interactions.

The retractable cords enable ease of putting away the tool, and whilst this may seem like an innocuous feature it can be argued that these features add to the overall usage experience of the tool. The way the instrument is stored and retrieved, connected and set-up all contribute to this sphere of practical use. This begins with the decision to use the tool and ends when it is returned to storage.

Main MAMI software - Stakeholder Requirements to Final Design Analysis

Description of Element of Kit	**Requirements as informed by 'tool as probe' to design**
Main MAMI Software	• easy-to-use • free • modular and flexible system • connection of multiple and varied hardware • routing to sonic output • selectable style of input device (serial, OSC, Human Interface, MIDI) • selectable amount of inputs from device as discrete (button) or continuous controllers (faders) • tailorable characteristics of inputs.
MAMI Tech Toolkit software	• preset to the tools in kit

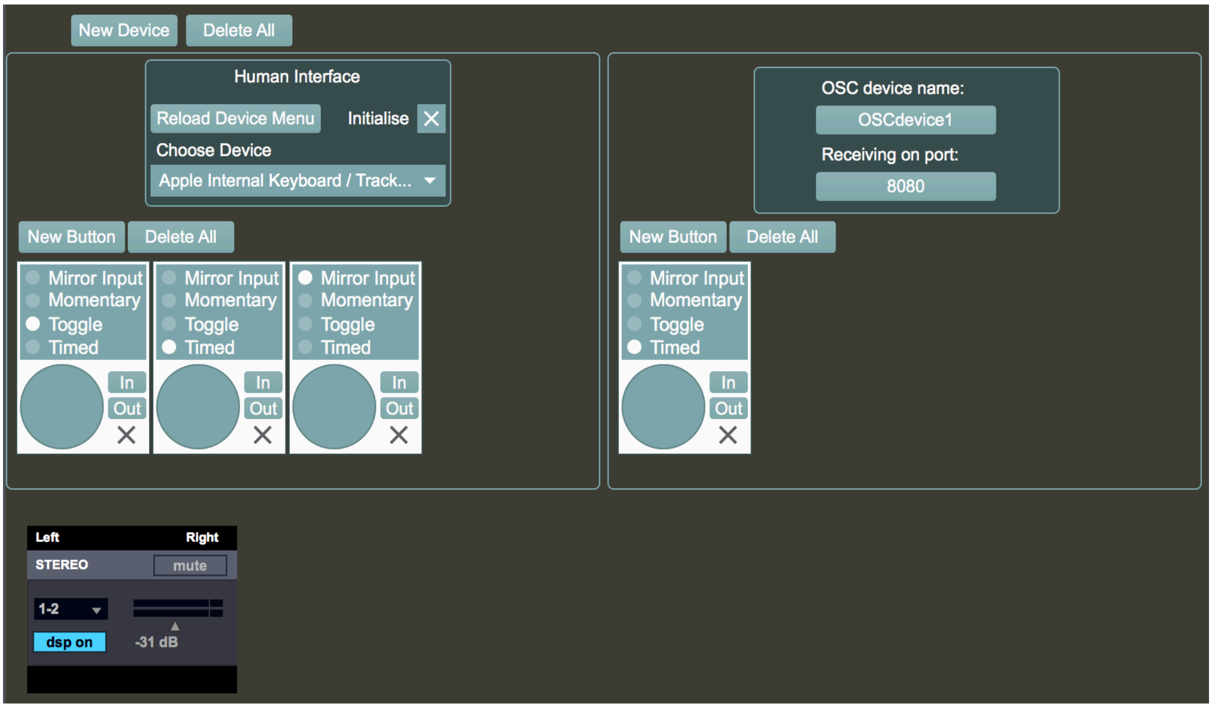

Figure 42 - MAMI Software

Figure 43 - MAMI Tech Toolkit Software

Main MAMI Software (Figure 42)

The MAMI software shown is that developed by the industrial mentor. It features the flexibility to tailor both the mechanism of input and the type of output enabling a highly configurable systems to be created based on the user. Further control of the characteristics that the input adheres allows for fine-grain tailoring. Target zones and thresholds can be programmed leading to an extra level of specificity to the user.

The software features pop-up dialog boxes for adding new device when opening up the software. This mechanism is used to aid in guiding the user through the interaction with what might be considered an 'alien' tool to them by constraining the options that are presented to users that are required to initiate the next state and so on.

The system uses familiar metaphors commonly found in graphical user interface design, particularly within music based software (drop-down menus, real-time modulating visualisers such as level bars (such as those found in graphic equalisers), radio buttons, check boxes, dials etc. These indicate the state of the devices connected, the data streams that are connected– as well as showing the software settings. These graphical user interface elements feature both input controls, and informational components in order to scaffold the use of the system and reveal what is able to be controlled.

MAMI Tech Toolkit Software (Figure 43)

The MAMI software was used by the researcher to form the MAMI Tech Toolkit software in order to lock the software to the tools in the kit for ease of use. In this way, the user does not have to re-input what each tool provides, they can just plug the tool in and select the port they have used. Pictures of the elements of the kit have been used to aid with selecting the software related to that tool without relying on words. Where possible graphics have been used as well as textual descriptions to allow greater accessibility. Natural language is used in order to help the user to resolve problems that they might have in finding the settings for the overall sound. Although there could have been further development to ensure that symbols and written text were used to aid in readability for a wider range of users.

Whole kit - Stakeholder Requirements to Final Design Analysis

Description of Element of Kit	**Requirements as informed by 'tool as probe' to design**
Whole kit features: • filterBox • squishyDrum • the Noodler • touchBox • USB cables and receivers	• easy-to-set up • wireless • used by a variety of users • move towards alleviating a fear of use Separation of controls from interface

• aluminum flight case complete • software on USB stick • instruction manual • quick start guide • laminated kit contents tick sheet	• ability to control settings whilst away from the computer. cohesive kit with tools that could be used together or individually • focus on quality of materiality that can sit alongside traditional musical instruments such as the acoustic guitar • ability to attach to stands/clamps/arms • presets that featured commonly used scales/notes/instruments • following an open source philosophy • use easy-to-access and affordable components • move away from screen based interaction toward tangible user interfaces. • kit that can stay within research sites after the research is over. • kit that is sensitive to typical practice based use in context of the research sites. Visual feedback on the system state such as indicator lights

Figure 44 - Whole Kit

The tangibility of the tools 'takes advantage of embracing the richness of human senses developed through a lifetime of interaction with the physical world' (Ishii and Ullmer 1997, p.7/8) in order to provide rich multi-sensory experiences and an interface to grasp against. The final tools construction infer quality. The tangibility of the tools also provides a mechanism for the users to experience their body. An analogous concept might be to think of weighted blankets that are used to provide the sensation of being embraced, in order to alleviate anxiety or stress. The use of the weighted blanket can be seen to provide an edge and a stopping point against which a person can delineate their own edges in a proprioceptive manner. In the same way the tools in the kit provide a means for the user to experience both their gestures as co-constituted with the tools, providing an opportunity to explore their own body. By extension of this mechanism the sound can also provide an 'edge' against which to interact and explore the sound/body relationship through. A concrete example of this type of exploration can be seen by considering the use of dual computer screens - where the arrangement of the screen in the physical world is misaligned with the arrangement of the virtual screens. Moving the mouse around incurs perceived 'sticking' on edges were moving past and through these will enhance the smoothness in other areas. The tools when used to interact with the sonic output can provide a similar sense of 'edges', 'stickiness', and 'enhancements'. These discrepancies can provide interesting points of exploration when considering interacting with sound.

The ability to split the kit up facilitates the tools being able to be taken away by the user and practiced with in order for the chance to develop a relationship with the tool, with each tool providing different characteristics that aim to support different users and use cases as developed through the work with the stakeholders. The three tools that use the computer as a bridge have separation of the controls from the interface (either controllable via a computer or via the iPad), which removes the controls as a distraction and allows the facilitator easy access to change settings as needed to maintain flow within sessions, thus concealing what is not necessary within session and enabling a potentially more inclusive mode of interaction for some users. The use of the iPad can also enable easier access to setting changes for users.

The state of the system can be accessed visually – for example LEDs were used in the receivers to indicate that the units were active. This could have been explored further with additional LEDs to show the state of the system (for example to show when the device was on, connected to receiver, sending data, and even utility lights such as when the battery was low.

The kits were provided to the research sites in a metal flight case containing all the components needed (minus the computer). The particular choice of sturdy metal box is both analogous to transporting important artefacts, and provides a practical storage solution for the tools that is robust. The aim was to consider how the kit would fit into practice, and give an overall sense of a cohesion to the kit, as well as a feeling of it being ownable by being portable – the case also considers the aforementioned ritual of use that runs from deciding to use, through using and back to storage.

The MAMI Tech Toolkit software was also provided on a USB stick as well as being downloadable to ease distribution and use in practice. Whilst these details may not involve the direct use of the tools in active music-making, they mediate the use of the tool. By providing tools that holistically consider their whole ritual of use, tools may integrate more easily into the context within which they are used. They become a *cogent* other to take into collaborations. They have an authenticity that is considerate to the practice that they are part of. In this way the tools enmesh with the practice within which they sit.

4.5.7 Conclusion of Stakeholder Requirements to Final Design Analysis

Technology can be used to leverage the engaging elements from the instrumental interaction associated with acoustic instruments whilst also providing the ability to design interactions from the ground up to suit users. In this way there is more room to explore how tools might be further broken down and integrated with acoustic instruments to effectively achieve the 'best of both worlds'. This notion could even extend to offering the user the ability to customise technology in the same way that other instruments are able to be personalised. The breaking down and reconstructing of the instrument in this way has a danger of confusing the user. This confusion can be mitigated by clear signposting of how a system works - both by conforming to expected interaction mechanisms (pressing something harder to make it louder) and within the form factor of the tool itself by providing a material and tangible interface to work against. Technology provides unique opportunities of using new modes of interaction to play music. There will no doubt be the development of systems of use and exemplars of techniques, much in the same way that Clara Rockmore couples with the Theremin to have an embodied control of its sound.

The exploration of the tools created engaged use, and as such an element of having to discover what sound was possible was a useful tools in order to maintain this engagement. Complex mappings where used to provide a low threshold and high ceiling to interactions to allow for tools to be instantly accessible whilst also provide chance for nuanced expression. The mappings used constraint as a tool to aid in achieving inclusivity by giving the users the chance to play without feeling worried that they were going to play something wrong.
Both the materiality of the tool in its construction and in the type of sonic content that was connected provide rich interactive experiences that focussed on authenticity within the feel and the fidelity of the sounds that were offered. This was more successful when using VST instruments as opposed to MIDI based instruments.

Settings and options were given in order to scaffolded the interactional possibilities of the tools in order to aid practitioners in their use of the tools. This could have been further explored in terms of hierarchical systems of access to settings, as these could have been tailored more specifically to users depending on their confidence with using technology.

4.5.8 Analysis of the MAMI Tech Toolkit against the Design Consideration

What is presented below is an analysis of the MAMI Tech Toolkit and the elements contained within, against the design considerations that have emerged from this research.

1. **Consider each layer of the system**

Each layer of the system is considered. The input - by providing hardware that allows for different modalities of interaction to allow access for different types of users, the processing - by allowing the user to make selections in order to tailor the systems mappings, and the output – by allowing changeable sonic feedback. This is achieved in the: filterBox by providing different types of VST instruments and the changeability of the settings within them; squishyDrum by providing different types of sounds and the ability to record and add own sounds; Noodler by the ability to tailor the trigger zones, change the type of sound, and add user sound files; and touchBox by allowing the reconfiguring of the physical set-up of the tool, and allowing changing of the timbre and notes that are triggered.

2. Decoupling the action from the sound production

The MAMI tools do decouple the action from the sound, apart from the touchBox in that the on-board speaker is present. To mitigate this the tools were always used through an amplifier that was placed as close as possible to the central user. There were also visual indicators of the data streams featured within the software to allow the users to see the data coming from the tools. In the Noodler there was a graphical representation of the position of the joystick within the target zone.

3. Expression vs Constraint

The mappings within the MAMI Tools range from simple - in which a button pressed triggers a note or sample, to complex - in which many inputs create real-time continuously modulate-able output such as controlling physical models, and triggering and modulating VST instruments. There is a configurability placed at interface level to allow tailoring of the system to suit individual needs. There is also the ability to add own content to create motivating systems.

4. Continuum of Control

Currently what is provided in the MAMI system sits at the instrumental and ornamental end of the continuum of control in that the sounds can be triggered or continuously controlled, but the system does not have any real agency in terms of taking this input and modifying it. In other words the system does not scaffold for instance timing, or it does not use the users input to modulate the output. The tools do conform the users input to particular notes within scales. There is room for more development in terms of tools that engage the more conversational end of the continuum of control by further developing the system to be able to scaffold skills such as timing, and by having some agency in order to provide a conversational interaction.

5. Natural Interaction

The filterBox and squishyDrum both adhere to the idea of natural interaction by following a direct correlation between energy input into the system - to amplitude of sound/timbral complexity of sound (in the squishyDrum – how many objects are in the shaker). There is a mimicking of interactions with acoustic instruments by using buttons that are analogous to those found on traditional instruments such as trumpets and by using gestures that match those used by traditional instruments; with the squishyDrum this is the act of hitting it like a drum; and with the squishyDrum and filterBox this is the act of modulating finger pressing to modulate the sound. The filterBox also features that lid which can be opened to modulate the sound.

The touchBox sounds until the user removes input to the system. The Noodler features the ability to stop the sound by having rest areas in the trigger zone within the presets, there is also a one click option to turn off the audio within the software that is accessible in the iPad app also. The Noodler allows the creation of trigger maps that allow mapping that use the natural motion of the user.

6. Form should inspire interaction

The tools in the kit are created with mainly natural materials to form enjoyable artefacts. They are aimed at giving a grown-up feel to them which parallels their acoustic counterparts.

7. Robust/Durable/Stable

The tools have been created in high quality materials with special attention given to ensuring that the internal electronics are robust in construction. The software was created with some error management in place such as not being able to open multiple instances of each separate tools application with the overall MAMI Tech Toolkit software. The fact that a proprietary version of MAMI was created as the tech toolkit software was in itself an attempt to minimise user error in set-up. There could have been much further testing to ensure that the software was stable in terms of crashes and that the user was aware of all aspects of the tools that could most likely incur malfunction (such as battery status and successful connections of the tools to the receivers).

8. Respect the Feedback Loop

Tactile feedback is provided through the use of the buttons, dials, and the joystick on the tools; and through the feel of pressing against the touchpads, the force sensitive resistor and the silicon squishyDrum cover. There is visual feedback of the streams of data being received within the MAMI Tech Toolkit software in real-time (minus latency within the system). There is more work to be done to make the system configurable to individual users (such as allowing changing of the size of graphical user interface elements, or removing unused functionality from the graphical user interface as needed).

9. Make It Meaningful to Those Involved

The filterBox has several VST instruments available as well as the ability to change the scale and tonic note. The squishyDrum has several types of shaker sound available as well as the ability to record in own content, or trigger from a folder of samples. The Noodler has the ability to choose from the range of general MIDI instruments, notes and scales as well as selecting sample based triggering, of which users own samples can be added. The touchBox has a variety of timbres, scales, and tonic note selections available as well as a variable decay length on the notes.

10. If You Can Add a Microphone- Do It

The squishyDrum enables recording of samples using whichever microphone input is selected by the user, which is then selectable as triggered samples. This could have been taken further in terms of being able to manipulate the sound. The other tools may have benefited from the inclusion of the ability to record and playback user content directly within the applications connected to them.

11. Think of Sound Quality

The filterBox uses high quality VST sounds. The squishyDrum uses physical modelling and user recorded or selected samples. The Noodler used MIDI but also provides the opportunity to use samples – either presets that are inbuilt that represent the songs that the stakeholders wanted to use within the sessions, or by the user uploading their own folder of samples. The touchBox uses synthesised notes and is polyphonic.

To control the level of the sound to suit the user each tool-specific application has volume controls within the application which are available on the iPad Mira app also. The touchbox has a headphone out and ¼ inch jack to allow different modes of listening to be chosen by the user and has a volume knob to enable easy control of volume.

12. Facilitate Choice/Offer Consistency

The software for the tools in the kit can be accessed by the facilitator and the user (depending on the user), however there could be more scope to improve this accessibility to allow the user to choose their own settings - as suggested in response to design consideration 8, in order to facilitate choice by the central user.

Within the Noodler there is the ability to save the trigger zone set-up to allow for recalling of setting related to individual users, however there is scope to improve the save function overall with the other settings in the Noodler, and within the other tools.

13. Participatory Design

The MAMI Tech Toolkit was designed in a participatory way by using action research as a methodology. The filterBox and squishyDrum were designed primarily with the industrial mentor and feedback from the stakeholders in meetings. The Noodler was developed throughout use in practical sessions with child one and two, and the music therapist. The touchBox was developed by the researcher using feedback from the action research cycles and assessing current gaps within the toolkit. The MAMI software was designed by the industrial mentor and the adjunct of the MAMI Tech Toolkit software was designed by the researcher.

The sonic output that can be created by using the tools (how they sound) - was informed by participatory design with the stakeholders. The design of the software was not participatory (in terms of showing it to the stakeholders to get feedback) but was participatory (in terms of using what they said to inform functionality) and so the aesthetics of the graphical user interface of the software would definitely benefit from future participatory work with stakeholders.

14. Small, Cheap and Easy to Use

The MAMI Tech Toolkit features hand-held and table top tools that fit in a flight case the size of a large briefcase. They connect to software that is designed to be easy to use. The touchBox is designed to be *switch-on-and-use* and the other tools are close to plug-and-play (plug-in, select port, open app, and play). Gallin and Sirguy's (2011) offer six points that impact plug-and-play design – a brief description is provided in how the MAMI Tech Toolkit addresses each:

1. Transparency - the data coming from connected tools can be seen in order to let the user know what is happening;
2. The interface is designed with the way it will be used in mind – in this case a musical use in which graphical elements within the software conform to music technology metaphors. There is an effort to remove complexity in the form of jargon and hard configuration within all the elements of the system, and an easy to follow manual is provided to assist the users in using the system. The mechanisms of interaction within the tools (buttons, joystick etc) are selected to be physically easy to use requiring light touch to operate. The tools also feature mounting fixtures to allow for positioning to suit users.
3. Only accessible parameters are visible – the MAMI software was used to create the tech toolkit software and as such much of the selectable parameters were hidden, however there is more work to be done here as there are still graphical elements that appear to be clickable or enable entering of data that either do not affect the system or may indeed disrupt the functionality. Each tool specific application only display selectable parameters or visual representations of the system state.
4. Technology is compatible with existing resources such as software, hardware, MIDI devices etc - The touchBox can be connected to existing amps. The MAMI Tech Toolkit software can be used on both Mac and Windows OS and also connects to the iPad.

5. The system has different levels of use – The MAMI and the MAMI Tech Toolkit software were both created using Max/MSP and are available on GitHub alongside the code for all of the tools and the plans for recreating them, allowing for any element of the kit or all of it to be taken, recreated and/or transformed by others. A particular instance of the MAMI Tech Toolkit was created for the stakeholders as part of this research and was packaged as a set of tools and an application that did not require any programming to use – this version contains within it a myriad of possibilities in terms of changing the settings within each tools specific application.
6. Compatibility with other communication protocols - The MAMI software created by the industrial mentor is compatible with a variety of hardware and uses common communication protocols (serial, human interface, OSC and MIDI). The tools in the MAMI tech toolkit use serial communication with the code available online, this means that others could create their own hardware and connect it to the MAMI Tech Toolkit software.

15. Wires are not awesome

The tools in the kit are wireless or stand-alone (touchBox). The selection of the setting can be wireless through the use of the Mira app on the iPad. With the pads of the touchBox the length of the wire can be easily changed and retracts for storage.

16. Think of the Whole Context

The MAMI Tech Toolkit was created with an understanding of the requirements and attitudes of the users in order to be inviting to use. These users were stakeholders and those that they facilitate and as such the toolkit was not user nor goal specific. The kit was created to be left within the setting, was not branded, and was open source in as much it could be recreated using the online resources associated with it.

17. Providing educational context for use

The way in which the tools from the kit can be used in terms of the sounds they create, has come from the embedded design process of practical use. This has led to the availability of presets that conform to what the stakeholder practitioners wanted or used frequently. There is room here for future work to link the tools in the kit with existing frameworks such as the Sounds of Intent (Welch et al. 2009) and to provide schemes of work related to the tools. This was beyond the scope of this research however.

18. Tech and do you even need it?

The toolkit was created to allow access to music-making for a variety of users – with the aim of providing both physical access and tools that support cognitively neurodiverse users by using motivating sonic output. The presets within the kit allow for them to be used alongside other musical instruments by conforming to standard musical scales. It is down to the needs of the individual as to the use (or not) of the tools within the kit.

4.5.9 Moving Forward

This cycle was used to explore the research aims of:

- creating novel tools that match criteria as specified by stakeholders, and addressing issues as found in the literature by creating design ideals, prototypes from these and forming them into a cohesive technology toolkit of hardware and software
- assessing the effectiveness of these novel tools with a view to improving practices by analysing created tools and technology assemblages against design considerations

This concludes the documentation of the action research cycles that were conducted as part of this research. As part of this cycle the final requirements for the toolkit were formed alongside the development of the last tool in the kit – touchBox. A discussion was provided about the technical development in finalising the kit. The package of the MAMI Tech Toolkit was then presented in terms of the individual tools, the software that they connect to and the overall contents of the kit. The 'tool as probe' was used as a mechanism to explore user requirements and how these informed the concrete creation of what was in the kit. The MAMI Tech Toolkit was holistically grounded in both theory and practical application. There was an analysis of the MAMI Tech Toolkit against the design considerations that have emerged from this research.

The next chapter provides an overall discussion of the research development as a whole. An overview of the major themes are provided with discussion around the methodology and methods used. The process of developing of new technology and writing-up is also discussed.

5. Discussion

5.1 Introduction

The previous chapter outlined the activities of the action research cycles, and how these informed the development of the MAMI Tech Toolkit. This chapter discusses and reflect on some of the major issues encountered during this research, with regard to the development of novel technology based tools, the research methodology and methods, and issues relating to the creation of this thesis.

5.2 Recurrent Issues in Developing Novel Technological Tools

This research began with the idea that creating novel tools would involve looking to the individual and their direct experience with the tools created, to think of musical instruments to the player, to focus on their lived experience, and as such to use research methods that would involve gathering knowledge about user experience, about perception and interaction with tools, and about successfulness in terms of accomplishing an outcome with the tools that made sense to the individual. In starting the research, and through working with stakeholders, it was clear that this approach would be difficult. The difficulties lie with both creating the tool, and assessing the tool.

In creating the tool several sticking points kept reoccurring throughout the technical developments. These were: 'musical devices' or in other words harnessing the input of the individual and turning this into the sonic output as created through mappings; expression vs constraint; transparency in tools; assessing the tool, and creating flexible technological tools. With regard to methodological issues: working with stakeholders using the AR methodology; developing technology with stakeholders; using the AR methodology; the research process; analysing the data, emancipatory issues; and issues from writing-up are discussed.

5.3 Unknown Unrecognised Issues with the iPad

What is presented in this section is an overview of the main issues that have been observed throughout this research in terms of practical use of iPads for active music-making.

These issues revolve around accessing the features of any given app and include: the use of a flat touchscreen; form factor of the iPad; and how gestures are used to access features. There are also issues around the iPad being a multiuse tool enabling ease of access to unwanted or inappropriate content; as well as issues with the iPad being a multisensory device in providing both visual and auditory feedback.

Accessing the touch screen could be difficult if not impossible for users with conditions that affected mobility. These conditions may affect ability to extend arms to a position that allowed the screen to be touched or to extend fingers in order to create the single point of contact that the screen required for use. Another facet of this is the recognition of a press on the screen (which varied from app to app) and meant that in some cases apps would not respond to a user interaction due to either below-the-minimum-amount of flesh or too much flesh being applied. This often led to confusion, frustration and/or abandonment from the user. Accidental palm presses would create unwanted output or unintended responses from the iPads app (for example triggering a different note than was intended to be selected or bouncing between notes). The lack of tactile or haptic feedback from the iPad was problematic at times particularly for those with visual or hearing impairments, or for those that could not see the screen when interacting due to the position of the iPad and their body whilst in use. This led to a lack of mechanism to navigate the screen for those with sight or hearing impairments, and a lack of feedback to let users know their interaction had been successful if auditory feedback was not heard.

The form factor of the iPad (both size, thin proportions, and being a flat screen) did not lend itself to being used one handed unless it was able to be secured on a lap or clamped to a stand– which in turn required specialist equipment (in the form of clampable cases). This limitation meant that often during this research the iPad was unable to be held and used at the same time. Often the iPads would have to be put into large cases to unsure robustness if dropped which at times hindered accessibility further. Gestures would sometimes trigger unwanted features such as screen rotations, closing the app, or popping-up unwanted menus. This was due to how the iPad was held or moved, or commonly used gestures (such as swiping) being performed by the user - whether accidentally or by being the only motion or mechanism of interaction available to that user.

The iPad being a multiuse tool enabled those involved in this research to use it to access apps they had used before, or the things they usually enjoy doing on the device. They were often adept (at times more so than those helping to facilitate the sessions) at navigating the tool in order to do the things they wanted with it. There were times when a specifically selected app would be loaded and within seconds it would be changed to another app which the user favoured. This meant that self-contained apps - such as the camera app, or apps in which the users could browse content - such as the web browser or YouTube/social media apps, could be accessed when not appropriate.

When working with the iPad the output was often audible and visual with no way of disabling or controlling the levels of either. This meant at times the visuals were distracting, overwhelming/underwhelming, or created difficulty in determining what was meaningful for the user, or what they were responding to - with a danger that they were solely concentrating on the visual feedback.

Ways to currently address these issues

Access to the iPad can be tailored in two ways - the first centres around controlling the content and privacy settings in order to constrain how users are allowed to use the device with regard to accessing content or apps, and the second centres on guided access that allows controlling or constraining the ways users can physically access the features within a given app. The first helps by preventing inappropriate use such as navigating age restricted apps, making app store purchases, searching the web and launching games etc. The second can be thought of as control of the iPad surface within each app. Changing settings within the guided access menu of the iPad allows areas of the iPad screen to be disabled. The use of guided access can facilitate those that may accidentally make contact with multiple points on the iPad surface by ensuring that only certain elements of the screen can be activated. Guided access also allows features to be turned off – such as the volume buttons, the motion sensors, the keyboards, the touch screen, the dictionary look-up, ability to accidentally close the app, and the sleep/wake button and also allows time limits to be set. The use of these can help to constrain the iPad in order to tailor to specific users and the areas of the screen they can access. They also allow for feature constraining to stop, for example, accidental changes in the volume, unwanted events such as keyboards popping up, or screen rotations from happening.

Ways to address these issues in the future

Further to the above options it is useful if apps provide the ability to calibrate features to users. Both with regard to the users physical mechanisms of interaction and how they interact with the iPad - as well as being able to tailor how feedback is provided. It is essential that a comfortable mechanism of interaction is able to be facilitated for the user through suitable modes of input and output. For example, during this research, the auditory output of particular apps would have often times benefited from being able to be filtered or equalised to ensure that levels were appropriate and tailored to the hearing abilities of those using the app. The same applies with the visual and tactile feedback –in terms of being able to tailor the position/size/colour/shape/brightness of interactional trigger zones to match the needs of the user.

5.4 Musical Devices

Musical devices for the purposes of this thesis, is used to describe the overall bundle of the tool system which includes: the mechanisms and modes of interaction (the physical sensors and the affordances they offer) as contained within the hardware; the processing that is used to sculpt this data; and the sonic output as a combination of the above (the mapping). Figure 45 highlights the reciprocal loops that are occur as part of the tools created within this research. Each loop comes with its own complexities that have had to be addressed when designing the tools.

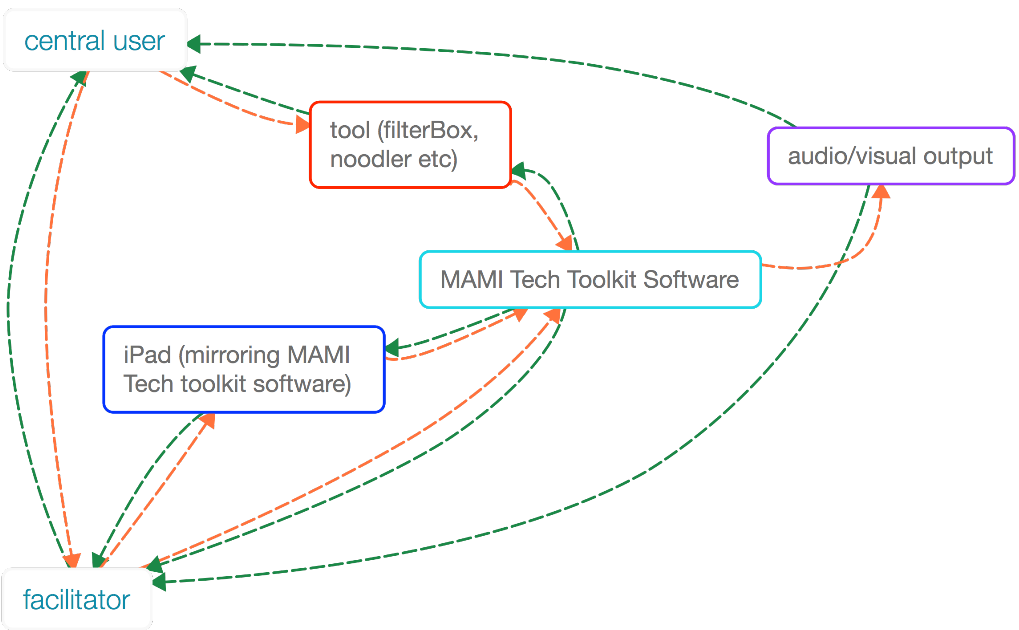

Figure 45 – The MAMI System Loops

The first loops can be considered as addressing issues of interaction via hardware, explored through reviewing and engaging with literature, and throughout the action research cycles which are then manifest in the final forms of each element of the kit. The second loop of interaction with the software settings (or via the iPad) can be considered as the 'sculpting' of the data captured from the interaction with users by the hardware, which is then mapped to the sonic output. Incurred throughout the exploration of these loops were issues that arose in terms of constraint versus freedom of expression and around transparency in tools.

5.5 Expression Vs Constraint

In discussion with the class teacher there was a worry that instruments that only allow for triggering of a sound did not cater for students in allowing a real sense of agency or actual expression. This could incur a whole thesis on expression, however expression as within this research 'is not a matter of reproducing dated romantic clichés or templates, but of finding personal ways to transmit one's own ideas' (Jorda 2005, p.229), this can be a push of a button or can also be technology that is 'played' in a manner akin to traditional instruments, 'allowing the performer to control every smallest detail, leaving nothing to the instrument 'intelligence' responsibility' (Jorda 2005, p.234). The wide range that these two poles emphasize has been discussed within the literature around the issue of expression/constraint when considering simple and complex mappings, that offer a continuum of control from pushing a button to trigger a sample, to nuanced and complete control over musical output, akin to that of playing a traditional instrument. This question needs to be rooted back to the individual, if we think of the ability to move towards becoming a virtuoso then we might imagine somebody being highly skilled in playing an instrument, such as a violin, and maybe performing a highly technical piece of music. This idea of the virtuoso might sit with us and our mental model in terms of what is typical and how the player has moved from the typical into the extraordinary. It is suggested here that what we consider virtuosic be seen as a relationship between typical and extraordinary *for a particular individual*. In the case of this research each individual could be considered as a collection of some typical and some atypical elements, and in this way pressing a switch to trigger a sound might be demonstrate a level of virtuosity for some. In reality this depends on both what the goal is, and who is setting out to achieve the goal. If the goal is to play something in time (whether to a particular beat per minute, to a desired rhythm, at a desired point by the user, or to create a desired effect such as layering sounds for example) then to be able to push a button in time (for reasons as suggested above) is considered a successful movement toward this goal. If the goal is to decide when to respond and move toward an intentional response, then the individual pressing the switch whenever they wanted would be a successful movement toward this goal. If the desire is to allow the fine control over the pitch of a note, then pressing a button to trigger a preset sound does not afford that type of interaction. When designing the kit these elements where considered to be able to facilitate both triggering of single events and continuous control of sound, that could be flexibly changed by the practitioner or user in order to scale the usability of the tools to the individual by providing a level of expression that matched their needs.

5.6 Transparency in Tools

When considering the above loops, what can be seen (Figure 45) is how the tool sits in the centre of the interaction and that careful consideration needs to be given in reconstituting the decoupling of physical input and sonic output, especially for individuals who might find difficulty in connecting cause and effect. The issue of this reconstitution is one which has been featured in the human computer interaction field (particularly in the new interfaces for musical expression sub-field), principally when considering the audience as observer (what is the performer is doing and how is that changing the sound?), feedback to the individual player (what am I doing and how is that changing the sound?) or when multiple users are co-creating music (who is doing what and how is that changing the sound?). This at times has extended, within this research, to other people present (alongside the central user) becoming part of this mediated process to support the individual to use the tool, in order to help forge these connections and reduce this abstraction. This highlights the interconnected web of use that are formed when these sorts of tools are in the contexts they have been used within as part of this research, and the importance of considering not only how the tool works and what it does but how these connections are made visible to the user at the centre. In this manner the facilitator or assistant can be considered part of the tool assemblage. In the cases of particular users such as those with profound and multiple learning and physical difficulties, there will almost always be another person to support them and they also will need to understand how the tools are working. These are the facilitators to tool use and include the teachers, the music therapists, the community musicians etc. as well as the teaching assistants and personal assistants, in that they are all musicking (Small 1998). An individual's interactions with their world may be mediated at some level through somebody else for these types of users. This level lies on a continuum based on the users' needs with the continuum ranging from 24 hours reliance and need for care to no reliance, with the 'typical' human spanning the later part of the continuum. These issues can be considered in terms of the those that facilitate tool use (such as teaching assistants, life nurses) as a proxy means to revealing/concealing necessary elements of the system to the user; magnify the capability/reduce disabling factors for the user at the centre by using their intimate knowledge of the person to ensure tools are set appropriately; and enabling access to expression/constrain tools to match the user's needs in an appropriate manner in order to be involving and not alienating. Within the MAMI Tech Toolkit there was a balance between providing a flexible system and something easy to use in order to be customisable without becoming overwhelming and not understandable. The two often did not work together in practice. There was a dichotomy between bespoke tailoring to one user or modular flexibility that may be 'good enough' for many users - as such the final application was tailored to be easy to use and featured functionality for use within a range of typical scenarios and use cases that stakeholders requested or that were observed during practice.

5.7 Assessing the Tool

When attempting to assess the tools difficulty came in four forms: objectively assessing subjective experiences; objectively assessing progression on a very individualistic basis, with tools designed for any form of wider use; the expression of the stakeholders to remain process led; and the oscillation between assessing the tools as tools (as might be considered linked to assessment in the field of HCI), and assessing the tools for their usefulness to the stakeholders (which might involve assessment frameworks to show progression for the individual). In this way, many of the frameworks available did not suit either objective – the designer or the practitioner - either through being specifically task based (as in HCI), or by honing in on particulars of the individual or specific musical goals, which then moved against the underlying ethos of this research to remain open and flexible in terms of who was using tools and what they were being was used for.

The success of the tool would have to come from either the individual's perspective, or the perspective of practitioners, both of which cause issues. The individual perspective would involve creating individualized profiles of the users (in conjunction with other stakeholders that could, by proxy, aid in the process) to get to some shared agreement of what would be a ‘successful’ outcome. This would face some difficulties both in terms of creating a tool, and then creating a scaffolding of assessment around the tool so that tool could be considered successful. This would be a considerable task and would not be transferable. Assessment from the perspective of the practitioner could involve a number of goals depending on the practitioner setting them, these could be music therapy goals, education goals, physiotherapy goals etc. Assessment tools would have to be bespoke to the practitioner, and any type of assessment tool would then have to be integrated into the already-full-bandwidth of the practitioner’s practice, which in itself was seen as not feasible by the stakeholders.

Aligning research to the school’s, the children and young people’s, or the practitioner’s goals would provide a built-in framework (integrating into resources already laid out) but there was recognition that these goals could all be different. Different practitioners may have different approaches (such as those in music therapy and sound therapy) that necessitate different goals, and different sessions could have different goals. These goals could be therapeutic, educational, or musical and could be person, music, or practitioner centric. Goals could be musical in nature (timing, dynamics, following a conductor) or feed into the development of other areas (physiotherapy, social interaction). They could be temporal in terms of in-the-moment goals or over-time goals. Some examples of goals were to allow expression, or to aid in developing fine motor control – these goals may have stronger links when considering a particular user group, in terms of either progressing on a spectrum of gaining control (when considering for example the links between autism and potential delayed development of fine motor skills) or of developing physical movement (for those who wish to improve range of movement, or gain strength and stamina). Aligning the research to the personal student profiles or learning outcomes may have provided a more robust framework for testing, which reflected the student at the centre more explicitly. There was no feedback mechanism or framework utilised to organise the feedback from the stakeholders, partly be due to difficulties mentioned above in taking subjective reactions and turning them into tacit objective developments, and partly that to put something in place would have required restricting the research in some way (honing into specific users/tasks). However, the mechanism for feedback should have been a core component to ensure the research was achieving its participatory aspirations in a more explicit way that could have been better transferred to other future research, so that is a limitation in this research.

When considering assessment of users interactions with the tools, frameworks recognised by the stakeholders (such as the 'P' scales or the Sounds of Intent framework), might have helped in order to quantify, or at least log reaction to developments, in order to feed into future developments. However, these frameworks start at a level and continue in a granularity that may bypass some of the concerns as outlined within the theory discussed within this thesis. Namely the recognition of tools and the intention use of them to actively to create music. Firstly, the users need to recognise the tool before they can proactively use it, suggesting that there is room to extend these frameworks into interaction with mediating tools by recognising the abstracted nature of the tools. This abstract nature is intrinsically more inherent in digital musical instruments than traditional musical instrument because of the extra layers of abstraction that are created from decoupling the action from the sound source. As such these frameworks do not necessarily take into account this abstraction as they are focussed on awareness, reaction, and interaction with sound and not awareness, reaction and interaction with tools that make or control sound.

A pragmatic approach was taken to use the practitioner to guide the design of the tools, which it was hoped would then culminate in tools that were better situated to serve the purpose the practitioner needed them for. This did remove the need to assess the tools for either purpose (as tools to do a task, or as tools to aid in individual development) via specific frameworks in either field as the focus was providing the practitioners with tools that enabled them to facilitate access to music-making, it did however, mean a lot of the development moved 'on the gut' on the researcher and core stakeholders in an implicit manner without much auditory trail.

5.8 Developing the Technology

The core development of the technology was a lengthy process that was often fraught with technical issues. There was frequent need to upgrade researcher skills-sets in order to be able to deliver a final product that closely aligned with the stakeholder's specification. Whilst the initial design came together quickly, the nuanced details of the design took longer. There were also some areas of the technology that were unreliable and some avenues that were abandoned due to constraints of time, money, and 'real estate' both in terms of space within the instruments actual physical design, and skills needed to implement the optimum design.

5.9 Methodological Discussion

In terms of *methodological reflections* what was interesting about this type of development was that there were many elements that intertwined together to push the research forward. All of which involved other peoples' (the stakeholders) input at each stage, this could be technical development, developments of ideas, or development of action.

Each of these actions could be thought of as plan, act, and reflect cycles in themselves and so could lead to '*nested cycles'* that then fit into the overarching phase. These could then be viewed as several mini cycles that sit within and contribute to the larger phase progression of each cycle. This can be explained by thinking of several activities within the main cycle, for example: a meeting – there would be a plan of the stakeholder activity (e.g. a meeting), act (have the meeting), reflect (reflect on the meeting) which would then feed into the next activity; or a session – there would be a plan (the activity session logistically e.g. which room etc.), act (have the session and document however planned), reflect (on how the session went, how tech worked etc.), plan (the next session and tech changes) etc. These are then *nested cycles.* These *nested cycles* could be used to continue the dialectic with stakeholders or to validate/clarify research progress – e.g. having another chat about a particular point/issue.

Some parts of the cycle were 'heavier' than others in terms of the importance, or the significance of the data, or the amount of activities that happened in them – this could perhaps lead to weighted cycles. In which a particular phase was of particular importance within that cycle. Depending on the activity or the outcomes wanting to be achieved, this could change over the course of several cycles, for example when it was pertinent to develop the technology, it was less pertinent to interact with the stakeholder so in cycle four of this research, the planning and reflecting stage were much smaller than the acting stage in terms of researcher resources used, and the outcome of the cycle was focussed on the physical toolkit and not so much on the gathering and reflecting on the stakeholder findings.

When thinking of the research as a whole, there could be considered to be an overarching cycle of planning the research as a whole, acting out the research and then the thesis being a reflection on the process – as an '*umbrella cycle'*.

In writing the thesis into phases within action research cycles there were problems with trying to fit activities into planning, acting, and reflecting to be able to tell a cohesive, coherent, and authentic story of the research to develop the justification of the final MAMI Tech Toolkit and the claims to knowledge. This involved trying to maintain the chronology of the process whilst representing the cycles as they are presented, which was difficult. It was sometimes difficult to distinguish what was happening at each stage or at least how to solidify this in writing-up. At times the research took on a plan - reflect, act - reflect, reflect - reflect form. Some cycles had phases that interlinked – for example, planning a meeting (this could involve ideas around who to invite, how to invite, how to even hold it - from logistics to semantics), acting (having the meeting, observing, taking notes, transcribing), reflecting (on the content of the meeting and feedback to the stakeholders) but within the action or reflecting time there may also be planning for the next action, thus the phases became *interlinked phases*.

The AR methodology allowed the research to be flexible and go with the flow of what was needed, using the available resources (either time, space, equipment, knowledge), at the time, by those involved. Any movement forward at any time was only as a combination of these things in a pragmatic fashion**.** This led to an uncertainty of the end product as expressed by one stakeholder. '*It's a strange something to be going on because we are thinking of an end product like a performance piece but also within the context of action research where you don't know where you are going and that's actually quite exciting but we are aware of that other agenda too but we are not quite sure how we are going to get there*' (class teacher/head of music 2nd stakeholder meeting).Though the form of action research adopted, this was never fully developed into a commitment to a particular form of action research, which could be seen as a lack of rigour (Deluca et al 2008). Had a more solid form been adapted, a better research scaffolding would have been present to both investigate the issue, present the research to stakeholders, and present the research to the broader research community. There was evidence that the stakeholders were forwarding the research autonomously by speaking about how they personally have developed from having time to reflect on the process of technology creation and integration, via the process of the research; and by the evidence of them enacting concrete changes by themselves - such as creating software (industrial mentor), or arranging for technology resources such as Spotify playlists, and iPad apps to be available for use by the children and young people in school A by the class teacher/head of music.

The 'fuzziness' of the research and the lack of agreed upon aims, objectives and goals that explicitly stemmed from the stakeholders was at times an issue. As the research aimed to remain open with the research aims for guidance, there was no formation of formal lines of questioning which were used across the data collection procedure and as such this made the analysis of the data more difficult as diffuse discussion occurred that then had to be distilled back into themes as presented. The openness and flexibility that made the research successful in terms of allowing interdisciplinary interaction, inter-site action, and inter-action activity also meant that the data were as heterogeneous as the means used to gather them. This did pose a limitation in that there were no locked down goals and assessment aims, or no specification of the users, and in effect a 'blank cheque' was created in terms of aligning to current discourse, practice, and gaps in knowledge. Difficulties were faced with consolidating both the varieties of inputs and all of the varieties of areas covered, this was also compounded by the need to reconcile what happened and how to portray what happened in an authentic manner. This has meant that whilst there is knowledge that has been created as part of the process, it is knowledge that is not homogenous or locked to a particular topic or area but is smaller parts of knowledge that contribute to several key areas about several key topics. Had the research been more constrained perhaps more in depth knowledge in a specific area or contributing to a specific field could have occurred. Problems have ensued in the write-up stage in terms of clearly formulating the contribution to knowledge with regard to the theory surrounding the particular fields at the centre of the research. Had there have been formalised questions not only would the data have been potentially easier to handle in terms of using the questions as anchors to arrange the gathered knowledge around, and using a field of study as a target to focus in and aim at, there potentially would have been opportunity for the introduction of quantitative analysis which may have better represented the stakeholders responses and needs in some cases to some particular issues – such as quantifying where technology might work and with what type of user. Although any form of 'locking down' the research there would have meant surrendering some of the openness of taking the research where the stakeholders wanted in true spirit of the action research methodology used.

5.10 Working with Stakeholders

There were times when things on the agenda weren't covered. This was due in part to researcher inexperience, and involved issues of people relations – stakeholder to stakeholder relations – researcher to stakeholder relations, and situation to stakeholder/researcher relations. As a researcher, there was the inclination to not want to be annoying, or to overstep boundaries and this sometimes led to agendas being abandoned or to miscommunication or expectations not being met. In hindsight, it may have been better to have rigid and procedural systems in place to outline interactions and outcomes that were expected as a lot of these were 'in the ether' and not solidly outlined. As mentioned a lot of the development moved forward on intuition. Many decisions throughout the research also occurred 'in the gut' in that the researcher chose direction and made decisions without direct attribution to their foundations but through consulting tacit knowledge. This can be seen as a limitation as there is potential for bias to enter the system, possibly leading to 'black box' research, where solid traceable links from the stakeholders and their input, to the output of the research are not able to be made transparent. Throughout the writing of the thesis an attempt has been made to reconnect these tacit decisions with the original forces that they were founded in.

Some methods used have illuminated issues that should be highlighted, in terms of the type of users at the centre of the research. These issues include participant voice within the research. Interviews and focus groups as well as sessions have provided those non-verbal or non-lingual participants an avenue to be part of the research. The interaction with stakeholders as proxy voices (Börjesson et al. 2015) for the children and young people at the centre of the research has also provided the chance to gain insight when participants cannot directly be observed or when the tacit and nuanced knowledge that practitioners and school staff have about the children and young people under their care, can be explored and used to inform development or reflect on developments. Whilst some stakeholder interaction, such as that with some of the children and young people, did not involve any lingual or written interaction on their behalf and remained purely on an interaction with the technology basis, other stakeholder interaction was extensive. This included spending whole days with one stakeholder, working next to their desk and develop next to them. There was also the realisation upon writing up that some stakeholders contributed more than was acknowledged at the time or than was potentially accounted for. It is then difficult to say a retroactive thank-you and engage with a stakeholder after a two/three-year gap between their interaction and when you figured out just how much they contributed.

Some stakeholders were more dominant simply because they integrated technology within their practice more than others. The way they used technology shaped the development of the MAMI Tech Toolkit - where it might have been beneficial to consider more closely practitioners that didn't use technology. In this way, the toolkit as developed plays more towards those that have some technological integration skills and not complete novices. This will hopefully be an avenue open to future work.

There was no framework in place for interaction with those that offered input, but were not formal stakeholders such as the teacher who stated - '*thank you for the sessions with* [child one], [they're] *really enjoying them*!' (child ones class teacher school A) highlighting the need for avenues of communication to be open and recordable in order to formally allow their feedback to be included in the research analysis and dissemination.

5.11 Working with Stakeholders to Develop Technology

When any mode of interaction can make any type of sound, the most important factor then becomes what people want and how they want to use such systems - these then are the constraining factors. These can sometimes be large constraining factors as people do not always know what they want or what is achievable. Technologists are often seen as wizards that produce magic, or at least that has often been the case in the context the researcher has worked in. Practitioners were varied in terms of experience levels of using technology however they have tacit knowledge about their practice. In this way, a two-way relationship was developed of showing, telling, and listening. The practitioners would offer usage scenarios and use case, and the researcher would use that to bring about technological solutions. This was a delicate balance between the need to give guidance, to show what is and could be possible, and suggest solutions, but not to take over or move into the realm of technology for technology sake as mentioned by Magee et al (2011).

Stakeholders felt the research offered them time to reflect that would not have occurred otherwise. *'It's nice to be thinking really have the time and space to really think about the philosophy behind what we are doing because we* never *get time to do that'* (class teacher/head of music).

5.12 Issues with research process

The three elements of the research; the technological solutions in development, the research activities with stakeholders, and the combining and collating of these into information, in the style of a curator, to form the actual research output, have sometimes been difficult to juggle and reconcile. Ensuring all correspondence was kept logged and together was difficult due to the multidisciplinary aspect of the research. There were times when key issues were not included or acted up but no clear reason why. This may have been due to researcher incompetence, or feasibility, or at the instruction or interaction of the stakeholders with their input changing the direction. This has at times marred the transparency needed in the action research process as a more robust record should have been kept in terms of all research decisions.

5.13 Analysing the data

The use of action research alongside an interpretivist and emergent philosophy which was actively trying to avoid focussing the research in meant that analysing the data became difficult. Saunders et al (2015) states that using purely inductive methods can be time consuming and the use of the research question should provide a tool to ensure data is coded in a way adequate to address the question or objective. Where the question and objective throughout this research was open, this meant that the data was varied.

The development saw the intertwining of developing technology, research, and practical application of technology and as such three streams of 'data' were involved at any one time of play. A limitation of the research was that these streams were not distinguishes as distinct from the outset, this meant that the data was messy to pick apart in terms of what data functioned to resolve technical issues, what data was used to inform technical development and what data could be transformed into a contribution to knowledge for the research. Sometimes data could be all three at once and would form a quasi-triangulation of sorts. The data would triangulate to inform the three perspectives. An example would be the piece of data that said: 'one child found the sound level too loud' - this informed the research in that it: highlighted an issue that went on to inform the discussion around contextual issues of technology (in terms of making sure individual needs are met by considering logistical matters of sound); highlighted a technical issue that needed to be resolved for following sessions (either by turning the volume down or providing ear defenders); and it informed future design (to make volume control accessible and allow for headphones sockets to be used on the touchBox for personal volume control). The findings could be thought of in different ways depending on how they influenced the development of the technology. If the finding influenced the technical development then they it was a technical finding. If it influenced considerations to how something was used in context then it was a contextual finding. If it created knowledge about interaction with sound then it was an interactional finding. It might have been beneficial to split the findings out in terms of these three categories in order to better show the progression of development.

When analysing the sessions, the data was analysed to saturation. This meant that only the first instance of a particular issue would be logged, and no quantitative measurements of occurrence would be formed. This subsequently meant that there was no 'weighting' of issues in terms of how much they occur and how 'big' of a deal they are. An example would be the app used in sessions creating sound that was either too loud or too quiet, which occurred multiple times. Or that stakeholders wanted portable tools, which was expressed multiple times also. It would have been beneficial, resources permitting, to have created some sort of representation of issues on a scale so as to see where future work might be most beneficial for more impactful outcomes. However, for this research issues were issues whether they occurred once or many times - in that they might occur in the setting again. If an aim of future work is to provide details of what the bigger issues might be, then this weighting would be important. For this thesis issues were logged to work toward the next step of technological development, but for future research there could be a focus on the most common barriers to using this tech and by provide contributions to knowledge such as a technology issues 'heatmap'. This could then provide starting points for future work and contribute to knowledge within the wider discourse of research.

5.14 Emancipatory Issues within this Research

In working at the micro level of the individual and considering issues around providing voice, and the emancipatory issues involved with this, there is often inherent bias in the system to those that can typically contribute at the behest of those that remain voiceless. Practices and procedures often necessitate involvement in typical ways (such as talking, reading, or writing about experience) to plan, act, and reflect on and in action, both in and over time. This was manifest in situations such as using the children and young people's feedback to decide what to do the following week in the session. Some of those who were not able to communicate their wishes with words, or body language were effectively invisible in any plans made, which are then made *for* them and not *with* them. There are no easy suggestions for dealing with these bigger issues as part of this thesis, other than always considering the requirements of the individual and keeping them central to anything that happens involving them and by consulting those that are closest to them. By monitoring how potential users communicate, assessing their physical and cognitive needs and abilities, and eliciting and monitoring responses appropriately their perceived desires/states of being can be used to build a picture of the individual. This may help in terms of finding tools which might be useful for them, and extends to finding mechanisms to truly allow some users to be part of the research process. New methods needs to be developed to fully explore this area to allow the voices of these individuals to be heard.

5.15 Writing-Up

The issues in writing-up have been in the reconciliation of: weaving a story that attempts to tell the full scale of the activities of the research, in order to show the breadth and depth of the undertakings; vs weaving a story that is readable for a particular audience. ‘Action researchers thus have “two masters”; the subject(s) of their research and the broader research community. It is often seen to be much more difficult to appease the demands of the research community than to deliver results for the subject of the research’ (Interaction Design Foundation 2016, para. 8).

Towards the end of the writing process it was evident – especially in the removal of the planning and reflecting phases of the diagram in cycle four (they were empty as no stakeholder activity had occurred in the final cycle) – that I had effectively removed myself from the development process somewhat. In effect this means that I have not included myself as a stakeholder, and that the many completely affecting decisions I have made during the research are not made explicit. However inclusion of this would have been on an ‘all or nothing’ basis in that documenting these decision and reflection in a more phenomenologically or ethnographically driven way, would have resulted in a thesis which would have had to carry another facet (theories, words, time, resources etc) to its already-diverse and heavily laden body.

5.16 Creating Flexible Tools

Creating a tool that would individually suit a unique user would do just that, the tool would suit only that user. Whilst that would be an absolutely noble pursuit and would contribute to the field of HCI in matters of designing for specific needs, in terms of this research it would not allow the tool to be transferable. This would go against one of the initial tenets in that tools created should be flexible and transferable, as guided by stakeholder input in the *with* and *for* capacity. Thus, the research moved forward following the will of the stakeholders and the focus of the research moved from a micro focus (individual perspective) to a meso focus (working for the practitioners). This involved concentrating on making tools that work *in context* with the idea that often, whether considered correct or not, the user at the centre is not the one who decides what is being used and how it is set-up. Tools that are used in sessions, are often not selected by the individual that will be using them nor are they configured by that user, they may be set-up and configured *for* that user and maybe even *with* that user, but this is dependent on a variety of factors that come into play. Scenarios of use are very individualistic each coming with their own intricacies. The tool, the context, and the user interlock in the usage of technological tools. This research has aimed, in part, to expound the issues that affect technology usage for each area, in an attempt to extrapolate out the orbiting nodules and intricacies of each that contribute to affecting the successful use of technology. Through this process there has been as attempt to explore connections as to common situations, common problems, and common solutions. This has involved considering which elements are at play when a tools is used for music-making in terms of questioning the levels to the scenario. For example, it is not just Joe Blogs plays with the filterBox - it is questions such as: who is with Joe; can he do it by himself; is he enabled; is he enjoying it; does he want to play; what else does he need; where is he playing it; what is it being used with; how is it being used; what is not working with it; what is working with it – logistically, goalistically; who paid for it; who set it up; who organised it to be there; why that tool; why Joe; what is the outcome that is trying to be achieved – in terms of goals for the school, Joe, the practitioner, the session, the performance; will it be used again; who looks after it; who knows how to use it. All of these questions form the basis on whether a tool is used and whether a tool is used successfully, and thus whether technology in general for music-making is pushed towards further uptake.

I see each individual that could come into contact with my tools as just that - individual, there is no way to measure how they interact, no way to test the level of engagement that could be generalized. What could be generalized would be a tool - a tool that in the right hands could be used to help more than one individual - a tool created as a response to gaps in provision identified from literature, and practical review. To have something that completely suits everyone was never going to occur in such a short time with limited resources but, I believe, me and the stakeholders have made headway into describing what has been done so far, the issues that surround these types of technological developments, and what is needed and in doing so have produced something of value that contributes to knowledge in the MAMI Tech Toolkit.

Within the literature there seems to be a focus on common situations and common problems, and whilst researchers such as Magee, Krout, Machover, Hunt etc. have extensively explored technology through use, in practice, and via empirical study (aiding the movement toward common solutions), there is still much work to do in this densely complex and interdisciplinary field. This research aims to contribute in the movement towards common solutions by providing tools that practically integrate and iterative to ascertain these common solutions – such that the two work *for* and *against* each other to progressively move forward. I believe these common solutions are already happening but are happening in silos, and are rooted in practice with the pragmatic practitioners that are themselves invoking the spirit of Levi-Strauss's bricoleur to create musical systems made of assemblages of technologies.

5.17 Methodological Considerations

Here is a section of some methodological considerations that have been created in response to the question 'think about what you did, and what you would do instead now?'.

The methodological considerations form a contribution to knowledge as a collation of suggestions for future researchers. They are aimed at those implementing an action research methodology to inform the design and creation of an artefact (in this case a kit of technological tools). They also show a fulfilment of action research requirements in terms of demonstrating the development of reflexive and dialectical critique by the researcher.

1. **Forming Research Questions/Aims**

Initial steps should involve the researcher recording their own ideas on the research gap alongside a literature review (incorporating a comprehensive search strategy that is documented) to identify/strengthen this gap. This will aid in identifying the potential scope of the problem and in defining a tentative research question or set of tentative aims. These tentative starting points can be presented to stakeholders and may simply be used as probe to the prompt the stakeholders into a dialectic exchange in which questions/aims/objectives etc. can be agreed on. These can change and any changes should be documented so that the path that the research has taken and why is made clear. The concretised questions/aims that are presented in the final thesis represent the elements of the process within them and so it is beneficial to be able to explore how they became solidified.

The formation of the research question/aim can link into the overarching *umbrella* cycle of the action research project.

2. **Find (a) stakeholder(s)**

These can be formed of geographically located or interest based individuals or organisations. Start to think of individuals or organisations that relate to the research gap (for this research it was places where people use music technology to provide access to music-making for those with complex needs), in other words identify a *key usage scenario* and out of this the *community of use* in order to seek out stakeholder involvement and proactively engage with those stakeholders – there will often be a snowball effect of connections within the stakeholders themselves. Use these to your advantage and document these connections.

3. **Working with stakeholders**

When approaching stakeholders, particularly if you are developing technology that has to fit into a current practice, meet people where they are (in their naturalistic setting if possible) and refrain from overloading them with extra workload. Explain clearly to the stakeholders what you know about your resources in terms of: what you have; what you can do; and what you want from them. In order to both manage expectation and create shared ideas of what might constitute the success of the research.

Think about what they can tell you and what they can show you when considering the methods that you use to collect data. Interacting with them directly to gain their thoughts and feelings can provide different data than watching them practice and seeing the practicalities about the situation. Also think about what you can tell them and what you can show them in other words - how to get across the potentials developmental pathways that the technology could take without being jargon heavy as stakeholders might not know the potentials that technology can offer. In this manner there will be an intertwining of expert knowledge and professional skills to complement one another.

Gather as many stakeholders as you can manage. Find the hotspots of activity and the *energy in the system*, in terms of key stakeholders (as these are potentially stronger agents of change and will get the research moving/carry it through), and blockages in the system in terms of those that seem to hinder the research from moving. Have ethics and feedback sheets available at all times as you never know when a potential stakeholder might appear or you will be given a piece of useful data. Report back to them what you discussed in a manner that is appropriate to them (by asking them how best to correspond with them) and give them opportunities to counter this. Register all feedback - be meticulous with details of dates/times/what the feedback was in connection with, to be able to see correlations between what was recorder and the technical developmental that came this, i.e. what happened and why. Be as rich in detail/recording this as possible.

Create a spreadsheet of stakeholders, their connection to the research and one another, their main area of practice, how best to communicate with each stakeholder, and their level of input – this can be used to give them a *weighting* when considering key stakeholders. This may be of importance – an example would be in this research that the stakeholders that were *heavier* were ones that were more technologically proficient and as such the created technology could already be seen as slanting toward those with more technical proficiency. These stakeholders might not necessarily represent the majority of the users that the tools were intended to support.

Keep the stakeholders as comfortable as you with regard with making it easy for them to contribute knowledge and comfortable for them to do so. This ranges from practical things like fitting around their schedules to providing inviting communicative spaces in order to encourage dialectics (even down to providing things like tea and biscuits). Ultimately you need stakeholders to cooperate in a range of activities to gather data from them. This included them: telling you how they feel about the research problem; showing you things that relate to the research problem; saying what they think should be done about the research problem; helping you to compile technical requirements; reacting to your suggestion of technological solutions; telling you how they feel about what you are doing with that information – i.e. feedback on the technological developments; and using the technology in order for you to observe its use. In a school setting particularly, the stakeholders will be laden with the requirements of their job roles and as such the bandwidth available for: the addition of new frameworks within which to work; activities that use their time; curating large amounts of feedback or reading through large amounts of information, will be low. Because of this the construction of any materials that require stakeholder input or output should consider the above points – this also connects to keeping a record of how best to correspond with each stakeholder – to ensure smooth data transmissions between you and them.

4. Action research cycles

Action research is commonly broken down into phases of planning, acting, and reflecting. However it is sometimes difficult to stick to this framework within the messiness of real world research. What is offered here is a response to the discussion in section 5.9 in that each action within the research can be considered as a plan, act, reflect cycle nested within the larger phase that that activity sits within. A recommendation of this research is that each activity become a cycle in itself to form a *microcycle* in order to allow for easier documentation, analysis, and synthesis of these activities. As such the *microcycle* can be *nested* within the larger phase that they might sit within. The activities can then more easily be sorted by type and placed chronologically to show progression if needed. A homogenous template to document these microcycles could be used with one per activity (example template in appendix O).

There is also the recommendation that there be an overarching action research cycle that ties in with the overarching research aim/objective. This can then be useful when it comes to writing the final report in terms of structuring what happened during the research.

5. Data Collection

Utilise naturalistic, in the field activities, when approaching the research problem area, to enable first-hand experience of problem. It is useful to combine methods such as observations, interviews and focus groups, as both research and stakeholder exploration of technology in practice enables the collection of a rich variety of data. Ultimately you want to know: what technology might be suitable before beginning the iterative design process of creating the technology; and then you want to gather data about its use. This can be through taking an insider or outsider research stance, and can be ethnographical in nature by observing stakeholders or auto-ethnographical through utilising the technology first-hand and recording your own response. Make sure that either way is documented as such to avoid confusion as to where data came from and who it is attributable to.

One particular feature of the development of technology through action research is the combination of: interacting with stakeholders; developing technology; and considering how the technology provides solutions within the context. In this way, it is suggested that data captured be divided into interactional, technical, contextual data. This allows for easy separation when it comes to analysis. Data can however move between all three, as shown in this research with the example of the sound level negatively affecting a participant and how this informed thoughts around all three suggested data types. As such the connection from the informing data to the analysed data should be documented – again to make explicit the trail that the research took and why. Also helpful with this is labelling any data in terms of whether it occurred at the time of the activity, shortly after the fact, or as part of a later process. This helps to connect what happened and why between stakeholder interaction, technological development, and further data analysis in order to show how they all worked together, what was known when, and what informed what.

Whatever data is collected (from stakeholders or from sessions) – there should be meticulous attention to detail in the documentation (fitting to the criteria as laid out in appendix O). In terms of how the data is captured, there is a trade-off between richness of data and time and resources it takes to analyse this data. However particularly when working with sound, or music, or technology in action, it can be beneficial to capture rich sources such as video, audio, gesture capture to gain knowledge that cannot be spoken or written about easily. Having recorded and transcribed data is invaluable at providing exemplar statements that relate to the analysed data as a staple of qualitative research. This also means that it is easier to be in the moment with the stakeholder rather than trying to take notes as well. Another useful tool is the use of real-time co-created written data – for example working with the stakeholder(s) to organise their and your thoughts on the research problem or any part of the process. As with any data collection, the best method is the one that garners the information needed to move forward or to interrogate the problem area further – this might require augmenting and/or creation of new method of data collection in order to tailor to a variety of stakeholders, as seen in the work of Moseley (2020) in which new methods were constructed to gain data from participants.

6. Developing the Technology

A key consideration when developing technology is the documentation of the process over time, and in the case of this research storage for dissemination. As such GitHub was used to log software developments in order to both keep records of all the iterations of prototypes and allow the final software to be shared, taken and adapted easily. This documentation should strive to encapsulate all the components of each iteration including:

- the code of both of the created technology, and of the surrounding code used to formulate the system (such as Arduino libraries, other abstractions)

- a description of the system in terms of version numbers of software or hardware (including details of which versions of prototypes were used for any research activities)
- images/videos of the prototypes in use by stakeholder(s), for other research activities (demo stand etc), and to provide documentation of their current state and functionality (e.g. a video demonstration of technology in use)
- resources that surround the material instantiation of the particular prototype (such as CAD files, bills of materials, tools/techniques used for creation).

This enables the technology to be reconstructed as needed, it also provides evidence of progression, and the ability to fall back to known working prototype.

A consideration worth mentioning is the stakeholder involvement at various stages throughout the technical development. It might be beneficial to split the technical developments into distinct phases of design, experimental, or analysis - as stakeholder involvement varies with each.

A logbook should be kept of the technological development to show what you did and why, and if you solved a problem - how. A particularly helpful tool is something like Evernote (Evernote Corporation 2020) as you can add metadata (such as tags) in order to keep all of the various information in order, or to be able to refer back to problems and the connecting resources that were used to help overcome them. These sources can sometimes be heterogenous (webpages, handwritten notes, emails, hastily drawn diagrams etc.) so a way to store, collate, and search them is vital.

Technological developments feature within them lots of opportunity to create a repository – personal, shared, or public – of abstractions in terms of reusable code/mechanisms for handling computational data. In this way, those developing technology should consider keeping a library of such abstractions (considered as chunks of code that perform specific tasks) as they are useful for future developments in terms of providing modules of existing solutions. These might be third-party or personal and should be labelled as such to enable traceability of solutions.

7. **Data analysis**

In terms of data analysis – the openness of this research in not tailoring to a particular thing (question or target central user) meant the data may become heterogenous and in analysis there was therefore a lack of anchor or framework on which to sculpt the data. This allowed the research to remain flexible, however forming a specific question may help to gain a deeper understanding about that particular question. As such there is a trade-off between openness and flexibility and depth of analysis in one area. Which way works best depending on remaining congruent with the underlying values of the research.

8. Being a researcher and developing technology

There are many roles that are assumed within conducting action research, doing qualitative research, and developing technology. It is a skill in itself in terms of knowing what has to be done. At times this means recognising what skills are needed and either upskilling yourself – or outsourcing to others. Either way keep a record of both to show this progression or to be able to attribute things to others.

9. Meticulous Documentation

A final word is on general meticulous documentation of all of the above (including time, place, multimedia account) as well your own thoughts and feelings, and the stakeholders thoughts and feelings on:

- The overarching research process
- The internals of the specific research process
- The interactions with the stakeholders

It is useful to keep an ongoing journal or log as well as a timeline with pertinent activities marked on it and any connected resources that were involved at that point. This can include any potential kernels of ideas that can be explored further – either through work with stakeholders, within the technology developments, or for other forms of dissemination such potential journal papers/presentations etc. Within this research several physical notebooks were chronologically kept (and digitally transcribed which was time consuming) to document the above – this was then combined with Evernote (Evernote Corporation 2020), Dropbox (Dropbox 2020), and emails from both the school and the university. Documentation specific to each stakeholder site and individual was held in a secure folder for each site and within it a folder for each key stakeholder or activity, with any media content generated (sounds of the tools in use for example) being stored in the same way. GitHub (GitHub 2020) was used to store information on technical developments (including Arduino (Arduino 2007) code, Max/MSP (Cycling74 2018) patches, Fritzing diagrams (Fritzing 2020), written resources). In order to collate all of these diverse resources it is beneficial to have a master log (electronic preferably as easier to link the above) that then links out to the other sources of documentation and provides a chronological digital trail of all of the research elements. This can be thought of as a sort of research diary within which all the other elements sit and can be linked together and also provides a space to record anything that doesn't fall into the above categories but that could be useful to keep record of.

Conclusion of Methodological Considerations

Ensuring all of the above will mean that any written reports coming from the research will be easier to compile, the road that the research and the researcher have taken will be easier to map out, and the process of technology development will be explicit. What will also be easier to navigate will be how the stakeholders input occurred, was used, and contributed to the final output of the research.

5.18 Conclusion

In conclusion, the following quote nicely sums up the overarching issues that have befallen this research:

> *'Practice-orientation is a labour-intense, risky, and long-term research approach. To be able to conduct in depth field studies in real world settings and to roll out innovative IT artefacts, one needs to build trustful cooperation with practitioners and their management. A considerable part of the research efforts are dedicated to satisfy the practitioners' problems which are not always academically interesting. In addition, the technical artefacts, which we build and roll out, need to be technologically well performing, stable, and usable. Hence, an open challenge is to develop design approaches to observe appropriation phenomena in a timely and cost-efficient way, not deformed by technical issues in a disturbing sense. Finally, practice-orientation is a risky research framework. Design case studies can break for a variety of different reason of which many are not under the control of the researcher'* (Wulf, Rhode, Pipek and Stevens 2011, p.510).

This chapter featured a discussion of issues that have occurred throughout the research. A series of nine methodological considerations were presented that have emerged from this research process. The next and final chapter provides a conclusion to this research and illustrate potential avenues for future work.

6. Conclusions and Future Work

6.1 Introduction

The previous chapter provided discussion around the issues encountered throughout the research alongside the presentation of nine methodological considerations. The final chapter presents the conclusion as well as highlighting potential avenues for future work. The research has been the culmination of five years of work alongside the industrial sponsor and the stakeholders within the other research sites. It has featured the research and development of several engineered technological elements in the form of a the MAMI Tech toolkit, together with the journey through the practical activities conducted during the research. From these activities many themes emerged, as well as a set of design considerations (section 4.4.10), and a set of methodological considerations (section 5.17). This write-up has given the difficult task of combining these interweaving and sometimes messy elements into an authentic story about how the technology toolkit came to be as it did and why. To this end in the writing of the thesis what was wanted to be achieved was:

- A sense of the level of participant interaction – this was a strong theme kept central to the research. If any decisions were made, then they were enacted from a place of participant interaction and in conjunction with stakeholders. This is true of both the activities that have taken place during the activities of data collection and analysis, as well as the technological developments that have been moved forward by these activities.
- A deep reflection on the process of collaboration by way of action research to develop technology, and the many facets that this can illuminate. This also includes the links to the research aims and how they have been used to underpin the research.
- An illustration of the use of organic and flexible research that has been achieved by the use of the above two points.
- A document to show the technical development of the MAMI Tech Toolkit in a manner that would be accessible to the lay audience but would also allow for others to recreate the technical elements of the research.
- To provide an account that participants find accurate as well as being accessible to those interested in the spirit of action research. This has involved making explicit

what was fed back to stakeholders and what was developed further through analysis to create the write up. This was important to show the who knew what and at what time so as to portray an accurate picture of how the research unfolded during the main data collecting, and which knowledge was transformed (Mcniff 2014) during analysis and write up.

6.2 Returning to the Research Aims

This section returns to the research aims by connecting the themes as emerging from the research activities with the research aims (Figure 46), and by discussing each research aim and objective, in an attempt to review the success and limitations of the research process. Not featured within this diagram is the final aim of **navigating the propagation of practices, technologies, and methods used to allow for transferability into the wider ecology** as the propagation can be considered as the publications and presentations associated with this research, alongside the online supporting documentation which pertain to the MAMI Tech Toolkit, which can be seen as a package can be found online.

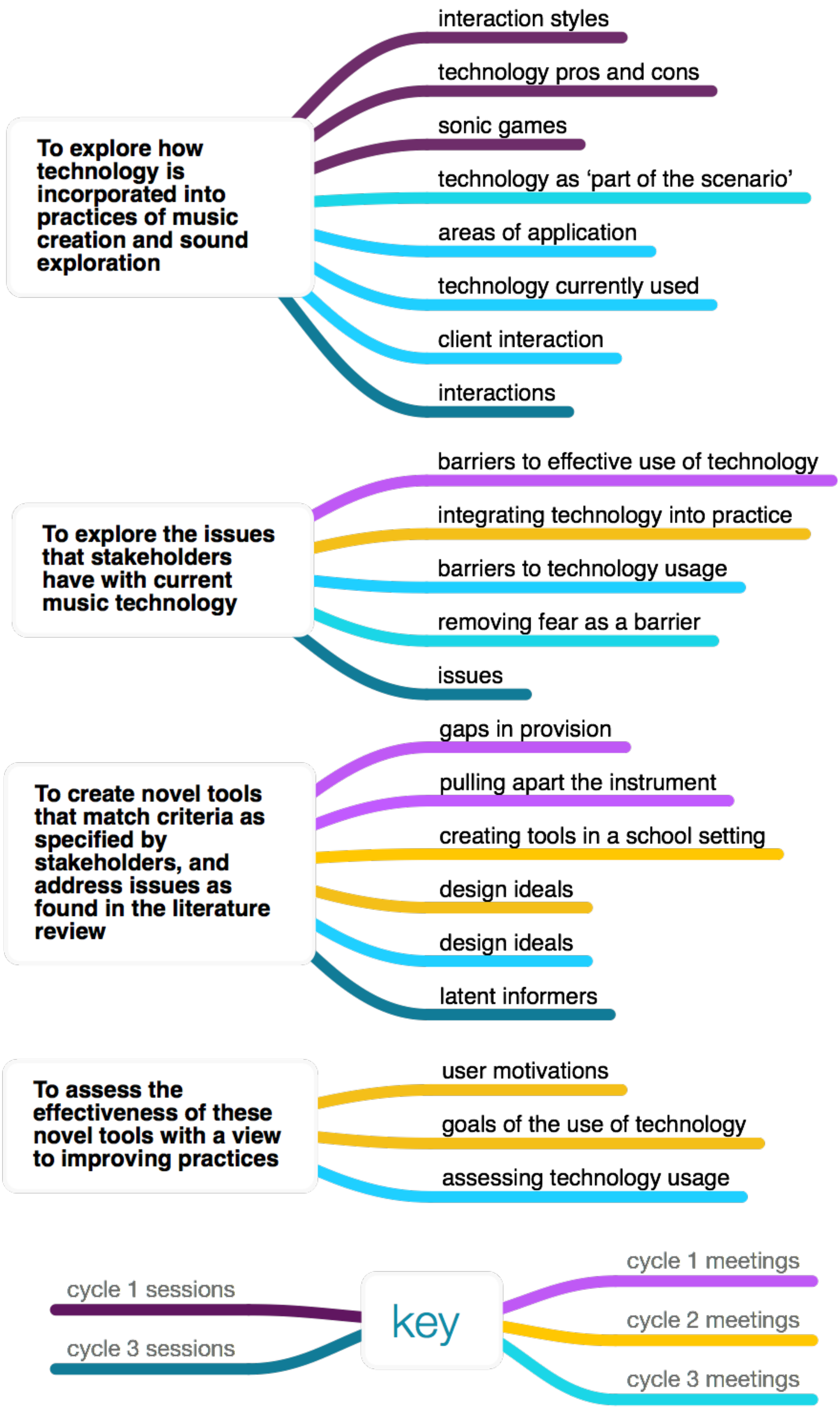

Figure 46 - Themes to research aims

- To explore how technology is incorporated into practices of music creation and sound exploration - To look at current things
    - Utilise current technology with children and young people
    - Gather a group of stakeholders to discuss direction of research
    - Review the literature

Technology usage was explored by undertaking sessions with children and young people using current technology, a group of stakeholders was gathered to allow for a diverse multi-disciplinary input to feed into the progression of the research. The literature was reviewed at the start to give foundation to the initial development of the tentative aims and then consulted throughout to inform progression and development. Limitations were a lack of procedure in terms of lines of questioning and interview procedure when gathering information from the stakeholders, whilst this meant that there could only be comparison of responses by analysing the data into categories or themes, it did mean that the stakeholders could openly discuss what they felt they wanted to discuss without constraint to specific questions.

- To explore the issues that stakeholders have with current music technology - To see what is wrong with those things
    - Meet with stakeholders to gather data about technology usage
    - Observe stakeholders as practitioners to identify where technology could help
    - Review the literature

Issues with technology were explored by involving several stakeholders, this involved both observing them as practitioners, and involving them in the development of the technology. The use of action research and specifically opening communicative spaces where practitioners were free to talk about their work in relation to technology was beneficial for both the researcher and the practitioner, it allowed them the space to reflect that would not usually be offered in terms of reflecting on, and discussing their work with others and their relationship with technology or the potential that technology could bring.

Literature was reviewed to identify issues that were pertinent in the further field. At times this was difficult due to the flexibility of the research, and the reflexive nature of the methodology followed, in this way research that was reviewed and skills that were needed were developed in an 'on-the-fly' manner as needed. This allowed for the literature to much more closely integrate with the needs of the research in a two-way manner. Knowledge was gained from literature, which was then used in practice, practice led to questions which required reviewing of literature.

- To create novel tools that match criteria as specified by stakeholders, and address issues as found in the literature review - To create new things
    - Review gaps in provision
    - Create design ideals in conjunction with stakeholders
    - Create prototype tools

Gaps in provision and barriers to technology use were identified from observing and interacting with stakeholders, and reviewing literature, these enabled designs to be created from both practical need and perceived gaps, as well as integrating specific requirements from the stakeholders. Prototypes were then iterated over in conjunction with the stakeholders to form the final kit. Like the integration of literature into practice and vice versa, the technical skills developed throughout the research followed the need for those skills. Literature/stakeholders would suggest a path for the technology, skills would then be developed to integrate the requested path which would then be fed back to stakeholders. The whole system was then designed with the design ideals put forth by the stakeholders and reflected on by them.

- To assess the effectiveness of these novel tools with a view to improving practices - To see if they work
    - Iteratively develop prototype tools through practical use
    - Work with stakeholder to ascertain success criteria

The tools were used in practice however this area has had limited development within this research. Assessing effectiveness of the tools has proven to be a difficult area. The success of the instruments used can only be determined by virtue of the fact that they were successfully used in sessions in the case of the Noodler. There is still a large amount of work that could have been done on the development of success criteria and of actually using the filterBox and squishyDrum in practice. It is hoped that the kit will be in use and future work will see the development of the above further. The inherent difficulties of success criteria were compounded by the individuality of the users and by the multi-disciplinary nature of the stakeholders. Even when stakeholders shared a field, such as that of music therapy, there was still variability in the goals that wanted to be achieved and also in the styles of music therapy that were being used. This made using something like the sounds of intent framework not achievable and the creation of a homogenous template for success impossible. Some success could be said for the kit in terms of allowing the stakeholders a mechanism for exploring their own needs, by allowing the users access to music-making.

- To navigate propagation of the practices, technologies, and methods used to allow for transferability into the wider ecology - To share these tools and findings
    - Manage creation of assets relating to development of technological tools
    - Locate appropriate outlets for disseminating varying elements of the research

An open source philosophy has been used when creating the technical elements of the kit and for dissemination purposes. This included using existing commercially available tools such as Arduino boards, alongside readily available electronics components to create the controllers. Also, by making available online resources to allow others to use what has been made and augment it for their own purposes. The aim has been to allow as much access as is needed to remain flexible for those who want to augment/extend/constrain the software, whilst also providing a system that can be used out-of-the-box sans programming. This means that the raw code can be freely downloaded, as well as free use of the proprietary application created as part of the tech toolkit. Dissemination in this manner includes the initial development blog posts, utilising GitHub for the technical development and code storing, creating online resources both for the recreation of the physical controllers (CAD files, fritzing schematics etc) and for opening up the proprietary software (Max/MSP files). Various research elements were also presented at conferences and published in a journal as specified in the authors declaration.

6.3 Future Work

There are many ways that what was developed could be further developed as has already been discussed throughout this thesis. There are also several elements that were hoped to have been developed or explored during this research that were not able to be included but may provide starting point for other research and as such are included here.

With regard to using technology in music-making practice there was a hope to develop practical tools to increase the use of technology. Research such as: a technology selection checklist to allow selection of technology based on target user groups such as that seen in the work of Whittington et al (2018); suggestions of how to incorporate into practice (in the form of practical examples); the movement toward an assessment tool to be used with those with complex needs when using music technology tools (in the form of the initial use assessment framework). This is felt needed as though frameworks such as the sounds of intent are available there is perhaps space for an assessment framework that can map the development of users and their recognition and use of tools for music making and not just with the recognition of sound; A database of alternate controllers, with searchable features such as modality of use, demographic of use, what have been used for to allow finding and selecting potential tools easier.

It is hoped that direct future work based on the MAMI Tech Toolkit will involve discussion around the kit in terms of both validating what was made in practice, conducting more cycles of research using the tools as probes within practice, and in creating new tools that could only be speculated about within this iteration of the research.

6.4 Concluding Remarks

Music technology can be an enabling tool to facilitate active music-making for some users who cannot access traditional acoustic instruments, however it is underused within the settings featured as part of this research. This research aimed to develop new tools alongside stakeholders that would provide a move towards technical solutions. The result was the MAMI Tech Toolkit consisting of one stand-alone tool and 3 tools that use the computer as a bridge. These tools were created as static pieces of hardware (albeit it considering different modes of interaction) with software that would allow for several types of sonic output, that seemed commonly requested by the stakeholders.

The focus of the research moved away from phenomenological experience of the individual and away from the researcher, and into the realm of research orientated design (Fallman 2003). 'In ROD a research component exists, but the objective is the creation of new products and solving the real-world problems that arise in that process. The guarantors of quality are the client and the marketplace' (Dahl 2015, p.77). The tools were developed by being situated and used for their designed purpose 'for it is through performance that our ideas, embodied as design prototypes, become testable' (Dahl 2015, p.76). In this way, the prototypes developed were used as digital probes (Hutchinson et al 2003) in order to provide a sounding board on which to further explore both the tools, the philosophies around their use, and the contextual surrounding within which they would be used.

The technology developed aimed to provide tools that were easy to use, required as little technical set-up as possible, and could be adapted quickly to the context being used in and to the type of user that might be using them. This was seen as a twofold approach of identifying current issues and developing working solutions to problems with technology in context and in practice, with the overall aim of achieving an accepted technology that will have longevity and legacy and that could be left with the stakeholders involved.

The MAMI Tech Toolkits are now 'in the wild' being utilised by the very practitioners that were fundamental in helping to design it. This toolkit has been formed of both tangible concrete material things (the tools), as well as being constituted within the contextual socio-cultural messy real world setting that it has been developed within. This co-construction has drawn on the philosophies of technology and meaning making in that the developments represent the product of the research as well as being probes that have been used to prod at issues around the creation and use of such tools. The context was explored, the tools was created, the tool in the context was explored, the tool was refined, the refined tool in the context was explored in a cyclical manner. In this manner the kit has been immersed in the third-wave of HCI and developed in the mode of the bricoleur.

In my opinion what is needed are easier to use tools that account for the heterogeneous quality of the user; tools that come as part of a package which consider their web of use; more development in the field of interaction with tools with those users with the most profound needs – in terms of assessing needs with regard to provision for music-making, and assessing interaction with tools for music-making; more resources and examples of best practice for use of all of the above that synergistically combines with as many existing resources as possible (adding to the Sounds of Intent framework for example for tool recognition). Developments like the ones in this research should consider their context of use as vital to the development of the tool.

This research is an ongoing and continual process of creating tools that ultimately move towards giving everyone access to music-making.

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Appendices

A.

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Interaction modality		**Commercially/Freely available**	**Description**	**Details**
Touch		**General Technology**		
		Switches	Broad range of electronic or mechanical tools to allow on/off selections	Tailorable to user, ease of integration to current resources, can be wired or wireless, trigger or start/stop sound effects, musical notes/phrases, recorded samples or sequences of samples. “For example, the client may activate a CD player or pre-recorded music track” (Knight and Lagasse, 2012, p. 192). Bache et al (2014) provide an in-depth review of practical switch use.
		iPad	Touch screen handheld device speaker, microphone, and motion detection	Multi-use device, tailorable to user, familiar technology, enticing, direct interaction with apps, self-contained with speaker on-board, commonly available. Useful for quickly recording multitrack music arrangements from live or plugged-in sources. Ability to capture sound using built-in microphone. Apps can emulate instruments enabling the client to play a

				stringed instrument by touching the screen, or a wind instrument by blowing into the microphone (Knight and Lagasse 2012). "Apps can be used to record, synthesize, manipulate, or provide feedback to client actions and sounds" (p. 194). Knight (2013) provides an in-depth review of iPad applications in music therapy.
		iPod Touch	As iPad	Similar to iPad but smaller in form factor and with enhanced security (not connected to a network)
		Apps	Pieces of software for use on tablet or smartphone devices	Wide variety, some free. Apps for Children with Special Needs (2018) is a website for finding specific apps aimed at children with special needs featuring music as well as other apps with reviews and videos. Offering the ability to tailor content and interaction to client requirements.
		Generic music production controllers (MPCs)	Trigger pads with velocity sensing	MIDI compatible. Some come with own software instruments, requires technical knowledge to set-up. Provides ability to pre-select sounds representative of a wide variety of genres enables clients an accessible way to perform their cultural or musical identities. Allows therapists to offer diverse sound palates valuable for playing differing feelings or emotions during improvisation (Crooke and McFerran 2019). Can also be used in composition to perform and record drum beats and melodic patterns (Crooke, 2018), or to trigger or launch a range of loops or samples, allowing for the playing of pre-composed pieces and live remixing. Music Radar (2019) provide an overview of available MPCs.

		Music based video games	Video game system using generic or bespoke to the game controllers	Familiar to users, enticing technology, easy set-up, can potentially use existing resources. Blaine (2005) provided a review of alternate music based video game controllers. Wikipedia (2017) provides a list of music based video games. Use of the WiiMote in music therapy has been explored (Benveniste et al. 2008), and developments such as the Wiinstrument can be downloaded to utilise the myriad of data that the WiiMote produces (Wiinstrument 2018). Games available include Wii Music by Nintendo.
		Specific devices	**Description**	**Details**
		Skoog 2	Wireless foam cube with 5 tactile pressure sensitive pads.	Wireless, portable, easy to set-up. Simple and intuitive. Own app and software to customise sensitivity and sound created, MIDI compatible. Many resources for use in special education on website. Provides direct correlation between physical contact and sound produced, using virtual musical instruments, samples or MIDI. Offering dynamic control over musical gestures (Skoog 2016). "The instrument does not simply trigger samples when pressed but uses sophisticated synthesis to dynamically manipulate the various instrument sounds though pressing, squeezing, rubbing, stroking, tilting or manipulating the Skoog" (Farrimond et al 2011, p. 28).
		Makey-Makey	Microcontroller board with 6 connectors that emulate QWERTY	Turn everyday objects into touchpads, no software to install, fast set-up. Can be connected to conductive objects such as fruit, conductive tape, pencil graphite, and clients touching each other in chains as a means to trigger sounds (Makey Makey 2012). The process allows appropriation

			keyboard presses and mouse control	enabling clients to gain authorship of their instruments, and become an intrinsic part of their deployment (Hayes 2016).
		AlphaSphere	Globe shaped MIDI controller with 48 playable velocity sensitive pads and own software.	AlphaSphere is a tangible controller, when connected to AlphaLive software/used with other MIDI software can be set-up to trigger and manipulate sound and provide a unique modality of access that can be enticing to clients (Place et al. 2014).
		MIDICreator	Device to convert signals from electronic sensors into MIDI data.	Clients can control sounds with physical actions and gestures, can be used to detect simple body movements (Krout 2014). Can be connected to MIDI to be used with other synthesizers. Sensors available include pressure, distance, proximity, direction etc. (Meckin and Bryan-Kinns 2013).
		I-CubeX	Software and digitizer for creating systems with a variety of sensors available	Tools to capture the human actions and/or environmental variables and make these signals available to other equipment such as a computer or a musical instrument to trigger sound, music, video, graphics, animation, robotic movement, etc. MIDI data is used, transmitted via MIDI cable, USB cable or Bluetooth wireless (I-CubeX 2018).
		Kyub	11 feather touch keypads on five surfaces of a 3-inch wooden cube with accelerometer	Maker friendly, open source DIY MIDI keyboard featuring capacitive sensing and accelerometer. Fully programmable, set scale, tweak note velocity curves, map different instruments to different pads to configure to musical taste (Kyub MIDI keyboard 2018). User can also configure the way the instrument looks and sounds by designing their own interface.

		Suzuki QChord	Electronic instrument with on-board speaker and LCD display.	A device for composition, teaching, and therapy. Incorporating technology from a basic keyboard and electric guitar and combining both in a portable, easy to use way. 84 different chord combinations, 100 instrument voices, orchestrated rhythms. Features three sections; a touch sensitive 4 octave 'strum plate', a rhythm section and chord button section. Each of these areas can be used independently or combined with a variety of sounds obtainable. Sounds are always in tune. Can be adapted to all ability levels. Can stimulate interaction, increase coordination, stimulate gross and fine motor skills, and increase self-expression. Pitch bend wheel for expression. Changeable song cartridges. Can connect to speaker or MIDI device (Suzuki Q-Chord 2018).
		Yamaha DJX-iiB	Groove machine in a box-shaped desktop module form with scratch pad and fader.	Can select from 70 patterns, mute parts, add preset hits or fills, and shift key of the patterns playing and use effects. Provides opportunities for the clients to compose music by assembling loops, importing other songs or sections of songs, and/or recording her or his own music, offering accessible and dynamic means of expressing emotions (Whitehead-Pleaux et al. 2011)
		Musii	Soft inflatable self-contained portable unit that emits sound and illuminates when 3 inflated cones are	Simple to use, needs no extra equipment or training to operate. Abilities to make music and colour through touch and movement with expansive library of soundscapes (over 50) and innovative musical system. Cannot play out of time or out of tune. A number of people can play harmoniously as a group or an individual can become an orchestra. Tactile physical form that enables the user to see and feel the beam that they are interacting with.

			touched, with wireless control	“Musii has been designed for developmental play in the SEN sector...The multi-sensory experience of playing Musii has many therapeutic possibilities including encouraging movement, development and awareness of proprioception, turn taking, cause and effect, creativity, expression and communication. It can be used for stimulation or for calming. The synchronised sound and lighting as well as the visual and tactile feedback of the inflatable enable a deeper understanding of the music you are making” (Musii Ltd 2014)
		Reactable	Table with touch screen and moveable objects (Reactable Technology, 2017)	Objects interact with the table surface and each other to make music. Allows intuitive and collective creation of complex musical pieces, collaborative sharing space between users, promotes imitation games, increases visibility of actions, enables monitoring other participant’s work, aids in reducing solitary play sequences, facilitates associative play (Villafuerte et al. 2012)
		Tenori-On	Hand-held screen with 16x16 grid of LED switches. Built-in speakers, dial and buttons control sound and beats per minute produced	Create, control or perform musical material on visually rich touch sensitive interface (Farrimond et al. 2011). Switches activated in different ways create music from 256 sounds. Engaging, motivating, sensory, well suited for improvisation, easy to use/hard to master. Combines visual and melodic sensory information, can stimulate cognition, memory, and perception. Can function as a rhythm machine with basic or complex rhythmic beats that can be looped or changed. Notes and melodic phrases can be added as well, creating up to sixteen layers of sound (Clements-Cortes 2014).

				Clements-Cortes (2014) provided an in-depth study of the Tenori-On in a clinical music therapy setting.
		Roland Handsonic	Device with 13 ultra-sensitive touch pads	850 ready-to-play sounds, or import custom sounds. Responsive and therefore not overly demanding to play, with easy adjustment of volume (Challis and Smith 2012). Can be calibrated to client need in terms of sensitivity. Can connect to other MIDI devices and MIDI can be recorded from the device for analysis.
		Korg Kaossilator/ Kaossilator Pro/Korg Mini Kaoss Pad	Audio effects unit with an X/Y touchscreen. Mini Kaoss pad features on board speaker and microphone	Positioning a finger-tip on the touchscreen triggers specific sound programs. Ability to trigger individual notes or patterns of notes depending on the nature of the chosen sound and settings selected. Moving around the screen moves between notes within a predefined scale or changes the nature of the sound. Allows the results of actions to be sampled as repeating loops. Particularly effective for those with restricted hand and finger movement, being easy to interact with, to produce complex musical ideas and patterns (Challis and Smith 2012).
		SoundHouse Special Access Kit (Banana Keyboard) -discontinued	Sixteen keys configured like an oversized piano with software component	Curved to suit the radial movement of an arm. Light touch activates music, sounds or speech programmed into each key. Allows connection of up to eight switches for activation of keys on the keyboard (Sound House 2017). Innovative, adaptable control surface that require musicians to press, squeeze or strike them to create and control music through corresponding musical software (Farrimond et al. 2011). User friendly, easy to learn. Arrange combinations of sounds (MIDI sounds or wave files). Recording feature enables real-life performances to be saved and

				voice and CD segments to be recorded. Arrangements can be printed off and formatted. Variety of global settings cutting down on individually programing each key or switch. Aimed at fostering development of switch use, cause-and-effect, timing, choosing (Sound House 2017).
		Numark Orbit	Wireless MIDI controller	16 backlit customizable pads, 4 selectable banks to assign up to 64 cues, lighting transitions, video clips, samples etc. Control wheel and on-board accelerometer. Can be configured and mapped to control other MIDI software, accelerometer for motion control. Comes with demo software that show how to use with tracks and effects (Numark.com 2018).
		Mogees	Resonance contact microphone	Enables instruments to be created from any surface/object alongside configuring of the sounds created with dedicated iPhone/iPad app. Integrates with standard digital audio workstations via Audio Units or VST plugin. Can be used to provide expressive instrument by using different areas of surface trigger different sound (Mogees 2018), allowing for objects to be used that are motivating, familiar, or engaging to clients.
Software Based		**General Technology**	**Description**	**Details**
		Generic digital audio workstations (Ableton Live/Audacity/Reaper/ Cubase/Logic/Sonare by Cakewalk/Garageband)	Music recording/composition software	Uses preset or user determined settings via on-screen, or pull-down menus. Allow for recording, composing, playback, and creation of music. Some come with content such as instruments and samples available for instant use. Ability to use software instruments (VSTs), input microphones, or electronic instruments. Garageband is pre-installed on Mac computers with out-of-the-box samples and instruments available. Reaper is affordably

				priced, Ableton is prized for live performance. Audacity is freeware. Can export notation in some cases. Krout (2014) provides a review on using software for music composition, arranging, notating, improvising, and sequencing.
		Specific Devices	**Description**	**Details**
		Clarion (Farrimond 2014)	Software instrument	Allows user to change every element instrument including sound, notes, shape, position and colour of notes, and how those notes are played. Integrates with eye gaze systems, SmartNav and iPad. Package offered by Open Orchestras including repertoire, training resources, support, and an evaluation framework (Open Orchestras 2018).
		Magix Music Maker	Digital audio workstation	Provides 425 sounds and loops, 7 free Soundpools (1,927 sounds and loops) 3 software instruments, 8 tracks, and 8 effects. Can be used with smart boards.
		HyperScore	A graphical composition environment	Users draw strokes and lines to explore musical ideas. Graphical elements are mapped to musical structures, allowing users to shape musical progressions visually (Machover 2004; Grierson and Kiefer 2013).
		MIDIGrid	Music software	Uses mouse and keyboard movements within a grid to trigger notes, chords, sequences or patterns of sound that can be played back and looped (Hunt and Kirk 2003).
		Microsoft Songsmith	Music software	Generates musical accompaniment to match a singer’s voice using computer microphone input. Musical style and feel of song can be selected. Songs can be posted songs online, or used to create music videos

		2Simple music toolkit	Software applications	Six programs that introduce key musical concepts in an interactive way (2Simple 2017).
Empty-handed	Camera based	Microsoft Kinect	RGB camera, depth sensor, and multi-array microphone	Provides full body 3D motion capture, voice and face recognition (KinectSEN 2018).
		EyesWeb	Open development software platform	Real-time multimodal system and interface that has been used extensively in research. System supports input devices including motion capture systems, video cameras, game interfaces (e.g., Kinect, Wii), audio input, analog inputs (e.g. for physiological signals). Outputs include multichannel audio, video, analog devices, robotic platforms (Camurri et al. 2000). Website features information on development (http://www.infomus.org/eyesweb_ita.php)
		MotionComposer (Available 2019)	System using 2 types of camera to detect movement	Allows gestures to be used to explore sound environments (Bergsland and Wechsler 2016).
		AUMI	Free software application	Interface that enables the user to play sounds and musical phrases through movement and gestures captured via webcam (Larsen et al. 2016; Oliveros et al. 2011).
		VMI (Virtual Musical Instrument 2018)	Free software	Uses web camera to detect motion. User virtually "touch" shapes on screen to trigger sounds. Requires no special equipment, Windows only based computer. Designed for use by therapists and educators, it is customizable according to the preferences and needs of the user, and can be used for specific therapy or educational goals (Virtual Musical Instrument 2018).

		BigEye – discontinued still available for download	Macintosh only software program	Uses video information to convert into MIDI messages. Allows tracking of objects through space converting their parameters into MIDI in real time (Legacy product 2018).
		Camera Theremin	Free test application	Create sound from movement using webcam (Camera Theremin 2018).
		Musical Gestures Toolbox	Toolkit for experienced Max programmers.	Collection of modules and abstractions for the graphical programming environment Max 5 to enable extraction of movement data from video (Jensenius et al. 2005).
		Aerodrum	Package featuring drumsticks, software, feet markers and camera	An air-drumming instrument. Runs on computer using a high-speed camera to track movements to trigger drums (Knight and Krout 2017).
	Break-beam	Beamz	Device featuring 4 breakable laser beams	Can be purchased as a professional package featuring software, songs, structured activities, therapy guides, and lesson plans
		Soundbeam	Device featuring ultrasonic beams and switches (both wired or wireless) and a synthesizer unit	Device which uses sensor technology (up to 4 ultrasonic or 8 switches) to translate body movement into music and sound using MIDI. New unit features touch screen interface, extensive library of sounds, recording and composing functions, training programs also available. Extensive support for use available through online resources (https://www.soundbeam.co.uk/).
		Theremin (Magee, 2006)	Moog Theremini – device featuring 32 wavetable preset sounds, and on-board	Can be used at any skill level, providing new ways to experiment with music and gestural control. Assistive pitch quantization allows each player to adjust the instrument's level of playing difficulty. “At the maximum position, the Theremini will play every note in a selected scale perfectly,

			speaker and sound engine	making it impossible to play a wrong note. As control is decreased, more expressive control of pitch and vibrato becomes possible. When set to minimum, the Theremini will perform as a traditional Theremin (Theremini 2018). Built-in tuner with real-time visual feedback of played notes and proximity (useful for correcting playing position). Store selected scale and root note, set and recall a specified playing range, and specify patch settings. Silent rehearsal available via headphone jack. Two line level audio outputs, a pitch CV output with selectable range, and a mini USB jack for MIDI I/O and connectivity (Theremini 2018).
		Optimusic/OptiBeams (Knight and Krout 2017)	Interactive light beams	Package with interactive light units (the beams), laptop with OptiMusic software, USB controller box, user button box, reflective pads/bats. Interact with colourful beams of light (2, 4, 6, 8 or 12 beams), pass hand or body through the beams or use reflective wand to trigger audio-visual events in real-time. Comes with over 80 interactive settings. Package also comes with training (on-site or e-training) (OptiMusic 2018).
		MidiGesture	Ultrasonic beam sensor	Sensor that plugs into the MIDICreator system (see MIDICreator).
		Leap Motion (Leap Motion 2010)	Small device to track hand movement	Uses two monochromatic IR cameras and three infrared LEDs to track hand and finger movement above device. Dickens et al (2017) provide an in-depth description of research conducted using the Leap Motion for music performance with users with complex disabilities.
	Brain Computer	Brainfingers (Brainfingers 2018)	Headband fitted with sensors	‘Detects electrical signals from facial muscles, eye movement and brain waves. Brainfingers does not directly target music creation, as it can solve

	Interface (BCI)			many tasks such as simple clicking, to complex combinations of controls. It is software that converts all the sensor input data into controls termed Brainfingers. This software is useful for a broad range of users, especially people with severe disabilities' (Larsen et al. 2016, p.329). Controls most AAC software, educational software and video games.
	Eye Gaze	EyeMusic; Larsen et al., 2016) - legacy files available online, requires technical skill to install (EyeMusic 2018)	Software utilising generic eye gaze equipment	System that uses eye movements as input to electronic music compositions. Can be used with established composition software allowing pre-recorded eye movement data to control musical compositions (Hornof and Sato 2004).
		E-Scape (Anderson 2018)	Software utilising generic eye gaze equipment (or switches)	Music software specifically designed to be used by people with disabilities to create or perform music. System operates via large guided pop-up menus controllable by one or more switches, mouse, keyboard, eye gaze, or MIDI controllers or sensors. "At every stage, E-Scape asks the user what they want to do and offers a range of options depending upon which level of complexity the user has chosen to work at" (Farrimond et al., 2011, p. 23). Two modes of operation - composition and performance. Can output MIDI data (Farrimond et al. 2011).
		EyeHarp	Free software utilising generic eye gaze equipment	Gaze-controlled or head-controlled music interface to help users learn and play music. Vamvakousis and Ramirez (2016) provide a comprehensive article on the development of the EyeHarp. The website theeyeharp.org also provides a wealth of information about the project (The EyeHarp 2018).

		Eye Play Music	Free software utilising generic eye gaze equipment	Trigger notes from a range of instruments available with adjustable note length and transposition. Create own scales. Load and save settings. Website features resource for use (MBMM 2017).
	Breath	Jamboxx	MIDI controller device	Hands-free electronic, breath-powered instrument. Uses sip and puff to determine amplitude of note. Software included to configure device and on board modulation wheel, button, and jack socket to allow switch connectivity (Jamboxx 2018).
		Yamaha WX5, WX11	MIDI controller devices	Breath powered MIDI controller that allows for one handed playing. WX5 features MIDI output however WX11 requires an additional MIDI connection box (MBMM 2017).
		Magic Flute	Stand-alone instrument	Self-contained instrument with built-in tone generating hardware. Plugs into external speakers. Two separate parts, the flute and control module with display. The flute being the remote control for the control module. Musicians can select different sounds or access the user settings without the help of another person (MBMM 2017). The volume is controlled by blowing in a mouthpiece and the pitch by moving the mouthpiece up/down with the mouth (Vamvakousis and Ramirez 2016). 'The instrument reduces the physical and cognitive challenges inherent within conventional wind instruments. One musician, with very limited lung volume, is nonetheless able to realize the full dynamic range of the instrument' (Farrimond et al. 2011, p.29).

Interaction modality		**Research only**	**Description**	**Details**

Touch		**General Research**		
		Collaborative interfaces review of literature (Blaine and Fels 2003)	Review paper of interfaces used for collaborative music making	Comprehensive review of context and design of a number musical experiences for novices
		Specific Research		
		Musicking Tangibles – RHYME Project	Tangible interfaces consisting of interactive digital 'furniture'	Examining the development and benefits of using interactive digital music furniture for disabled children by using two co-creative tangible instruments. ORFI -26 soft pyramid shaped, pillow like modules, in three different sizes (30 to 90 cm) featuring bend sensors and lights, the units can communicate wirelessly with each other. Wave Carpet -7-branched, wired, interactive, soft, dark carpet with orange velvet tips that glow. Central arm contains microphone, two arms contain accelerometers that change the recorded sound. Two arms contain bend sensors that create rhythmical background music. One arm contains a web-camera. Contain 5 software programs, offering different music and dynamic graphics to show via projector embedded in one arm, or via full wall projection. Center contains two speakers and strong vibrator in. Contains IR- sensors allowing interaction with RGB LED lights (Andersson and Cappelen 2014).
		NoiseBear (Grierson and Kiefer 2013)	Malleable controller	Development of robust, wireless, malleable controller for children with cognitive or physical disabilities

		Bean	Gesturally controlled digital instrument	Device designed around a Wii nunchuck controller for use in a music therapy setting (Kirwan et al. 2015)
		MAWii	Digital musical instrument using generic WiiMote controller	Research exploring WiiMotes as virtual instruments for children with behavioural disorders (Benveniste et al. 2008).
		WamBam	Self-contained electronic hand-drum	Created using piezo sensors. Paper describes development and testing of device used in for music therapy sessions with severely intellectually disabled clients (Jense and Leeuw 2015).
		TouchTone	Digital musical instrument	Device featuring touch sensitive pads designed to develop musical ability, bimanual coordination and increase social participation of children with hemiplegia (Bhat 2010).
		Computer Assisted Music Therapy	Augmented reality software	Details system developed with Augmented Reality techniques allowing music composition and creation activities using sound and colour, via cards (Correa et al. 2009).
		SenseEgg	Wireless controller device	Development of a hand-held egg shaped device featuring seven on-board sensors (button, slider, accelerometer, wind Sensor, ultrasonic distance sensor) and a suite of software patches aimed at for musical exploration and teaching. Featured a component that allowed control of settings via an iPad (Blatherwick and Cobb 2015).
Software Based		DIYSE software	Software that utilises Guitar Hero controllers	Details development of software allowing connection of existing controllers (Guitar Hero and WiiMote etc.) to compose and restore music

				tracks, and design mapping strategies between interface and played sounds, for people who with intellectual learning disabilities (Luhtala et al. 2011).
Empty-handed	Camera based	Movement to Music-MTM	Web camera and software system	Developed to address the need for affordable home-based musical play system, incorporating automatic movement recognition technology that is non-contact and non-invasive (Tam et al. 2007).
	Break-beam	Benemic/Octonic	Stand-alone instrument	Device with array of eight low-cost infrared distance sensors. Enabling triggering and manipulation of sounds using MIDI messages (Challis 2011).
	Eye gaze	Eye conductor	Software uses webcam	Software based musical interface to play music through eye movements and facial gesture using eye tracker equipment and webcam. Detects gaze and selected facial movements enabling playing of instruments, beat building, sequencing melodies or triggering musical effects (Refsgaard 2018).

Table 5 - Accessible Music Technology

B.

Welcome to the MAMI Tech Toolkit

Hello and welcome to the Tech Toolkit.

This kit is comprised of 4 hardware tools and some software to enable you to use this hardware to make noises! The tools in the kit are the touchBox, filterBox, the squishyDrum, and the Noodler.

touchBox

The touchBox is a **stand-alone device**, meaning that it does not need to connect to a computer. It has on-board speaker, buttons, dials, screen, and connectable trigger pads. These allow control of the sound, settings, and triggering of the notes.

In touchBox you can use the buttons to control the type (timbre) of the sound (from Square, Triangle, Sample, Sine, and Saw), the octave of the notes (plus or minus 2 octaves), the scale (Major, Minor, Akebono, Pygmy, Equinox, Sapphire, Gypsy, Silver Spring, Integral, Dorian, Golden Arcadia, Pentatonic Major, Pentatonic Minor, and Blues), and finally the tonic note of the scale (A, A#, B, C, C#, D, D#, E, F, F#, G, G#

You can connect up to 8 pads using the 3.5mm jack sockets along the front of the device. Each pad triggers a different note in ascending order from left to right, in the selected scale starting from the selected tonic note. The box will load in the scale of A Major with the square wave timbre, with the starting note being A below middle C.

Tools that Connect to the Computer

The other 3 pieces of hardware send all of their data to the computer via a receiver (one for each device**).**

<u>The filterBox</u>

The filterBox system comprises of the filterBox, its receiver, and the software app that it connects to.

The hardware

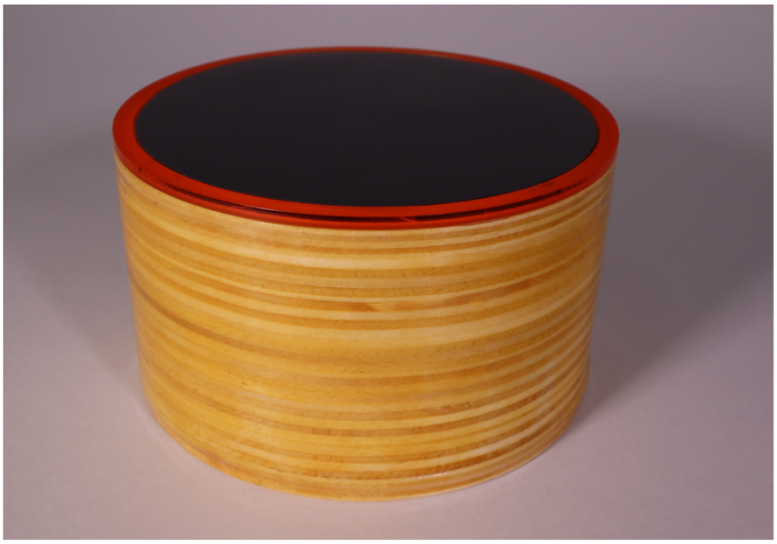
The filterBox features 2 buttons, a pressure strip around its middle, and a light sensor underneath the lid. The buttons control notes moving up and down through the selected scale. The pressure strip controls the volume of the notes, and the light sensor control the filter of the notes.

The software

The software app allows for the selection of a virtual instrument (VST), turning on/off of the sounds, control of the volume, selection of the channel for the sound to come out, and selection of the musical scale. There are also icons that visually show the interaction with the buttons, pressure strip, and the light sensor.

The squishyDrum

The squishyDrum comprises of the squishyDrum, its receiver, and the software app that it connects to.



The hardware

The squishyDrum features 3 pressure sensors underneath the top of the silicon layer atop the drum. It also features 2 piezo sensors which can detect knocks on the enclosure.

The software

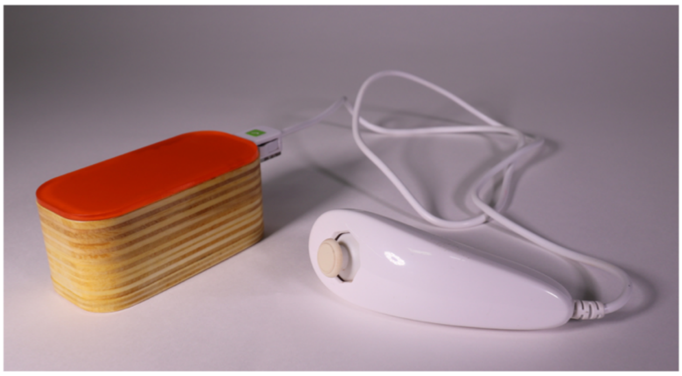
There are two software apps that work with squishyDrum. One software app, named squishyShaker, allows for the selection of objects to be used as shaker style items, the pitch of the sound to be selected, the channel for the output of the sound, the volume, and an icon to turn the sound off. The other software app, named Simple Sample, allows for 3 samples to be triggered by pressing the pressure sensors, and for 3 samples to be recorded via the computer to then be triggered by pressing the pressure sensors.

The Noodler

The Noodler comprises of the Noodler, its receiver, and the software app that it connects to.

The hardware

The Noodler features 2 buttons, an X/Y joystick (left to right, and up and down), and an accelerometer (detects which way up the Noodler is and how fast it is moving in space).



The software

The Noodler software allows coloured zones to be used as trigger zones for notes or samples. It uses the joystick and buttons. The trigger zones can be drawn in and saved or loaded from presets.

There are 2 modes –MIDI notes triggering, or sample triggering.

MIDI note triggering – in this mode you can select the notes that are triggered by assigning a note to a colour or you can choose to connect the trigger zones to a scale. You can also select the instrument (from 127 choices) and the octave (-2 octaves to +4 octaves). You can also select whether to use MIDI instruments from the general MIDI standard or MIDI drums. You can also select if the note stays on whilst you stay within a trigger zone or whether it has a set duration, which you can also change.

Sample triggering – in this mode you can select a folder of samples and then assign those samples to the different colours of the trigger zones. You can select which samples the buttons trigger also. As well as this you can select if the sample plays to the end or stops as soon as you leave the trigger zone.

Mira iPad App

The Tech Toolkit software can also be connected to an iPad to enable control of some of the settings whilst away from the computer. To enable this, you must have an iPad and have downloaded the Mira app (which costs £9.99).

C.

Child One Performance with the Noodler

The Noodler was used with child one for a Christmas performance. Over 300 guests attended the performance at a church in which the whole school participated in the performance. The Noodler was used for one song (Away in a Manger) performed by the class that child one was part of. The event was filmed with the music therapist reviewing the footage. What follows is an analysis of the transcript from the music therapists review:

The Noodler is handed to child one just prior to the start of the song, '*what I am really pleased about already is [child one] looks very conformable holding it, but that's a major issue in that [child one] would not be holding that if he wasn't comfortable with the feeling of it with some recognition of what it is about he would either drop it or hand it immediately to somebody else, so that is actually quite significant*' (music therapist).

Whilst waiting for recognition of awareness of cause and effect in using the Noodler. '*so first aims are that [child one] can participate meaningfully and by that, I mean that he is aware of what he is doing and that he knows he is part of a group activity and that he has direct influence on the sound, which is exactly what is happening there so that's great*.'

The child then tries to hand the researcher the Noodler. '*Now you see so that's what [child one] would do when he wants some reassurance, he is basically saying do I carry on doing this?* (music therapist). After some words of encouragement, the child goes back to exploring the Noodler.

The music therapist offered the following explanation (provided in full) as a suggestion of how technology may have the potential to unlock a person to the world around them and help then engage with it :-

> *'And when he does that (child one's head moves side to side) ... that is [child one] engaging and they are now even just becoming aware of the group…. so, all of this is significant stuff. It is [child one] taking account of his surrounding and his part in what's happening and what's interesting about that to me, and of course a lot of this is assumptions so nobody can say this is definitely what's happening, but what I see with [child one], which often belongs to people on the autistic spectrum, is that the more comfortable they become with whatever it is they are doing, the more*

open they get to their surroundings. So, what's happening there is [child one] is starting to look around the whole building, and if you keep in mind that for [child one] that is going to be hugely challenging, that building is a church building, its echoey, its tall, there are hundreds of things in it, there are hundreds of people in it, all of that would be immensely stressful to someone like [child one], so what they will do instinctively is they will close of what they can't cope with…. so, in other words watching them go from uncertainty to comfort holding the Noodler, actually generating sound, and then after a while beginning to look around …oh this is where I am…this is who is in the room with me, and oh this is the building. So that's extremely positive that's [child one] …. the Noodler opening [child one] to their environment and giving them a sense of comfort, and that's I would say a really positive outcome from that... yes, to me that's been an extremely worthwhile journey' (music therapist).

D.

Bournemouth University

Research Ethics Checklist

About Your Checklist	
Reference Id	8953
Status	Approved
Date Approved	26/11/2015 11:47:36
Date Submitted	26/11/2015 09:46:22

Researcher Details	
Name	Asha Ward
Faculty	Faculty of Media & Communication
Status	Postgraduate Research (MRes, MPhil, PhD, DProf, EngD, EdD)
Course	Postgraduate Research - FMC
Is This External Funding?	No
Please list any persons or institutions that you will be conducting joint research with, both internal to BU as well as external collaborators.	Centre for Digital Entertainments at Bournemouth University, [redacted]

Project Details	
Title	Technology to Help Users with Complex Needs to Make Music
End Date of Project	03/09/2018
Proposed Start Date of Data Collection	03/09/2015
Supervisor	Ann Bevan
Approver	Research Ethics Panel

Summary - no more than 500 words (including detail on background methodology, sample, outcomes, etc.)

This project will see me working at the [redacted] Having worked at the school during my placement year and during the testing stage of my dissertation I am well established within the school and carry full security checks to work there. The project will involve following an Action Research methodology to create new pieces of technology to help users with complex needs interact with and create music. Action research requires that a team is put together featuring key people who will be directly affected by the research to work alongside me as co-researchers and as democratically equals in regard to any research decisions that are made. In this regard it is difficult at this stage to set out the exact methodology that will be followed however it is likely that I may be following a mixed methods approach and may use methods from both qualitative and quantitative research types. This may include interviews, surveys, focus groups, observation and field notes, and videoing of sessions. It is also difficult to define a sample, as this will be partly based on convenience sampling within the school and has to again be discussed with my team upon commencing the research as to who would benefit the most, how many people should be involved, and the types of technology that might be most beneficial. The solid facts I know at this time are that I will work at the school 2 days a week with the rest of the time spent working in Bournemouth on technical solutions to then take back to the school. The days at the school will be working with various groups of children and the key team members to try out technical solutions that are being developed as part of the research or to discuss what could be made. In the initial stages exploratory work will be done to ascertain what the needs of the research are in the eyes of the key team members and as the project proceeds this will lead to practical developments of technological solutions. Tools that are likely to be created are bespoke pieces of hardware and software. These solutions and tools will then be tested for efficacy as

related to the research questions established by the key team members with an assessment method discussed with them that may feature qualitative or quantitative forms of assessment. The outcome is likely to be a toolkit that users with complex needs can use to access music making, this may feature hardware, software, and online resources to help with creating or selecting suitable technology for various types of users and practically using them in the context of the school.

External Ethics Review	
Does your research require external review through the NHS National Research Ethics Service (NRES) or through another external Ethics Committee?	No

Research Literature	
Is your research solely literature based?	No

Human Participants	
Does your research specifically involve participants who are considered vulnerable (i.e. children, those with cognitive impairment, those in unequal relationships—such as your own students, prison inmates, etc.)?	Yes
Is a DBS check check required?	Yes
Does the study involve participants age 16 or over who are unable to give informed consent (i.e. people with learning disabilities)? NOTE: All research that falls under the auspices of the Mental Capacity Act 2005 must be reviewed by NHS NRES.	Yes
Will the study require the co-operation of a gatekeeper for initial access to the groups or individuals to be recruited? (i.e. students at school, members of self-help group, residents of Nursing home?)	Yes
Will it be necessary for participants to take part in your study without their knowledge and consent at the time (i.e. covert observation of people in non-public places)?	No
Will the study involve discussion of sensitive topics (i.e. sexual activity, drug use, criminal activity)?	No
Are drugs, placebos or other substances (i.e. food substances, vitamins) to be administered to the study participants or will the study involve invasive, intrusive or potentially harmful procedures of any kind?	No
Will tissue samples (including blood) be obtained from participants? Note: If the answer to this question is 'yes' you will need to be aware of obligations under the Human Tissue Act 2004.	No
Could your research induce psychological stress or anxiety, cause harm or have negative consequences for the participant or researcher (beyond the risks encountered in normal life)?	No
Will your research involve prolonged or repetitive testing?	No
Will the research involve the collection of audio materials?	Yes
Is this audio collection solely for the purposes of transcribing/summarising and will not be used in any outputs (publication, dissemination, etc.) and will not be made publicly available?	Yes
Will your research involve the collection of photographic or video materials?	Yes
Will financial or other inducements (other than reasonable expenses and compensation for time) be offered to participants?	No
Please explain below why your research project involves the above mentioned criteria (be sure to explain why the sensitive criterion is essential to your project's success). Give a summary of the ethical issues and any action that will be taken to address these. Explain how you will obtain informed consent (and from whom) and how you will inform the participant(s) about the research project (i.e. participant information sheet). A sample consent form and participant information sheet can be found on the Research Ethics website.	

The research undertaken is to be done so in a special educational needs school as the research directly involves children who are vulnerable because of special medical or physical needs that dictates the levels of interaction they can achieve. Interaction with technology to engage with musical themes for people that cannot or do not have the ability to use traditional mechanisms for communication is the aim of the product to be developed. These participants are essential in enabling me to test my product on its intended target market and test the functionality and suitability for special education needs. The gatekeeper will be an employee of the school with whom the author has had previous work experience and who runs the facility at the school that carries out similar work within an interactive sensory studio. Anyone that is attending the school will be in company of the professionals of the school will be able to partake in the research with the deepest respect held for their personal circumstance and knowledge of their boundaries. The students will always have a professional of the school with them that has specific and in-depth knowledge of their particular case. Any issues regarding permissions by the students and student awareness of participation will be discussed with all relevant parties so as not to expose any vulnerable person to situations beyond normal life. Express permission will be gained when working with the children as the school deems necessary and with the parents/carers if necessary. The materials involved in the testing will not be out of range of what is usually experienced by the students and will comply with any rules and regulations as specified by the school. The author does have a criminal record bureau check to be able to work within the school and has rapport with the school and staff. The collection of audio evidence will only be done with express permission from all parties involved and will only be used for transcription/summarising. The collection of photographic and video evidence will only be done with express permission from all parties involved and will only show activity involving devices created and how they are interacted with, if needs be with censoring of the parties involved and only with their written permission. All information will be stored on encrypted hard drives and any physical evidence collected will be stored in a locked cabinet. Care will be taken to keep participants anonymous unless express permission has been given by all relevant parties for identities to be disclosed.

Final Review

Will you have access to personal data that allows you to identify individuals OR access to confidential corporate or company data (that is not covered by confidentiality terms within an agreement or by a separate confidentiality agreement)?	Yes

Please explain below why your research requires the collection of personal data. Describe how you will anonymize the personal data (if applicable). Describe how you will collect, manage and store the personal data (taking into consideration the Data Protection Act and the 8 Data Protection Principles). Explain how you will obtain informed consent (and from whom) and how you will inform the participant about the research project (i.e. participant information sheet).

This research requires personal data such as ages and disabilities of those involved. This will be used to assess how technology used with them is working. This will be stored on password protected hard drives with any physical data being stored in a locked cabinet. Any data shared within the school with key stakeholders, who are part of the school staff, will be done so using the school secure computer systems following their policies and procedures. The minimum amount of data will be collected to allow for analysis of how the technology is working and to allow discussion within the stakeholder group. Any video will be stored on password protected hard drives or within the school secure computer system. Any information gathered will be linked into the ethics work packages developed to allow for consent to be obtained and participants to be informed of what data is being collected and how it will be used.

Will you have access to personal data that allows you to identify individuals OR access to confidential corporate or company data (that is not covered by confidentiality terms within an agreement or by a separate confidentiality agreement)?	Yes
Will your research involve experimentation on any of the following: animals, animal tissue, genetically modified organisms?	No
Will your research take place outside the UK (including any and all stages of research: collection, storage, analysis, etc.)?	No

Please use the below text box to highlight any other ethical concerns or risks that may arise during your research that have not been covered in this form.

Although an example information sheet for participants has been included as an attachment there will be requirements to adapt this sheet and the manner in which the information is delivered depending upon the participants. Every effort will be made to help any participants to understand the information on the sheet in a way in which is understandable to them, if this is not possible then the information will be delivered to the person in charge of the participants well being in line with any policies followed by the school within which the research is being undertaken. Ethics Panel Amendments:The use of ethics work package based on stages of the research will allow for Ann Bevan as supervisor, as well as the [redacted]se on the specific needs of that stage of the research in terms of who will be involved and how. The PIS/PAF forms can then be developed to for that specific stage of the research. The packages will also mean that the implications of the participants being co-researchers can be better explained to the participants. They will then be more aware of what is expected of them both in terms of participation in the research and of what their participation means to the research.Video footage: Will mainly be used for analysing but may be used for dissemination or presentation externally of the school. The work packages will allow for a better idea of how each stage of video footage will be used, this can then be reflected in the PIS/PAF forms to allow participants to know exactly how the footage will be being used. If the footage is used for showing outside of the school then the relevant permission will be obtained either from the participant or from the legal guardian of the participant before it is used for external events.

Attached documents
Participant’s Agreement Form Updated.docx - attached on 17/09/2015 16:40:46
Information sheet for participants2.0.docx - attached on 18/09/2015 13:27:11

E. Agenda from 8/12/2015

<u>**Stakeholder Steering Group Meeting Agenda**</u>

Intros

Hello all!

Recording the meeting? Just for transcribing which I will later analyse and check with you is an accurate portrayal of what was said?

Thanks for coming!

1. My research- **Action Research**- definition

Action research is a participatory process concerned with developing practical knowing in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solution to issues of pressing concern to people, and more general the flourishing of individual persons and their communities.

Research with people not about them with cycles of planning, action, reflection.

Action research:

- A set of practices that respond to peoples desire to act creatively in the face of practical and often pressing issues in their lives in organisations and communities.
- Engagement with people in a collaborative relationship, opening up communicative spaces in which dialogue and developments can flourish
- Draws on many ways of knowing, both in the evidence that is generated in inquiry and its expression in diverse forms of presentation as we share learning with wider audiences.
- Value orientated, seeking to address issues of significance concerning the flourishing of human persons, their communities and the wider ecology in which we participate
- A living, emergent process that cannot be pre-determined but changes and develops as those engaged deepen their understanding of the issues to be addressed and develop their capacity as co-inquirers both individually and collectively

2. **Tentative aims**

- To explore how technology is incorporated into practices of music creation and sound exploration- To look at current things

- To explore the issues that stakeholders have with current music technology- To see what's wrong with those things

- To create novel musical instruments and tools that match criteria as specified by stakeholders and address issues as found in the literature review- To create new things

- To asses the effectiveness of these novel instruments with a view to improving practices- To see if they work

- To propagate the practices, technologies, and methods used to allow for transferability into the wider ecology- To share these tools and findings

3. **Progress so far**

Orchestra project developing so far with me, ! Been running for 4 weeks in 30 minute sessions, we had 2 groups but moved down to 1 group as we didn't feel we could quite meet the needs of some of the first group, some moved into the second group. We hope this will change into the new term when we have further developed more appropriate tools.

The tools we have been using are the Orphion App on the iPad which we have here and we are also developing bespoke hardware which we have to demo but haven't quite developed enough for a session yet. So we can have a play!

Working toward my finishing in April, I will then rejoin hopefully in October.

4. **Open up the floor**

5. **Key themes for discussion/action**

6. **Summary of key actions for the group to take forward**

F.

Asha Blatherwick EngD Stakeholder Meeting

Notes from Meeting at '[redacted] - 8/12/2015

Attended by:

[redacted]

Technology and research in the school setting:

- Action research has benefits within a school setting especially for the children involved, it is a school model of research and this kind of research has been conducted within the school in the past ([redacted] and others on network) may provide useful resources such as questionnaires etc.
- There is work being done with technology in the school that connects to the tentative aims of this research looking at incorporating technology into practice but not letting it overpower the session, keeping the children focussed on the sounds rather than the controls
- Although tools have been created in past research, they tend to be taken away once the research is over
- Technology is growing fast with many new things available, in particular the iPad and apps available for music making. Allowing for a more manageable and portable music therapy session that doesn't necessarily require a tailored environment
- Things such as set-up time, space required, technical knowledge, having to organise set-up may lead to tools being abandoned
- The environment that is available may restrict what can be done
- Times of year can affect how successful things are in the running
- There will be different agendas for each of the stakeholders involved that feed into their own practice, these have to be managed to ensure an authentic positive experience. Key to this is making as much information as possible available to give a full picture of anyone involved
- There is flexibility in the research to allow for responsiveness to attend other sessions both in school, and externally run, that will help feed into the research - [redacted] sessions, Zone Club, South West Open Youth Orchestra etc.

Technology and acoustic instruments:

- There is space to incorporate technology with live instruments to allow for access without the need to have technique, using technology to allow all instruments to sound cohesive together to enable ensemble playing
- There is interest in exploring where technology is not necessary and where technology and acoustic instruments combine as this human interplay can create motivation for joining in

- Exploring the use of voice combined with bespoke instruments for vocal manipulation would provide a good avenue for creating resonance – the voice is an instrument most have
- There are various ways of using technology such as creating new instruments from the ground up, augmenting current instruments, or using technology as an interface to access an acoustic instrument. Whilst this research will focus on creating new instruments, future work could explore other ideas. Some past research and upcoming research explored/will explore the latter two ways of using technology
- Some of the issues surrounding access to acoustic instruments is wider than the scope of the research

Maximising accessibility to technology based instruments:

- Access can be provided to some technology by judging situations as they occur in practice and adapting the equipment as needed
- It would be useful to run some one-to-one sessions to allow for more bespoke attention to be given to some children. This has worked in the past to allow group playing and ensembles to form over time
- Involving the children and others in the school that are actively incorporating technology into practice will allow for a more authentic picture of what's happening and issues to be exposed
- Authentic observation of instruments in use can lead to a more successful development of something that has lasting effect on pupil experience
- There is a demand for flexibility in terms of the types of activities explored in sessions to allow for different ability levels to participate- with regard to cognitive ability and physical barriers

Issues to consider when creating new instruments with technology:

- The chance to take the journey to becoming a virtuoso with a technology based instruments, by having scope for improvement over time, is of particular interest from an orchestral standpoint.
- To allow for maximum capability for expression and growth of self-esteem, and the feeling of ownership and intimacy with an instrument. This relates to the type of instrument that would suit each individual and the way it is set-up to allow them to excel based on their capability
- The shape, texture, feel, and feedback of an instrument can draw the children in, making sure the music and sound belong to all the senses to create a whole experience whilst minimising the need for configuring the instrument in ways that are not accessible to those playing them
- Resonance and sensory feedback are important for creating enticing instruments – if resonance is not present then other means of feedback should be generated, this resonance can be used as a powerful tool to feel sound through the whole body
- Plug-and-play solutions are the ideal but require lots of development often leading to a high cost. Whilst the end goal of the research is to create self-contained units there has to be realistic goals along the way

The instruments we presented:

- Aiming for form and function to link with the shape of the design and actions available with it to lead to a natural interaction- i.e. you squeeze something harder and it gets louder whilst still retaining the tactile feel
- The filter box is tailored more towards right handers
- It is important to look at the capabilities of the children to establish where the design should go (squeezing the filter box to create sound and difficulty with that) and to set things up to enable instant access
- The handheld designs were exciting and allowed for a feeling of ownership when in use. These could potentially form an 'orchestra in a box' that could be taken home by the children. The designs and plans of which would also be freely available online to allow for others to create their own
- The pressure style box is a design that can be developed further featuring a microphone and a motion sensor
- There are still design issues to work around such as battery life if including vibrating motors and issues using wireless technologies such as radio

G.

<u>Stakeholder Steering Group Meeting 2 Agenda</u>

1. **Report from last meeting**

Time to discuss the points from the report. Raw transcription available.

2. **Progress so far**

Orchestra project development happening to be able to provide instruments for the sessions that are going to start in Term 2 of this year. Moving away from using iPad to incorporate more devices and flexible software to use with these. Developing a modular piece of software that bespoke or off-the-shelf devices can be connected to - MAMI.

3. **Things from last meeting**

- Past research information on the network -
- Other sessions that are running within the school -

4. **Key themes for discussion/action**

How to test instruments success? What angle- does it tie into learning outcomes? Educational/therapeutic? Accessibility for all involved in use of the technology? Tie in to performance?
Developing design principles that are informing/could inform the design process.
Style of delivery for feedback/reports and amount of meetings.
Ethics – permission from students involved in orchestra so I can better document.

5. **Summary of key actions for the group to take forward**

H.

Asha Blatherwick EngD Stakeholder Meeting

Notes from Meeting at Threeways School - 8/2/2016

Attended by:

[redacted]

Report Delivery

- Length of feedback and format is okay for the stakeholder meetings
- Reports allow for reflection on philosophy behind the work undertaken as it is sometimes hard to get time to use that vision to make projects successful

Modular Accessible Musical Instrument (MAMI) Development

- [redacted] spoke about the focus of his time being the software development side of the research as this is often one area that is lacking with accessible instruments. The hardware has to be connected to software to explore its possibilities which can be a sticking point. This is where MAMI will really help as it will provide a modular system that can be adapted to any piece of hardware connected to it
- [redacted] demoed his development of the MAMI software with a joystick.
- Most hardware instruments hardware are fader and button based, the software allows users to map any input to a musical output (scales/notes/arpeggiators/filters/samples)
- Things like joysticks provide unique opportunities to use the skills some of the children and young people (CYP) have developed when using things like their wheelchairs
- We discussed the costs so far and the potential of purchasing equipment such as the LattePanda (small computer) to create instruments without having to rely on an external computer
- The developments can then be shared with the wider community; a plug and play hardware and software system would be a great outcome for the project
- The modular aspect of the technology can aid in letting people explore in a fun and adaptive way, not focussed on bespoke instruments so tailored that there is no ability to transfer them to others –something adaptable is the best outcome for the school in terms of being used and not left in a cupboard

Current State of the Research and Future Plans

- Behind intended schedule due to other work commitments and length of time taken to develop the technology and software
- One potential avenue for exploration is to bring in an external facilitator to run the workshop/sessions. We are developing the technology to widen access and participation whilst an external facilitator could help to leapfrog the research across into organising the sound into sessions and performance pieces

- There may be the chance to use the money for the orchestra project as seed money for match funding to allow for the payment of a professional or volunteers, either professional or student in the field, to facilitate sessions. We would be able to offer a brief, the raw materials, and the profiles of the CYP which a facilitator could use to develop something to push the research forward from previous years, creating something with longevity
- There also is the option to contact Open Up Music and Doug Bott, leading to further knowledge exchange
- Other organisations that could be helpful are Zone Club in Bristol, Carousel Music in Brighton, and Rhythmix in Brighton

Content of the Sessions

- Use of visuals to create a framework and give structure and shape to sessions, within which the CYP can explore sounds – exploring the notion of the story map
- In previous years the performative element was not the most successful part of the project, these came when children were in sessions discovering themselves and their musical capabilities
- Its nice for the CYP to have a musical experience to look forward to with the chance to develop virtuoso skills

Interaction, Engagement, and Design

- Adapting existing technology and looking at things that already motivating for inspiration – this could then help with getting the attention of some of the CYP, the use of shape and visuals to stimulate them to respond and interact. Some CYP may not always need the visual element
- There are non-verbal cues, such as facial expression that show engagement level, there is also the knowledge of the child by those around them, such as lifetime nurses, that can be invaluable when assessing the success of any techniques or technologies used
- Some pupils get kinaesthetic feedback from the device and the interaction itself, not always from the sound- depending on attention span, there can be ambiguity as to whether an action is done to produce the effect or because the action itself is motivating
- Sensory feedback may not come from the device in their hands but the resonance that we are hoping to offer them
- There should be a focus on natural interaction where function is a part of form
- Some CYP prefer individual play whilst others thrive when part of a bigger ensemble. The intrinsic motivation and focus in playing and being part of something may exhaust the potential of the soloist but the group dynamic can excite students in a different way
- There is a need to keep the ensemble and collaborative aspect in mind as when developing the technology is important as we can become shut off from the needs of a group dynamic

Focus of the research

- The focus of the research is open at the moment- there may be a need to consider whether the focus should be narrowed to working as groups, focussing on the technology that is created, or/and innovative ways of widening participation
- The 'outcomes and end product' model of working are current buzz words in the creative arts and can hamper the creative flow- there is a pull toward product led rather than process led learning. The products do not always speak of the learning that's gone on internally
- Sessions that focus on being engaged, discovering, exploring, participating, and being part of something are important. This follows more closely with the model currently used within school where the best learning opportunities are in process led moments
- A fixation on how things look and sound at the end, or on how it responds to our interaction can exclude people and create anxiety that can ruin the process and shut down much needed playfulness
- To wider participation people need to feel confident that the end product is not the focus and the focus is on getting hands, head, and heart anchored into the process
- There is a strange dichotomy to thinking of the end product, such as a performance piece but using action research where the outcomes can be unknown, this can be exciting

I.

[redacted]

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Designing electronic instruments

November 10, 2015

At [redacted] we are always looking for new and interesting ways to interact with sound. We have been developing some ideas for new instruments for the electronic orchestra at [redacted] that allow people to play with sound whilst following a few design rules, what we want is:

- A focus on natural interaction, i.e. form affirms function and in this vein we talked about the opening and closing of a box to control a filter
- Instruments that do not involve pressing on flat glass like a tablet screen, we want something more tangible
- Preferably some local feedback in the form of vibration
- Objects that are nice to hold and feel, perhaps finished in wood with a nice varnish like a traditional stringed instrument
- As we need to focus on accessibility we need to consider not depending on finger dexterity
- We want to provide an instrument that really offers a chance for the player to express them self
- We need to tread the line with offering the user control over the creative process, whilst enabling the orchestra as a whole to play cohesively - the real challenge!

We have been looking at a couple of initial ideas for development in terms of the outer casing of the instruments and the inner gubbins that make it work. They are the 'filter box' and the 'pressure box'.

Filter Box

A box that can sense how much it is open and link to a filter in an electronic instrument.

A nice wooden box with a hinged lid that operates very smoothly. We have been looking at what type of box might be suitable and hinges that are robust and pleasing to open, and also what kind of sensor components would give the right kind of response. Thoughts so far include:

- LDR (light dependent resistor) on the inside so that as the lid is opened, the amount of light hitting the sensor changes the filter, this is a affordable option as this component is cheap to purchase but the problem comes when trying to calibrate the sensor as ambient light levels can change during a performance and in different environments.
- Flex sensor against the inside of the lid so that as the lid is closed the flex sensor is compressed. Flex sensors cost around £7 each so not as affordable as the LDR but does not have to be calibrated as they should always give the same reading. Homemade flex sensors can be made extremely cheaply as seen in this instructable, we have some ready made from a previous project that we will trial in this instrument which follow a similar set-up but use anti-static foam at the centre.
- Stretch sensor attached between the bottom and the lid of the box, this would give readings when stretched open and could be used as a nice string to pull the lid closed to give tactile feedback.
- Magnet on the lid and hall effect sensor inside so that as the magnet moves away the sensor returns to the base value.

We will have to do some small prototypes to figure out the cheapest and best way to create this box!

Pressure Box

A deformable surface, think tambourine but with a stretchy skin that can then be pushed into to create or manipulate sound. There are a couple of places the inspiration for this has come from, the first is the pads on the Alphasphere and the second is the Firewall. We are still looking to have the wooden outer to hold but perhaps in a circular shape. Options for the sensor include:

- Electronic force sensor
- Air pressure sensor (this would require a sealed box)
- Cheap DIY force sensor
- Distance sensor placed underneath the skin

We will be developing and testing from these initial ideas and will connect those blog posts related to that to here so you can keep up to date with the progress on these new instruments for musical expression!

Designing electronic instruments - 2

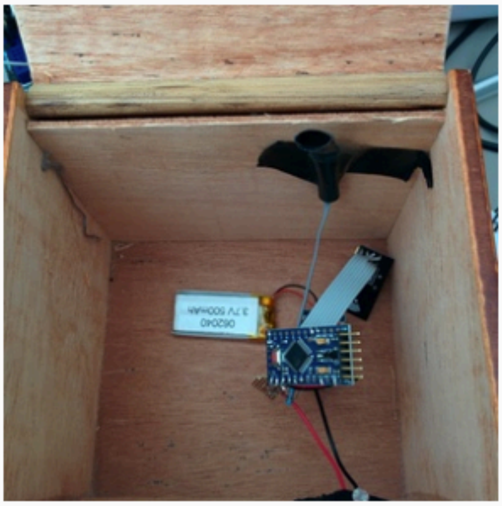
February 24, 2016

Following on from this post.

On Monday we met to discuss the first prototypes of the two instruments we wanted to explore as detailed in the previous post.

The Filter Box

We took a look at the first Filter Box prototype as seen in the pictures below which was set-up in a temporary box for testing of the sensors. I bought several small wooden boxes to try for size, shape, and general ergonomic-ness when holding, and to enable discussions as to what might be good features and functionality to have in the box.



Our idea was to create a wireless filter box. I wanted to use some of the nrf240l1 radio modules I have acquired as they provide a very cheap mechanism for wireless communication, and there are lots resources available to make them work with Arduino. A detailed tutorial on using Arduino + Nrf24l01 running into Max/MSP software can be found on my website here.

Discussing the box!

We discussed:

The wooden boxes I had purchased and selected a small oval shaped one as the best shape and size to fit in the hand.

Buttons- having some (x2) to enable more functionality- options included click buttons that would provide tactile feedback when depressed or valve style that would more naturally mimic an interaction with an instrument such as a trumpet, like a valve, these would give feedback not as obviously as a click but more suited the instrument paradigm.

Adding a force sensitive resistor (FSR) that could then be pressed harder or softer to achieve some of the effects you would with other instruments such as when fretting a guitar, and allow expression through fingertip movement and pressure of the hand on the box. The mapping of the FSR could then be naturally connected to something like the amplitude of the sound so when pressed harder the sound would be louder, again going with what a player might naturally expect from an interaction of that style.

Light dependent resistor (LDR) this worked well as a mechanism to control some sort of filter, or for example the mute of a trumpet, the cutoff frequency of the sound or the volume. This is taking the movement of the opening and connecting it to any kind of parameter that might need fine movement and can be used to get effects like vibrato and tremolo. A parallel can also be drawn between something like scratching (dj style) by opening and closing the lid, and when connected to a filter controlling some element of feedback, using noise as the sound generator. We had a little play with using the light dependent resistor to control the cutoff frequency on a filter over sounds and using the motion to trigger MIDI notes but felt that the latter did not really play into the strengths of the opening and closing of the box as much as the controlling of an effect.

The aim with the filter box was to create something that when held in a natural position would allow access to the 2 buttons and the FSR as well as facilitating the opening and closing of the lid so that the elements could be used in conjunction with each other and separately in an ergonomic way.

The Pressure Box

We discussed the pressure box and using an array of piezos arranged around the bottom of the circular wooden box to create 8 potential pressure points. The Arduino pro mini we are using in the instruments allows for 8 analogue inputs so would suit this set-up. The box can then be filled with foam and topped with a soft tactile yet spongy material such as neoprene, or potentially some sort of skin stretched over the top in the style of a tambourine and secured down with pins. Being that the piezos are very sensitive to vibration there may be some cross talk between the 8 units but this could provide useful for expression. The sensitivity of the piezos allows for tapping the box to trigger or modulate the sound also.

Future boxes

The hexagonal box though not used yet could potentially feature a new mode of interaction for each of its faces to allow a player to choose their preferred interaction mode and mechanism, this may be one for future exploration.

Next Steps

I will now review what we have discussed and implement them into some more prototypes!

Designing electronic instruments - 3

February 24, 2016

Following on from post 1 and post 2 on this project.

On Monday we met to discuss the latest prototypes of the Filter Box and the Pressure Box.

Filter box:

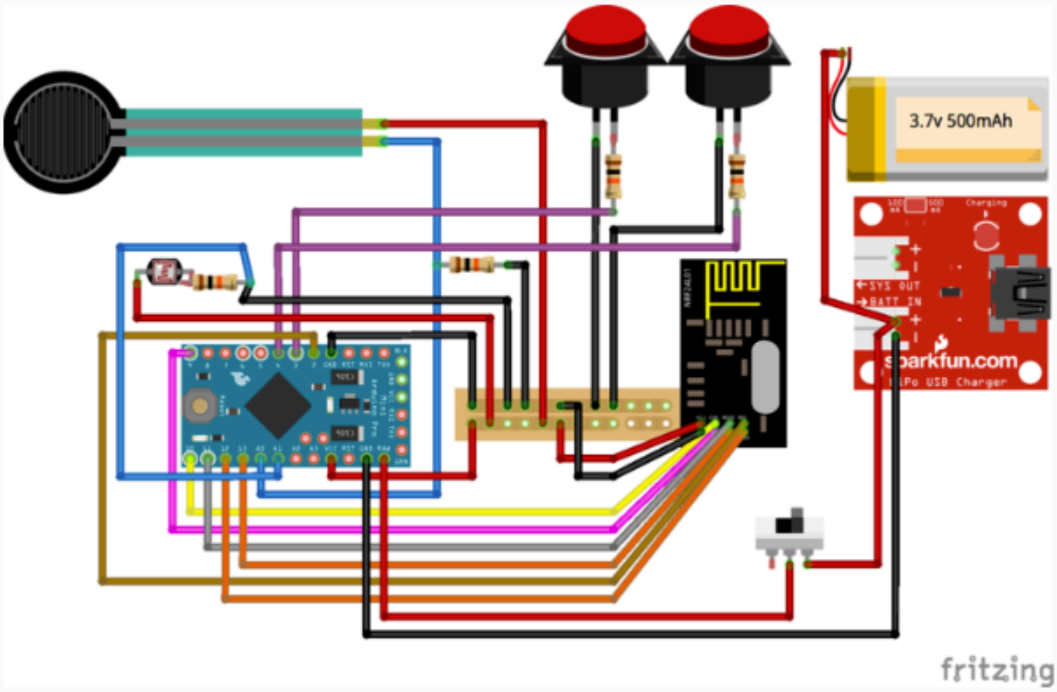
We had selected the small oval box as the one most suitable for the Filter Box and I set to work adding 2 valve style buttons and 1 force sensitive resistor to go alongside the light dependent resistor already installed in the prototype.

Parts added to existing prototype:

2 x Valve style buttons

1 x Force sensitive resistor (FSR)

Circuit:



A note on the resistors for the buttons; no resistors are needed on the buttons if you enable the inbuilt resistors in the Arduino, you can do this in the code uploaded to the board. We did not use resistors on the buttons and so the code below will mean that the buttons are considered to be high or on until pressed which will then turn the input to low or off. So these buttons send a 1 when not being pressed and a 0 when pressed.

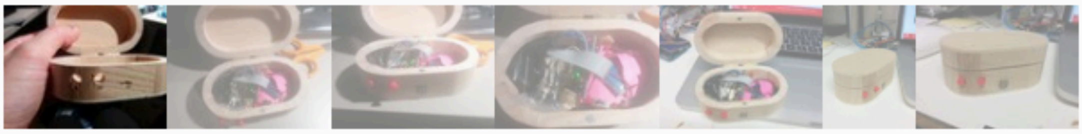
The Code:

https://github.com/[redacted]

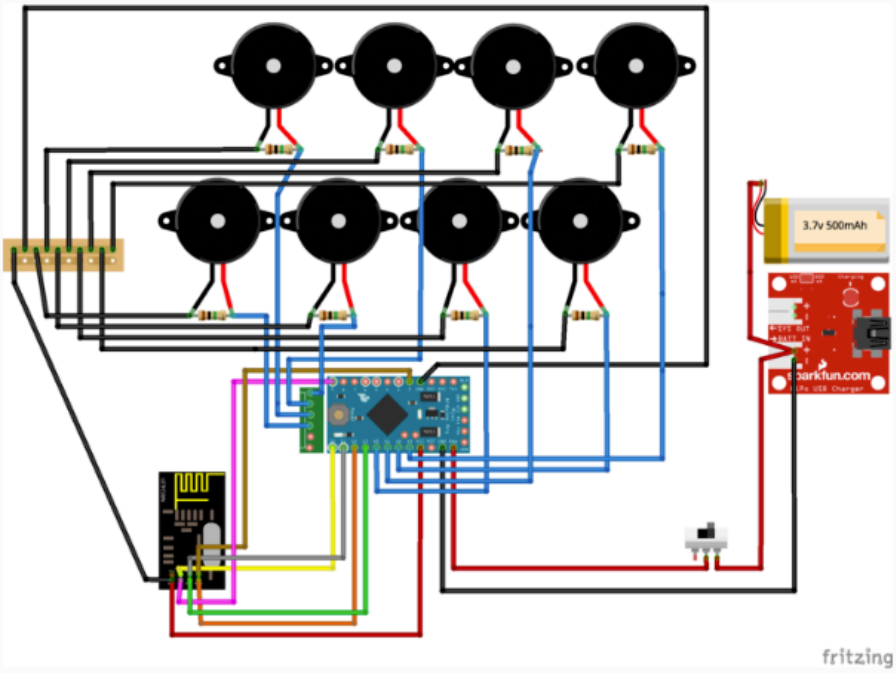
Creating the Filter Box

The box required 2 more holes drilling to match the size of the valve fitting, these then had to be glued into place to secure. A small slit had to be drilled and filed to allow for the FSR to pass through.

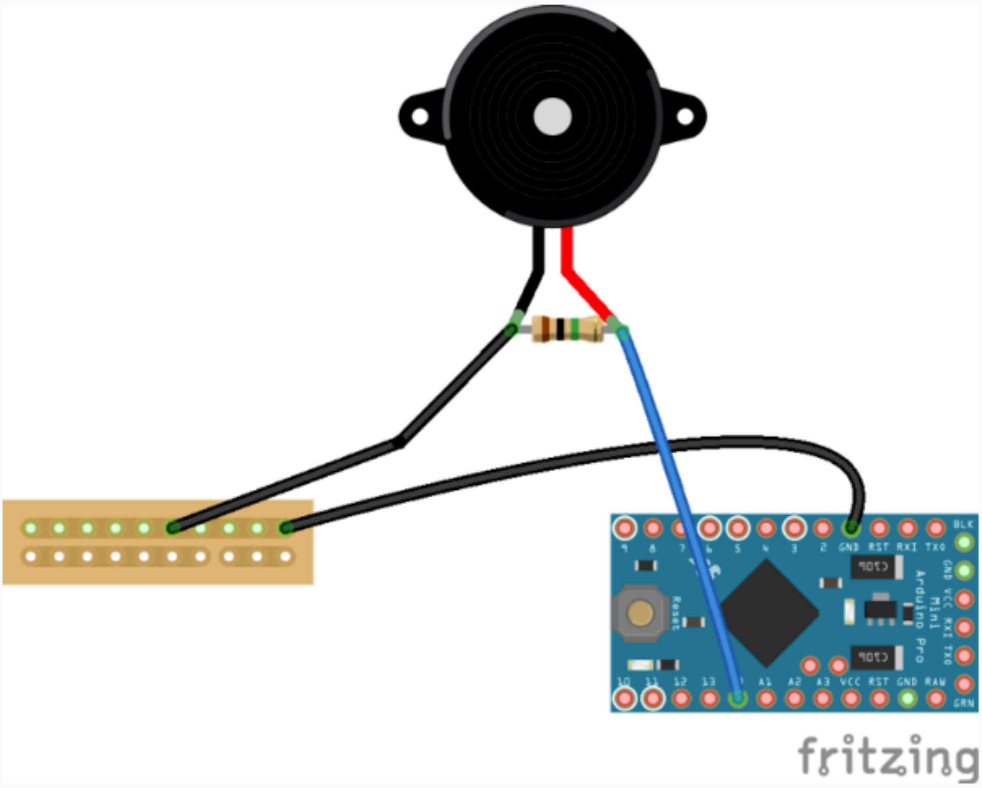
Electrical tape and paper was used to ensure that none of the vital circuitry was touching each other as the box is quite a small space for all the components needed. The Filter Box was then ready for some testing!



The Circuit:



Here is a more simplified view of how each piezo is wired in:



A note about the circuit: The software used to draw up the circuit didn't have the exact same Arduino board as we are using so the green section to the left of the Arduino board is simulating the analogue inputs that are in different positions on the Arduino. The picture below shows more clearly the holes for the analogue inputs (A0-A7) A4 and A5 are the holes above A2 and A3.

A note about the circuit: The software used to draw up the circuit didn't have the exact same Arduino board as we are using so the green section to the left of the Arduino board is simulating the analogue inputs that are in different positions on the Arduino. The picture below shows more clearly the holes for the analogue inputs (A0-A7) A4 and A5 are the holes above A2 and A3.

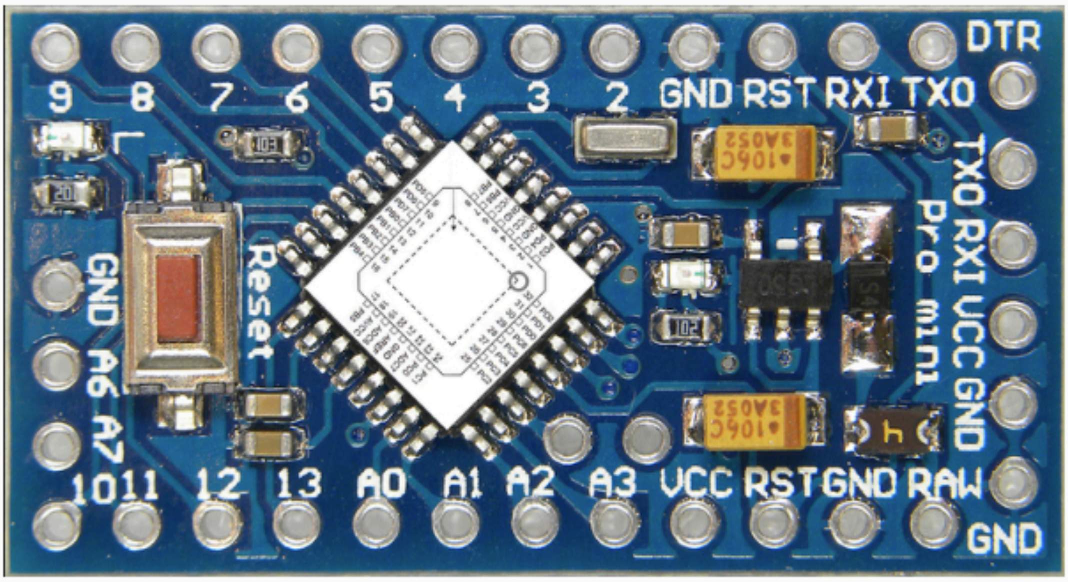
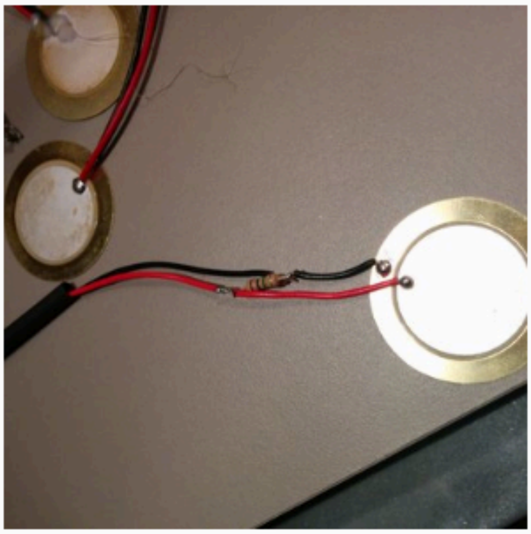
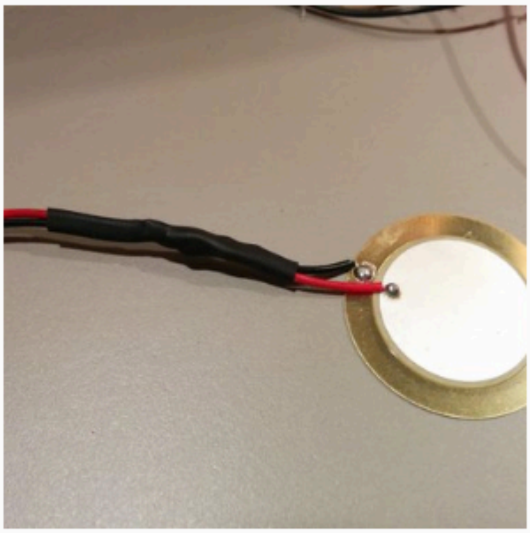


Image from http://www.dominicdube.com/wp-content/uploads/ArduinoProMini000b.jpg

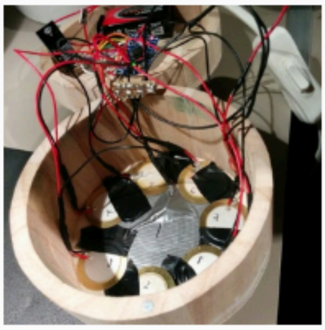
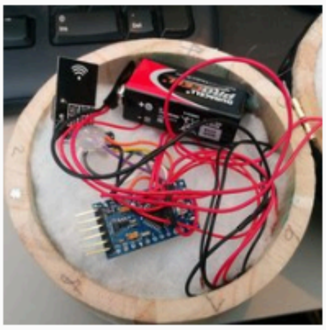
Each of the piezos had to be prepped as they require a 1 MOhm resistor running between their 2 wires as seen in the circuit diagram. The resistor was installed at near the disc of the piezo and some heat shrink was used to seal everything in.





The piezos were then arranged around the bottom of the box with electrical tape to stop them touching. Two layers of thick but airy foam wadding were used to provide the bouncy resistance needed. The components were stashed between the two layers. Once the correct battery has arrived these components should sit nicely over the middle piezo.




Attention then turned to the lid. We decided it would be best to cut out a hole in the lid thus having a ring of wood on which to attach the skin (tambourine style) and then pin it on the edges with thumb tacks. This would also allow us to put clasps on the side of the lid to attach to the box so as to provide access to the components if needed without removing the skin.

We took to the CNC router to nicely remove the inner lid before adding the skin made from a thick piece of lycra like material folded double.

Testing will be done with these prototypes to see what the next steps are........

In threeways, Interactive, Hardware, Coding
Tags accessible musical instruments, Threeways, Orchestra Project

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Designing electronic instruments - 4

February 24, 2016

Following on from post 1, post 2, and post 3 on this project.

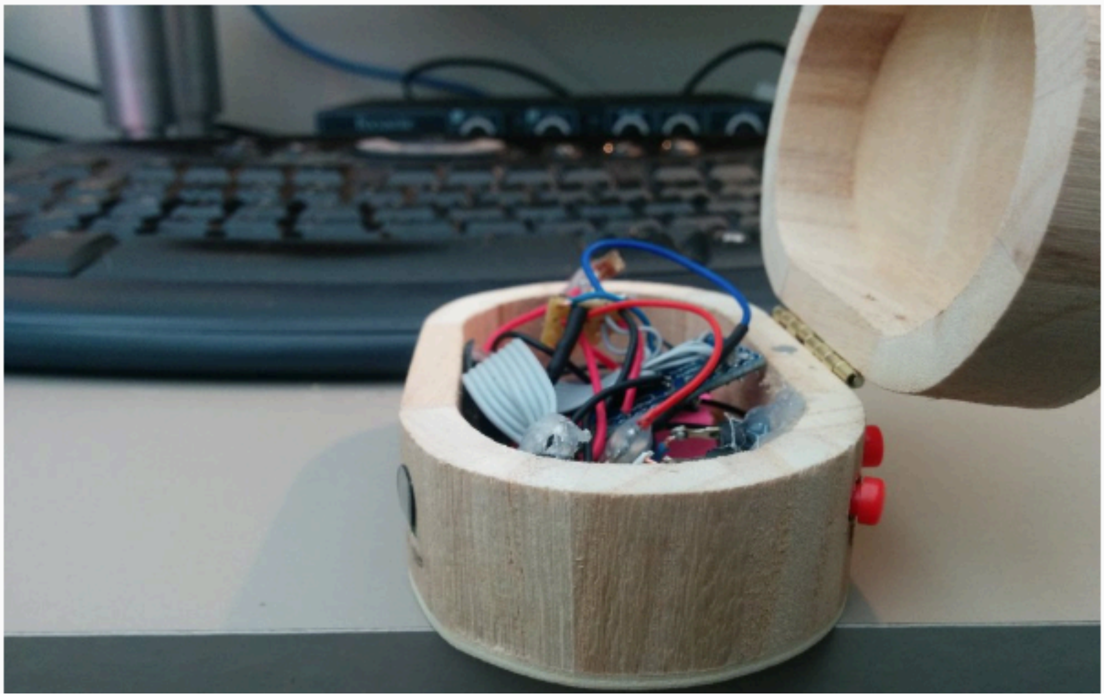
We met on Monday to take a look at the modifications to the Filter Box and give them a little test with the Max patch that [redacted] has been developing, and then I went away to make the modifications.

Filter box testing:

A couple of modification were discussed to make the box more ergonomic and natural to use and hold and that will allow for easier interaction with the inputs the box offers.

These were:

- Move the hinge to the other side of the box to enable holding and opening like a book
- Change the button style as they are not working quite right in fitting nicely to the finger or giving adequate feedback, maybe to tiny arcade style buttons that accommodate fingers with a dip, or custom made buttons attached to a micro switch
- The pressure sensor is in an awkward position on the front making it difficult to use it with the buttons so move to back where the thumb pad of the hand naturally presses against it



We met again the following Monday to discuss the above modifications.

We found it was still difficult to access the force sensor and the buttons at the same time. Also to trigger the sound the button and force sensor have to be used at the same time so what might be better is to leave the sound level high until you press the force sensor which will then lower the volume, this would mean there would be less chance of a player pressing the buttons and thinking they were not playing it correctly or it was not working.

There is also an element here that could play into having to control and mould a sound with the instruments, [redacted] has mentioned in the past creating an instrument that you would have to fight against in order to play. This could be a good opportunity to explore a concept like that, to have the instrument playing and you use the inputs to bring the sound in order.

We also discussed the possibility of the light dependent resistor being a little bit volatile in performance situations as there are potentially flashing lights or light changes that could trigger the instrument and disrupt the players sense of cause and effect. Also any photographs taken with flash could trigger the sensor. This will require testing to see how much of an issue this would be. One suggestion is to move the sensor down a well next to the back hinge of the box so the box will be less responsive until it is more fully open......a little more fiddling required :)

HOME Q BLOG ABOUT CONTACT LEARNING

Designing electronic instruments - 5

February 24, 2016

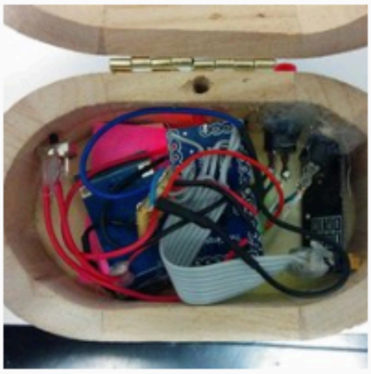
Following on from post 1, 2, 3, and 4 on this project.

We met on Monday to take a look at the few modifications to the Filter Box and to see if they improved how the instrument felt and worked in the hand, we also looked at the Pressure Box.

Filter Box

A couple of the things we changed were:

- Moving the force sensitive resistor (FSR) to the left which meant that it sits under the hand better and enables a natural pressure to always be present
- Moving the light dependent resistor (LDR) to the back middle where the box hinges, at the bottom of a drilled out hole, so that the box has to be opened fully to trigger the sensor and it is not as sensitive to ambient light changes


We had a play about and made the following points:

- FSR for now in much better position as is accessed automatically by hand when squeezing and can be used by finger too.
- LDR in better position drilled down the back to give more uniform reading in changeable light scenarios- might also work to use a led strip so the whole thing is self contained- a nice feature is that moving towards the light can be used as a tool to give expression
- might be nice to extent the functionality with an accelerometer so that physically shaking the box could be connected to audio parameters, there would be a lot of data to play with!
- buttons still a bit dodgy- one is more flush to the box than the other so the desire is to overcompensate and push in the other one really hard. Will try the new bigger arcade style buttons, they are more rigid but have an easier action and less resistance when the spring is removed

Pressure Box

We also took a look at the Pressure Box and ran it into Max to take a look at its responses:

- Needed more foam and perhaps a layer of more solid foam
- The piezos are fine with short sharp hits but do not respond to long pressure pushes which is not ideal. They do give a response from pressure after idling at 0 for a short time, but not until releasing them. Kind of the opposite to what we wanted to happen. This might mean that the piezo is not quite right depending on the type of instrument we want to design sonically for. A more percussive application could work well as the response to this action seems to fit with the action itself, however if we want to be able to press down slowly over time then another solution must be found!

We shall keep exploring and testing!

[redacted]

Designing electronic instruments - 6

February 24, 2016

We have been having a bit of a hiatus from developing hardware for the orchestra project at [redacted] multiple reasons. On re-engaging with the project we started examining the issues we often have with developing accessible instruments. One of the main things we focussed on was the fact that we always have to create new software when we want to try out some hardware, whether it be an existing device or something bespoke. Wouldn't it be great if we had some kind of modular system that we could plug any bit of hardware into and map its controls to various sound generators/effectors, parameters etc... To some extent with a Max patch to read the incoming control data and a Live template to do something with the data, you can do this. However, if we want to make stuff that can be accessed by anyone, or even stuff that is built in to an embedded system then we may want to avoid using Live and create something that can work as a Max read only patch.

So... with all this in mind we have started developing MAMI, Modular Accessible Musical Instrument. This is kind of a mammoth undertaking in catering for any kind of input, various outputs and making it extremely flexible and routable so we will ultimately focus on our own immediate usage requirements, but with a view to making something that can be built upon long term. At the point of writing I have built a system with which you can dynamically create devices and assign input receivers within those devices, I have focussed on Human Interface (joysticks, keyboards, games controllers etc) devices so far and am moving on to Serial input. I am viewing every controller as having combinations of analogue (sliders, knobs, joysticks, pressure sensors etc) and digital (buttons, keys etc).

Needless to say, it will be a while before a first release !

J.

Meeting about the tech toolkit!

Can I record what we talk about?

Agenda

Questions/what to cover!

1. **Demo the kit so far** - do you want it? the instruments so far and their features?
2. **How to gather feedback** – pre-post questionnaire/survey monkey/in-app notes/own written documents/own journal/feedback form/interview?
3. **What do with bloop**? – this is a kind of pie-in-the-sky part inputs/outputs? examples - Resonance ball, SenseEgg? Mic input? Standalone? iPad integration? 3 things each changeable?
4. **What would make it successful to them**? creating criteria from this?
5. **Computer?** Do they have one available?
6. **Case studies of use** –one possible outcome?

Start by introducing the tech toolkit and what is contained in it

The kit

Noodler – sender/receiver - 9v battery on sender
The device - accelerometer, x/y joystick, two buttons
The output - set trigger zones by drawing, trigger midi notes of samples, select the notes and the samples triggered by which colour, choose a folder of samples

FilterBox - sender/receiver - 9v battery on sender
The device - fsr, ldr, 2 buttons
The output - up and down notes and filtering of those using selected virtual instrument

SquishyDrum - sender/receiver - 9v battery on sender
The device - 3 x fsr, 3 x piezo
The output - undetermined

TouchBox – 2xAA batteries
The device - Stand-alone box with 8 copper contact pads with selectable waveform, scale, root note, octave select - output via internal speaker, headphones, or 1/4in jack
The output - synthesised notes!

Measuring Use
I want to get info from each device. When it is turned on and how long for potentially? For hard figures on usage.

K.


```
/*******************************************************************************
  Digital Handpan V2 Code for Teesny
  Joel Bartlett @ SparkFun Electronics
  Original Creation Date: December 16, 2017
  Modified Code: David Cool
  Modify Date: January 12, 2017
  Modified further by Asha Ward
  Modify Date: 4th April 2018

  This sketch produces polyphonic notes when any number of eight capacitive touch pads are
  touched, thus replicating a Handpan (or Hang) steel drum. This sketch
  makes use of the Teensy Audio Shield (https://www.sparkfun.com/products/12767)
  as well as the Teensy Audio System Design Tool (http://www.pjrc.com/teensy/gui/).
  All capactive touch sensing is handled by the Teensy's built in Touch Sense Pins.

  Hardware:
    Teensy 3.2 Dev Board (https://www.sparkfun.com/products/13736)
    Teensy Audio Board (https://www.sparkfun.com/products/12767)
    Various buttons and potentiometers

  Development environment specifics:
    IDE: Arduino IDE V 1.8.5 with the Teensyduino Add-on installed V Teensy Loader V1.30

  This code is beerware; if you see me (or any other SparkFun
  employee) at the local, and you've found our code helpful,
  please buy us a round!
  Distributed as-is; no warranty is given.
*******************************************************************************/
//These libraries are included by the Teensy Audio System Design Tool
#include <Audio.h>
#include <Wire.h>
#include <SPI.h>
#include <SerialFlash.h>
#include <Bounce.h>
#include <LiquidCrystal_I2C.h>
#include <SD.h>
#include <TimeLib.h>

#include "note_frequency.h"
#include "TeensyAudioDesignTool.h"

// A simple data logger for the Teensy

#define ECHO_TO_SERIAL   1 // echo data to serial port
#define WAIT_TO_START    0 // Wait for serial input in setup()

// the digital pins that connect to the LEDs
#define redLEDpin 2

//----------------
#define volKnob A13 //grey wire
#define decayKnob A10 //black wire

//an array to define each of the eight touch sense pins,
//all other touch sense pins are used by the Teensy Audio Shield (16,17,18,19)
int pinTouch[] = {0, 1, 15, 16, 17, 25, 32, 33}; //25 = white, 32 = yellow, 33 = blue

int scale_index = 0;//var to keep track fo which scale is being used
int note_index = 57;//starting note value (A)
int octave_index = 0;
int wave_index = 1;//var to keep track of which wave is being used
int numOfWaves = 4;//5-1=4


int dcVal = 0;//value to control the decay of each note
int padNumber = 0;//debug for printing pad values to OLED

///////////////////CHANGE THIS WHEN ADDING MORE SCALES
int numOfScales = 13;//indexed at zero (subtract 1)
///////////////////////////////////////////////////////

int scale[8];

//buttons for incrementing or decrementing through each scale
Bounce button0 = Bounce(4, 15);
Bounce button1 = Bounce(3, 15);
Bounce button2 = Bounce(29, 15);
//buttons for incrementing or decrementing the octave
Bounce foot0 = Bounce(5, 30);
Bounce foot1 = Bounce(8, 30);

float vol = 0;
bool debug = false;

LiquidCrystal_I2C lcd(0x27, 2, 1, 0, 4, 5, 6, 7, 3, POSITIVE);  // Set the LCD I2C address

////////////////////////////////////////////////////////

const int chipSelect = 10;
// the logging file
File logfile;

//////

void error(char *str)
{
  Serial.print("error: ");
  Serial.println(str);
```

```
  // red LED indicates error
  digitalWrite(redLEDpin, HIGH);

  while (1);
}
////////

void setup()
{

  SPI.setMOSI(7);  // Audio shield has MOSI on pin 7
  SPI.setSCK(14);  // Audio shield has SCK on pin 14
  //initialize buttons
  pinMode(4, INPUT_PULLUP);
  pinMode(3, INPUT_PULLUP);
  pinMode(5, INPUT_PULLUP);
  pinMode(8, INPUT_PULLUP);
  pinMode(29, INPUT_PULLUP);
  button0.update();
  button1.update();
  button2.update();
  foot0.update();
  foot1.update();

  setSyncProvider(getTeensy3Time);
  //initialize Serial
  Serial.begin(115200);
  Serial.println();
  lcd.begin(20, 4);  // initialize the lcd for 16 chars 2 lines, turn on backlight
  lcd.backlight(); // finish with backlight on
 // ------------

// START OF LOGGING

//  while (!Serial);  // Wait for Arduino Serial Monitor to open
//  delay(100);
  if (timeStatus() != timeSet) {
    Serial.println("Unable to sync with the RTC");
  } else {
    Serial.println("RTC has set the system time");
  }

//#if WAIT_TO_START
//  Serial.println("Type any character to start");
//  while (!Serial.available());
//#endif //WAIT_TO_START

  // initialize the SD card
  Serial.print("Initializing SD card...");
  // make sure that the default chip select pin is set to
  // output, even if you don't use it:
  pinMode(10, OUTPUT);

  // see if the card is present and can be initialized:
 // if (!
  SD.begin(chipSelect);
//  {
//    error("Card failed, or not present");
//  }
//  Serial.println("card initialized.");

  // create a new file
  char filename[] = "LOGGER00.CSV";
  for (uint8_t i = 0; i < 100; i++) {
    filename[6] = i / 10 + '0';
    filename[7] = i % 10 + '0';
    while (! SD.exists(filename)) {
      // only open a new file if it doesn't exist
      logfile = SD.open(filename, FILE_WRITE);
      break;  // leave the loop!
    }
  }

//  if (! logfile) {
//    error("couldnt create file");
//  }

  Serial.print("Logging to: ");
  Serial.println(filename);

  // connect to RTC
  // Wire.begin();
  //  if (!RTC.begin()) {
  //   logfile.println("RTC failed");
  ////#if ECHO_TO_SERIAL
  //    Serial.println("RTC failed");
  //#endif  //ECHO_TO_SERIAL
  // }


  logfile.println("hour,minute,second,day,month,year");
//#if ECHO_TO_SERIAL
//  Serial.println("hour,minute,second,day,month,year");
//#endif //ECHO_TO_SERIAL

  // If you want to set the aref to something other than 5v
  analogReference(EXTERNAL);
//
//if (Serial.available()) {
```

```
    time_t t = processSyncMessage();
    if (t != 0) {
      Teensy3Clock.set(t); // set the RTC
      setTime(t);
  }
// }

  printLog();
//  digitalClockDisplay();
  delay(1000);

//END OF LOGGING BIT

//---------

  Wire.begin();
  delay(100);

  //set aside audio memory
  AudioMemory(64);

  //initialize audio settings
  sine1.begin(WAVEFORM_SINE);
  sine1.amplitude(0.125);
  sine1.frequency(440);
  sine2.begin(WAVEFORM_SINE);
  sine2.amplitude(0.125);
  sine2.frequency(440);
  sine3.begin(WAVEFORM_SINE);
  sine3.amplitude(0.125);
  sine3.frequency(440);
  sine4.begin(WAVEFORM_SINE);
  sine4.amplitude(0.125);
  sine4.frequency(440);
  sine5.begin(WAVEFORM_SINE);
  sine5.amplitude(0.125);
  sine5.frequency(440);
  sine6.begin(WAVEFORM_SINE);
  sine6.amplitude(0.125);
  sine6.frequency(440);
  sine7.begin(WAVEFORM_SINE);
  sine7.amplitude(0.125);
  sine7.frequency(440);
  sine8.begin(WAVEFORM_SINE);
  sine8.amplitude(0.125);
  sine8.frequency(440);

  dc1.amplitude(0);
  dc2.amplitude(0);
  dc3.amplitude(0);
  dc4.amplitude(0);
  dc5.amplitude(0);
  dc6.amplitude(0);
  dc7.amplitude(0);
  dc8.amplitude(0);


  //initialize volume
  sgtl5000_1.enable();
  sgtl5000_1.volume(0.8);
  sgtl5000_1.lineOutLevel(5);


  changeScale();//start off at middle C
}
//////////////////////////////////////////////

void printLog(void)
{

  logfile.print(year(), DEC);
  logfile.print("/");
  logfile.print(month(), DEC);
  logfile.print("/");
  logfile.print(day(), DEC);
  logfile.print(" ");
  logfile.print(hour(), DEC);
  logfile.print(":");
  logfile.print(minute(), DEC);
  logfile.print(":");
  logfile.print(second(), DEC);
  logfile.print('"');
#if ECHO_TO_SERIAL
  //    Serial.print(now.unixtime()); // seconds since 1/1/1970
  //    Serial.print(", ");
  //    Serial.print('"');
  Serial.print(year(), DEC);
  Serial.print("/");
  Serial.print(month(), DEC);
  Serial.print("/");
  Serial.print(day(), DEC);
  Serial.print(" ");
  Serial.print(hour(), DEC);
  Serial.print(":");
  Serial.print(minute(), DEC);
  Serial.print(":");
  Serial.println(second(), DEC);

#endif //ECHO_TO_SERIAL
```

```
  // Now we write data to disk!
  logfile.flush();


}
////////////

void loop()
{
  volumeCheck();//check the volume knob

  touchCheck();//check if any of the capacitive pads have been touched

  dcValCheck();//check the decay knob

  buttonCheck();//check for button presses to change the scale

  oledPrint();//print to lcd

}

void oledPrint()
{

  lcd.setCursor(0, 0);
  lcd.print("Scale = ");

  if (note_index == 60)
    lcd.print("C ");
  if (note_index == 61)
    lcd.print("C# ");
  if (note_index == 62)
    lcd.print("D ");
  if (note_index == 63)
    lcd.print("D# ");
  if (note_index == 64)
    lcd.print("E ");
  if (note_index == 65)
    lcd.print("F ");
  if (note_index == 66)
    lcd.print("F# ");
  if (note_index == 67)
    lcd.print("G ");
  if (note_index == 68)
    lcd.print("G# ");
  if (note_index == 57)
    lcd.print("A ");
  if (note_index == 58)
    lcd.print("A# ");
  if (note_index == 59)
    lcd.print("B ");


  if (scale_index == 0)
    lcd.print("Major     ");
  if (scale_index == 1)
    lcd.print("Minor     ");
  if (scale_index == 2)
    lcd.print("Akebono   ");
  if (scale_index == 3)
    lcd.print("Pygmy     ");
  if (scale_index == 4)
    lcd.print("Equinox    ");
  if (scale_index == 5)
    lcd.print("Sapphire  ");
  if (scale_index == 6)
    lcd.print("Gypsy     ");
  if (scale_index == 7)
    lcd.print("SlvrSpring");
  if (scale_index == 8)
    lcd.print("Integral  ");
  if (scale_index == 9)
    lcd.print("Dorian    ");
  if (scale_index == 10)
    lcd.print("GldArcadia");
  if (scale_index == 11)
    lcd.print("PentMaj   ");
  if (scale_index == 12)
    lcd.print("PentMin   ");
  if (scale_index == 13)
    lcd.print("Blues     ");

  lcd.setCursor(0, 1);
  lcd.print("Volume = ");
  int newVol = map(vol, 0.0, 0.8, 0, 100);
  lcd.print(newVol);
  lcd.print("%  ");

  lcd.setCursor(0, 2);
  lcd.print("Decay = ");
  lcd.print((int)dcVal / 10);
  lcd.print("%  ");

  lcd.setCursor(0, 3);
  if (wave_index == 0)
    lcd.print("Sine       ");
  if (wave_index == 1)
    lcd.print("Saw        ");
  if (wave_index == 2)
```

```
    lcd.print("Square  ");
  if (wave_index == 3)
    lcd.print("Triangle");
  if (wave_index == 4)
    lcd.print("Sample   ");
    lcd.setCursor(9, 3);
    lcd.print("Oct: ");
    lcd.print(octave_index);
    lcd.print("      ");

    lcd.display();

  delay(10);
}
/////////////////////////////////////////////////////
void volumeCheck()
{
  vol = (float)analogRead(volKnob) / 1280.0;

  mixerMain.gain(0, vol);
  mixerMain.gain(1, vol);
}
/////////////////////////////////////////////////////
void dcValCheck()
{
  //check knob and set value as delay on dc constant for sine wave decay
  dcVal = map(analogRead(decayKnob), 0, 1023, 1, 1000);
}
/////////////////////////////////////////////////////
void touchCheck()
{
  //Each capacitive touch pad will vary based on the size and material it is made of
  //The value necessary to trigger each note will require some trial and error to get the
  //sensitivity just right. Try adjusting these values to get the best response.

  if (touchRead(pinTouch[0]) > 1300)
  {
    //once a pad is touched, a value from the note frquency froma table is looked up via a 2D table
    //with x corresponding to a scale and y corresponding to one of the eight notes on the drum.

    if (octave_index == 1)
      sine1.frequency(note_frequency[scale[0] + 12]);
    else if (octave_index == -1)
      sine1.frequency(note_frequency[scale[0] - 12]);
    else if (octave_index == 2)
      sine1.frequency(note_frequency[scale[0] + 24]);
    else if (octave_index == -2)
      sine1.frequency(note_frequency[scale[0] - 24]);
    else
      sine1.frequency(note_frequency[scale[0]]);
    dc1.amplitude(1.0, 5);
  }
  if (touchRead(pinTouch[0]) <= 1300)
  {
    //one the pad is released, the note fades out with a decay val set by the dcVal knob
    dc1.amplitude(0, dcVal);
  }


  if (touchRead(pinTouch[1]) > 1300)
  {
    if (octave_index == 1)
      sine2.frequency(note_frequency[scale[1] + 12]);
    else if (octave_index == -1)
      sine2.frequency(note_frequency[scale[1] - 12]);
    else if (octave_index == 2)
      sine2.frequency(note_frequency[scale[1] + 24]);
    else if (octave_index == -2)
      sine2.frequency(note_frequency[scale[1] - 24]);
    else
      sine2.frequency(note_frequency[scale[1]]);
    dc2.amplitude(1.0, 5);
  }
  if (touchRead(pinTouch[1]) <= 1300)
  {
    dc2.amplitude(0, dcVal);
  }


  if (touchRead(pinTouch[2]) > 1300)
  {
    if (octave_index == 1)
      sine3.frequency(note_frequency[scale[2] + 12]);
    else if (octave_index == -1)
      sine3.frequency(note_frequency[scale[2] - 12]);
    else if (octave_index == 2)
      sine3.frequency(note_frequency[scale[2] + 24]);
    else if (octave_index == -2)
      sine3.frequency(note_frequency[scale[2] - 24]);
    else
      sine3.frequency(note_frequency[scale[2]]);
    dc3.amplitude(1.0, 5);
  }
  if (touchRead(pinTouch[2]) <= 1300)
  {
    dc3.amplitude(0, dcVal);
  }
```

```
if (touchRead(pinTouch[3]) > 1500)
{
  if (octave_index == 1)
    sine4.frequency(note_frequency[scale[3] + 12]);
  else if (octave_index == -1)
    sine4.frequency(note_frequency[scale[3] - 12]);
  else if (octave_index == 2)
    sine4.frequency(note_frequency[scale[3] + 24]);
  else if (octave_index == -2)
    sine4.frequency(note_frequency[scale[3] - 24]);
  else
    sine4.frequency(note_frequency[scale[3]]);
  dc4.amplitude(1.0, 5);
}
if (touchRead(pinTouch[3]) <= 1500)
{
  dc4.amplitude(0, dcVal);
}

if (touchRead(pinTouch[4]) > 1300)
{
  if (octave_index == 1)
    sine5.frequency(note_frequency[scale[4] + 12]);
  else if (octave_index == -1)
    sine5.frequency(note_frequency[scale[4] - 12]);
  else if (octave_index == 2)
    sine5.frequency(note_frequency[scale[4] + 24]);
  else if (octave_index == -2)
    sine5.frequency(note_frequency[scale[4] - 24]);
  else
    sine5.frequency(note_frequency[scale[4]]);
  dc5.amplitude(1.0, 5);
}
if (touchRead(pinTouch[4]) <= 1300)
{
  dc5.amplitude(0, dcVal);
}

if (touchRead(pinTouch[5]) > 1300)
{
  if (octave_index == 1)
    sine6.frequency(note_frequency[scale[5] + 12]);
  else if (octave_index == -1)
    sine6.frequency(note_frequency[scale[5] - 12]);
  else if (octave_index == 2)
    sine6.frequency(note_frequency[scale[5] + 24]);
  else if (octave_index == -2)
    sine6.frequency(note_frequency[scale[5] - 24]);
  else
    sine6.frequency(note_frequency[scale[5]]);
  dc6.amplitude(1.0, 5);
}
if (touchRead(pinTouch[5]) <= 1300)
{
  dc6.amplitude(0, dcVal);
}



if (touchRead(pinTouch[6]) > 1300)
{
  if (octave_index == 1)
    sine7.frequency(note_frequency[scale[6] + 12]);
  else if (octave_index == -1)
    sine7.frequency(note_frequency[scale[6] - 12]);
  else if (octave_index == 2)
    sine7.frequency(note_frequency[scale[6] + 24]);
  else if (octave_index == -2)
    sine7.frequency(note_frequency[scale[6] - 24]);
  else
    sine7.frequency(note_frequency[scale[6]]);
  dc7.amplitude(1.0, 5);
}
if (touchRead(pinTouch[6]) <= 1300)
{
  dc7.amplitude(0, dcVal);
}


if (touchRead(pinTouch[7]) > 1300)
{
  if (octave_index == 1)
    sine8.frequency(note_frequency[scale[7] + 12]);
  else if (octave_index == -1)
    sine8.frequency(note_frequency[scale[7] - 12]);
  else if (octave_index == 2)
    sine8.frequency(note_frequency[scale[7] + 24]);
  else if (octave_index == -2)
    sine8.frequency(note_frequency[scale[7] - 24]);
  else
    sine8.frequency(note_frequency[scale[7]]);
  dc8.amplitude(1.0, 5);
}
if (touchRead(pinTouch[7]) <= 1300)
{
  dc8.amplitude(0, dcVal);
}
```

```
}
//////////////////////////////////////////////////
void buttonCheck()
{
  button0.update();
  button1.update();
  button2.update();
  foot0.update();
  foot1.update();

  //if button 0 is pressed, increment the scale being used
  if (button0.fallingEdge())
  {

    note_index++;
    padNumber++;
    //check for overflow
    if (note_index > 68)
    {
      note_index = 57;
    }
    if (padNumber > 7)
    {
      padNumber = 0;
    }
  //  octave_index = 0;
    changeScale();
  }

  //if button 1 is pressed, decrement the scale being used
  if (button1.fallingEdge())
  {
    scale_index++;
    padNumber--;
    //check for overflow
    if (scale_index > numOfScales)
    {
      scale_index = 0;
    }
    if (padNumber < 0)
    {
      padNumber = 7;
    }

   // octave_index = 0;
    changeScale();
  }

  //if foot pedal 0 is pressed, increment the octave
  if (foot0.risingEdge())
  {
    octave_index++;

    if (octave_index > 2)
      octave_index = 2;
  }

  //if button 1 is pressed, decrement the scale being used
  if (foot1.risingEdge())
  {
    octave_index--;

    if (octave_index < -2)
      octave_index = -2;
  }

  //-------
  //if button 1 is pressed, cycle through wave types
  if (button2.risingEdge())
  {
    wave_index++;
    //check for overflow
    if (wave_index > numOfWaves)
    {
      wave_index = 0;
    }
    switch (wave_index) {
      case 0:
       // Serial.println("WAVEFORM_SINE");
        sine1.begin(WAVEFORM_SINE);
        sine2.begin(WAVEFORM_SINE);
        sine3.begin(WAVEFORM_SINE);
        sine4.begin(WAVEFORM_SINE);
        sine5.begin(WAVEFORM_SINE);
        sine6.begin(WAVEFORM_SINE);
        sine7.begin(WAVEFORM_SINE);
        sine8.begin(WAVEFORM_SINE);
        break;
      case 1:
       // Serial.println("WAVEFORM_SAWTOOTH");
        sine1.begin(WAVEFORM_SAWTOOTH);
        sine2.begin(WAVEFORM_SAWTOOTH);
        sine3.begin(WAVEFORM_SAWTOOTH);
        sine4.begin(WAVEFORM_SAWTOOTH);
        sine5.begin(WAVEFORM_SAWTOOTH);
        sine6.begin(WAVEFORM_SAWTOOTH);
        sine7.begin(WAVEFORM_SAWTOOTH);
        sine8.begin(WAVEFORM_SAWTOOTH);
```

```
        break;
      case 2:
       // Serial.println("WAVEFORM_SQUARE");
        sine1.begin(WAVEFORM_SQUARE);
        sine2.begin(WAVEFORM_SQUARE);
        sine3.begin(WAVEFORM_SQUARE);
        sine4.begin(WAVEFORM_SQUARE);
        sine5.begin(WAVEFORM_SQUARE);
        sine6.begin(WAVEFORM_SQUARE);
        sine7.begin(WAVEFORM_SQUARE);
        sine8.begin(WAVEFORM_SQUARE);
        break;
      case 3:
      //  Serial.println("WAVEFORM_TRIANGLE");
        sine1.begin(WAVEFORM_TRIANGLE);
        sine2.begin(WAVEFORM_TRIANGLE);
        sine3.begin(WAVEFORM_TRIANGLE);
        sine4.begin(WAVEFORM_TRIANGLE);
        sine5.begin(WAVEFORM_TRIANGLE);
        sine6.begin(WAVEFORM_TRIANGLE);
        sine7.begin(WAVEFORM_TRIANGLE);
        sine8.begin(WAVEFORM_TRIANGLE);
        break;
      case 4:
      //  Serial.println("WAVEFORM_SAMPLE_HOLD");
        sine1.begin(WAVEFORM_SAMPLE_HOLD);
        sine2.begin(WAVEFORM_SAMPLE_HOLD);
        sine3.begin(WAVEFORM_SAMPLE_HOLD);
        sine4.begin(WAVEFORM_SAMPLE_HOLD);
        sine5.begin(WAVEFORM_SAMPLE_HOLD);
        sine6.begin(WAVEFORM_SAMPLE_HOLD);
        sine7.begin(WAVEFORM_SAMPLE_HOLD);
        sine8.begin(WAVEFORM_SAMPLE_HOLD);
        break;

    } //end case
    //------


  }
}

void changeScale()
{
  //Change numOfScales variable at top if adding new scale!!

  int root = note_index;

  if (scale_index == 0) //Major Scale  2,2,3,2,3,2,2  (WholeStep, WS, WS+HalfStep, WS, WS+HS, WS, WS) Asha changed to w,w,h,w,w,w,h
  {
    scale[0] = root;
    scale[1] = root + 2;
    scale[2] = root + 4;
    scale[3] = root + 5;
    scale[4] = root + 7;
    scale[5] = root + 9;
    scale[6] = root + 11;
    scale[7] = root + 12;
  }
  if (scale_index == 1) //Minor Scale  3,2,2,3,2,3,2
  {
    scale[0] = root;
    scale[1] = root + 3;
    scale[2] = root + 5;
    scale[3] = root + 7;
    scale[4] = root + 10;
    scale[5] = root + 12;
    scale[6] = root + 15;
    scale[7] = root + 17;
  }
  if (scale_index == 2) //Akebono Scale  2,1,4,1,4,2,1
  {
    scale[0] = root;
    scale[1] = root + 2;
    scale[2] = root + 3;
    scale[3] = root + 7;
    scale[4] = root + 8;
    scale[5] = root + 12;
    scale[6] = root + 14;
    scale[7] = root + 15;
  }
  if (scale_index == 3) //Pygmy Scale  2,1,4,3,2,2,1
  {
    scale[0] = root;
    scale[1] = root + 2;
    scale[2] = root + 3;
    scale[3] = root + 7;
    scale[4] = root + 10;
    scale[5] = root + 12;
    scale[6] = root + 14;
    scale[7] = root + 15;
  }
  if (scale_index == 4) //Equinox Scale  4,1,2,2,2,1,4
  {
    scale[0] = root;
    scale[1] = root + 4;
    scale[2] = root + 5;
    scale[3] = root + 7;
    scale[4] = root + 9;
```

```
    scale[5] = root + 11;
    scale[6] = root + 12;
    scale[7] = root + 16;
  }
  if (scale_index == 5) //Sapphire    3,2,4,1,2,3,2
  {
    scale[0] = root;
    scale[1] = root + 3;
    scale[2] = root + 5;
    scale[3] = root + 9;
    scale[4] = root + 10;
    scale[5] = root + 12;
    scale[6] = root + 15;
    scale[7] = root + 17;
  }
  if (scale_index == 6) //Gypsy    1,3,1,2,1,2,2
  {
    scale[0] = root;
    scale[1] = root + 1;
    scale[2] = root + 4;
    scale[3] = root + 5;
    scale[4] = root + 7;
    scale[5] = root + 8;
    scale[6] = root + 10;
    scale[7] = root + 12;
  }
  if (scale_index == 7) //Silver Spring  4,1,2,2,3,4,1
  {
    scale[0] = root;
    scale[1] = root + 4;
    scale[2] = root + 5;
    scale[3] = root + 7;
    scale[4] = root + 9;
    scale[5] = root + 12;
    scale[6] = root + 16;
    scale[7] = root + 17;
  }
  if (scale_index == 8) //Integral  2,1,4,1,2,2,2
  {
    scale[0] = root;
    scale[1] = root + 2;
    scale[2] = root + 3;
    scale[3] = root + 7;
    scale[4] = root + 8;
    scale[5] = root + 10;
    scale[6] = root + 12;
    scale[7] = root + 14;
  }
  if (scale_index == 9) //Dorian  2,1,2,2,2,3,2
  {
    scale[0] = root;
    scale[1] = root + 2;
    scale[2] = root + 3;
    scale[3] = root + 5;
    scale[4] = root + 7;
    scale[5] = root + 9;
    scale[6] = root + 12;
    scale[7] = root + 14;
  }
  if (scale_index == 10) //Golden Arcadia  4,3,4,1,2,4,1
  {
    scale[0] = root;
    scale[1] = root + 4;
    scale[2] = root + 7;
    scale[3] = root + 11;
    scale[4] = root + 12;
    scale[5] = root + 14;
    scale[6] = root + 18;
    scale[7] = root + 19;
  }
  if (scale_index == 11) // pentatonic major ws, ws, hs+ws, ws , hs+ws
  {
    scale[0] = root;
    scale[1] = root + 2;
    scale[2] = root + 4;
    scale[3] = root + 7;
    scale[4] = root + 9;
    scale[5] = root + 12;
    scale[6] = root + 14;
    scale[7] = root + 16;
  }
  if (scale_index == 12) // pentatonic minor ws+hs, w, w, ws+hs, w
  {
    scale[0] = root;
    scale[1] = root + 3;
    scale[2] = root + 5;
    scale[3] = root + 7;
    scale[4] = root + 10;
    scale[5] = root + 12;
    scale[6] = root + 15;
    scale[7] = root + 17;
  }
  if (scale_index == 13) // blues ws+hs, w, h, h, ws+hs, w
  {
    scale[0] = root;
    scale[1] = root + 3;
    scale[2] = root + 5;
    scale[3] = root + 6;
    scale[4] = root + 7;
```

```
    scale[5] = root + 10;
    scale[6] = root + 12;
    scale[7] = root + 15;
  }
}

time_t getTeensy3Time()
{
  return Teensy3Clock.get();
}

/*  code to process time sync messages from the serial port   */
#define TIME_HEADER  "T"   // Header tag for serial time sync message

unsigned long processSyncMessage() {
  unsigned long pctime = 0L;
  const unsigned long DEFAULT_TIME = 1357041600; // Jan 1 2013

  if (Serial.find(TIME_HEADER)) {
    pctime = Serial.parseInt();
    return pctime;
    if ( pctime < DEFAULT_TIME) { // check the value is a valid time (greater than Jan 1 2013)
      pctime = 0L; // return 0 to indicate that the time is not valid
    }
  }
  return pctime;
}

void printDigits(int digits) {
  // utility function for digital clock display: prints preceding colon and leading 0
  Serial.print(":");
  if (digits < 10)
    Serial.print('0');
  Serial.print(digits);
}
```

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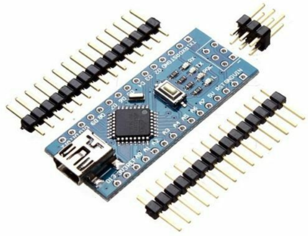
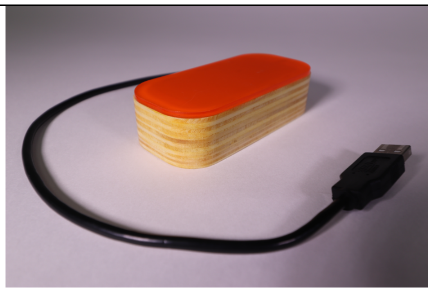
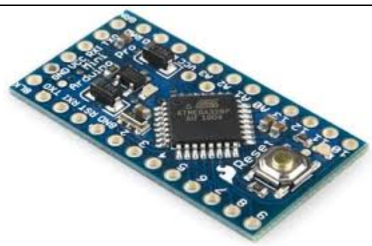
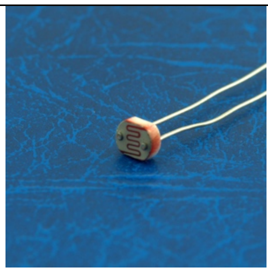
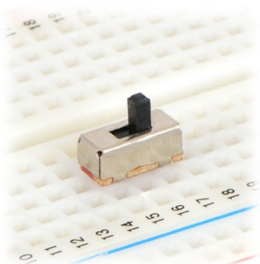
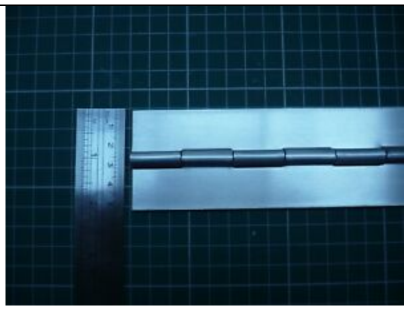
Kit Item	Components	Details	Image	Price per single unit (multiply by amount specified in details to get price per tool)
Generic components in all tools	Wire	22 AWG multicore used to connect all components to circuit		
	Stripboard	PCB Vero copper stripboard used to breakout ground and power lines		
	M4 Unheaded threaded hex drive solid steel screw	To connect enclosures together		

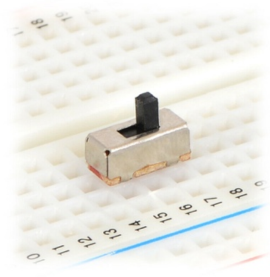
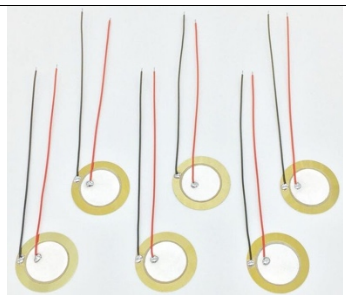
	M6 Unheaded threaded hex drive insert fixing type D wood insert nutes	To allow for mounting of tools onto arm/tripods/stands		
Receivers Internal	NRF24L01 2.4GHz Antenna RF wireless transceiver module	Connected to Arduino and communicating via SPI protocol		£1.15
	5V Arduino Nano v3.0 (ATMEGA 328P) clone	The microprocessor. Connected to Nrf24L01 via SPI protocol. Has USB connector to allow easy connection to computer		£3.09
	Mini USB B Male to USB A Male cable	0.5M cable sealed into enclosure (to protect from loss) connects Arduino to receiving computer	See image below	£0.65

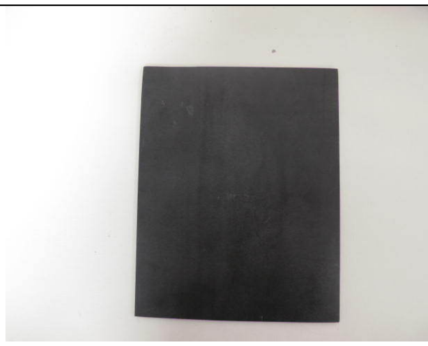
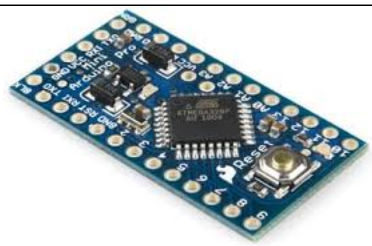
Receiver enclosure	One per kit was wooden and two were ABS project boxes as below. Wooden receiver was CNC cut poplar plywood with 3MM acrylic detail plates	Bespoke created. Layered, glued, and varnished. Laser cut acrylic panels used to top and add detailing in five different colours for the five separate kits		
	ABS project box (60x35x20mm)	one grey and one black per MAMI Tech Toolkit to enable distinguishing of the tool in the kit to the paired receiver		£1.47
filterBox internal	NRF24L01 2.4GHz Antenna RF wireless transceiver module	Connected to Arduino and communicating via SPI protocol		£1.15
	Arduino Pro Mini 3.3V 8Mhz (ATMEGA328) clone	The microprocessor for sensors. Connected to Nrf24L01 via		£2.50

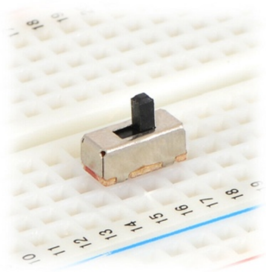
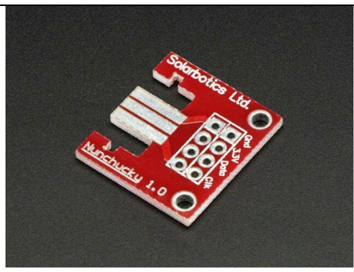
		SPI protocol. Battery positive line attached to the RAW pin on the Arduino clone allows for 9V battery to be used		
	Panel mount battery holder case box with clipping lid	Allows easy changing of batteries		£1.07
	PP3 9V Battery Connector Clip Tinned Wire Leads 150mm	To place inside battery case		£0.38
	Light dependent resistor (Photoresistor GL5516)	Placed in a hole where the acrylic flap closes onto		£0.10
	Miniature SPST momentary push button (push to make)	Two per filterBox of different colours. Internal 10K pull up		£0.32

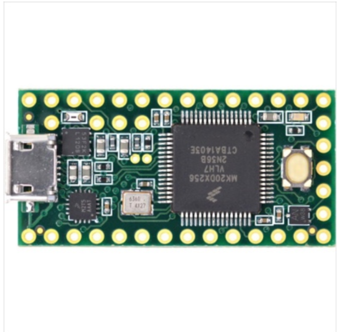
		resistor activated within Arduino code so no resistors needed		
	0.25W 10k Ohm Carbon film resistors	Two per filterBox to connect force sensitive resistor and light dependent resistor to ground on the Arduino		£0.05
	Interlink Electronics FSR408 24" Strip Force sensitive resistor	The strip can be cut to length with new wires attached to enable multiple filterBoxes to be made from one strip		£7.20
	3-Pin SPDT 0.3A Mini slide switch	To turn the filterBox on and off		£0.68
filterBox enclosure	Same construction as wooden receiver enclosure			

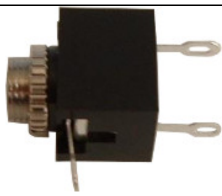
	Undrilled metal piano hinge	Cut to size and glued in place		£2.80
squishyDrum internal	NRF24L01 2.4GHz Antenna RF wireless transceiver module	Connected to Arduino and communicating via SPI protocol		£1.15
	Arduino Pro Mini 3.3V 8Mhz (ATMEGA328) clone	The microprocessor for sensors. Connected to Nrf24L01 via SPI protocol. Battery positive line attached to the RAW pin on the Arduino clone allows for 9V battery to be used		£2.50
	Panel mount battery holder case box with clipping lid	Allows easy changing of batteries		£1.07

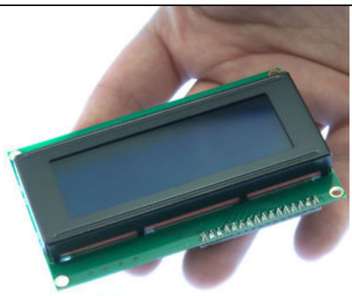
	PP3 9V Battery Connector Clip Tinned Wire Leads 150mm	To place inside battery case		£0.38
	3-Pin SPDT 0.3A Mini slide switch	To turn the filterBox on and off		£0.68
	Force sensitive resistor (FSR) pad	Three per squishyDrum arranged around top under silicon sheet		£3.00
	27mm piezo disc	Two per squishyDrum attached to inside side of enclosure		
	0.25W 10k Ohm Carbon film resistors	Three per squishyDrum to connect FSR pads to ground on the Arduino		£0.05
	0.25W 1M Ohm Carbon film resistors	Two per squishyDrum to connect piezo to		£0.05

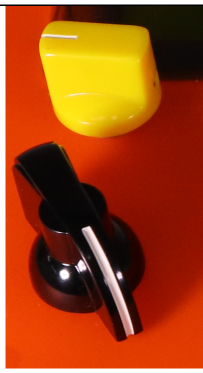
		ground on the Arduino		
squishyDrum enclosure	Same construction as wooden receiver enclosure			
	3mm black silicone rubber sheet – self-adhesive backing	Placed over force sensitive resistor pads		£2.56
The Noodler internal	NRF24L01 2.4GHz Antenna RF wireless transceiver module	Connected to Arduino and communicating via SPI protocol		£1.15
	Arduino Pro Mini 3.3V 8Mhz (ATMEGA328) clone	The microprocessor for sensors. Connected to Nrf24L01 via SPI protocol. Battery positive line attached to the RAW pin on the Arduino clone allows for		£2.50

		9V battery to be used		
	Panel mount battery holder case box with clipping lid	Allows easy changing of batteries		£1.07
	PP3 9V Battery Connector Clip Tinned Wire Leads 150mm	To place inside battery case		£0.38
	3-Pin SPDT 0.3A Mini slide switch	To turn the filterBox on and off		£0.68
	Solarbotics Ltd. Nunchucky 1.0 module	Enables connection of Wii Nunchuck with locking clip mechanism. Communicates with Arduino using I2C protocol		£3.00
The Noodler enclosure	Same construction as wooden			

	receiver enclosure			
	Nunchuck remote controller (attachment for Nintendo Wii)	Plugs into the enclosure to allow easy changing		£5.49
touchBox internal	Teensy 3.2 USB microcontroller development board			£18.00
	Audio adaptor board for Teensy 3.0 - 3.6	A hat that sits on top of the Teensy 3.2 microprocessor		£14.00
	Mono audio amp breakout - TPA2005D1	To drive an 8-Ohm speaker at up to 1.4 Watts		£5.50

	Speaker 66MM 1.5 WATT 8 OHM			£4.00
	Panel mount 3.5mm female stereo jack socket	Eight per touchBox to allow connecting of touch pads		£0.20
	Panel mount 6.35mm female stereo open jack socket	Line out for audio to allow connection to amplifier		£1.10
	Panel mount 3.5mm female stereo headphone jack socket	To enable headphones to be connected		£2.99
	Metal panel mount DPDT toggle switch	Allows changing between internal speaker and headphone out		£2.50

	20X4 Character I2C LCD Module Display			£6.80
	Arcade style push to make microswitch button	With clicking feedback. Five per touchBox. Four different styles and colours all together with two of the same style and different colours to allow differentiation	 	Average price £2.00
	10k Linear Alpha 9mm Metal Shaft potentiometer (PCB or panel mount)			£1.83

	Potentiometer knob covers	Two different styles (one chicken head pointer knob, one Davies 1510 style knob) and colours per touchBox to enable differentiation and position by touch		£0.65
	On/Off round rectangle rocker switch with waterproof cover SPST 12V	To switch touchBox on/off		£1.17
	2xAA panel mount side by side battery holder with wire connectors	3D printed cover was made to screw over these		£0.47
	5V Step-up breakout (NCP1402)	To allow the LCD screen to be run from a 3.3V source. Accepts voltage inputs between		£3.60

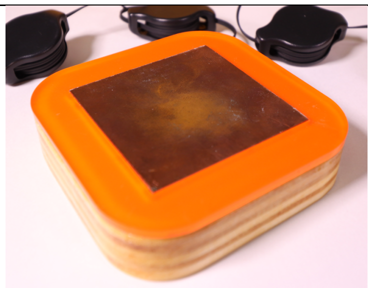
		1 and 4 Volts and outputs a constant, low ripple 5V output		
Touch Pads	3.5mm Retractable Aux Audio Cable	Eight per touchBox with one end removed and attached to copper touch pad encased in enclosure as below		£1.48
	Copper pad	Copper sheet plate cut to 50mm x 50 mm		£0.40
	Screw On Rubber Feet	Four per touchBox for stability and to allow speaker room		£1.10
Touch pad enclosure	Same construction as wooden receiver enclosure			

Table 6 - Bill of Material for Each Tool in Kit

M.

Kit item Arduino code	Description of code element	Functionality	Libraries needed	Available from	Information for use	Code origin/modifications
filterBox, squishyDrum and the Noodler receivers main code	Serial peripheral interface (SPI) communication	Allows serial communication with Arduino as master device	SPI Library	Included in Arduino IDE download	https://www.arduino.cc/en/Reference/SPI	
	nRF24L01+	Enables wireless communication using nRF24L01+ transceiver modules	RF24 library (TMRh20 2015)	http://tmrh20.github.io/RF24/	The nRF24L01+ module can be used as either transmitter or receiver. This guide was followed to make the radios work https://forum.arduino.cc/index.php?topic=421081.0. Hardware hook-up to the Arduino board is outlined at the top of the code.	Original code from Robin2 (2016) entitled SimpleRxAckPayload.ino. Modification include changing the slave address and changing how the serial data is printed in order to make compatible with MAMI software.

filterBox transmitter main code	SPI as above					
	nRF24L01+ as above					Original code from Robin2 (2016) entitled SimpleTxAckPayload.ino. Modification included adding code for vibration motor reading (not utilised in final kit), reading in sensor states (button presses, light dependent resistor and force sensitive resistor state), utilising stock Arduino example code for digitalRead and analogRead to read sensor values. Edge detection used to determine button states (Igoe 2011).

squishyDrum transmitter main code	SPI as above					
	nRF24L01+ as above					Original code from Robin2 (2016) entitled SimpleTxAckPayload.ino. Arduino example code for analogRead used to read in the sensor values.
the Noodler main code	SPI as above					
	nRF24L01+ as above					
	Wire	Allows communication with I2C devices	Wire library	Included in Arduino IDE download	https://www.arduino.cc/en/reference/wire	
The Noodler second header tab	Nunchuck_funcs.h	Allows reading of data from nunchuck	Utilises the Wire library	https://todbot.com/blog/2008/02/18/wiichuck-wii-	Webpage to left has detailed instructions on how to use. In this research the code is added to a new tab inside	Code modified from Kurt (2008).

				nunchuck-adapter-available/	the main code within the Arduino sketch.	
touchBox	SPI as above					
	Wire as above					
	Audio, SerialFlash, Bounce	Allows access to the Teensy audio library	Teensy audio library	https://github.com/PaulStoffregen/Audio	The Teensy Audio Design Tool added these libraries for use with the Teensy board and the Teensy audio adapter.	Code modified from Stoffregen (2014).
	LiquidCrystal_I2C	Allows communication from Arduino board to LCD screen	Newliquidcrystal_1.3.5 library (Fmalpartida 2016)	https://bitbucket.org/fmalpartida/new-liquidcrystal/downloads/ or https://github.com/fmalpartida/New-LiquidCrystal		Modified the code of Bartlett (2018) to use different LCD display using the NewLiquidcrystal_1.3.5 library.

touchBox second header tab	TeensyAudioDesignTool.h	Specifies the functionality and sound that the device makes	Teensyduino installed		A Teensy 3.2 board was used in the touchBox requiring the use of Teensyduino in order to program the board – available here: https://www.pjrc.com/teensy/td_download.html The Teensy Audio Design Tool was used to create the code within this header file – available here: https://www.pjrc.com/teensy/gui/	Code modified from Bartlett (2018) and Cool (2017). Modified the scale set and some of the scale values.
	Note_frequency.h	Specifies the frequencies of the tones produces				Code written by Bartlett (2018).

Table 7 - Code Breakdown of the Hardware

Kit item Max/MSP code	**Description of code element**	**Functionality**	**Packages needed**	**Available from**	**Information for use**	**Code origin/ modifications**
MAMI Tech Toolkit Main Patcher	serialBpat Bpatcher	• select amount of serial inputs from device • load, select and initialise serial ports • select baud rate		https://github.com/lwoodbury/MAMI		Industrial mentor
	buttonBpat BPatcher	Control functionality of connected button		https://github.com/lwoodbury/MAMI	Initially used in setting up final software configuration for final MAMI Tech Toolkit software.	Industrial mentor
	faderBpat BPatcher	Control functionality of connected fader		https://github.com/lwoodbury/MAMI	Initially used in setting up final software configuration for final MAMI Tech Toolkit software.	Industrial mentor

	Outputs patcher	Mechanism for showing output from incoming sensors		https://github.com/lwoodbury/MAMI		Industrial mentor
	inBut BPatcher	• view controller input • set controller • set threshold • reverse range		https://github.com/lwoodbury/MAMI		Industrial mentor
	jnFad BPatcher	• view controller input • set controller • remap range of fader		https://github.com/lwoodbury/MAMI		Industrial mentor
filterBox patcher	channel_plug1 Bpatcher	communication with VST				Industrial mentor
	makeNote sub patcher	Locks notes into selected scale				Industrial mentor
Simple Sample (final patcher	sample player sub patcher	Basic mechanism of				Industrial mentor

entitled SimpleSample6)		loading and triggering samples from a folder of sounds into a poly~ object				
squishyShaker (final patcher entitled squishyShaker1)	shakers~ object	Physical modelling that turns sensor data into shaker sounds	PeRColate	https://github.com/Cycling74 /percolate	The help patcher from the shaker~ objects was used to create the main functionality of the patcher	Trueman and DuBois (2006)
The Noodler (final patcher entitled doodlerNoodler17)	DRAW ZONES sub patcher	Allows the mouse (or finger/stylus for touchscreen) to be used to draw the trigger zones				Industrial mentor
	sample player sub patcher	Basic mechanism of				Industrial mentor

		loading a folder of sounds into a poly~				
	ScaleMaster	Snaps MIDI notes into selected scales	ScaleMaster	https://www.xfade.com/max/ScaleMaster/		Muir (2010)

Table 8 - Code Breakdown of the Software

N.

MAMI
Tech Toolkit
Manual

Hello and thanks for agreeing to trial the use of the modular accessible musical instrument (MAMI) Technology Toolkit! Below are instructions for setting up the system and an overview of the features of the software.

The software features a main application, alongside several apps to be used with each specific piece of hardware in the system.

<u>Setting up!</u>

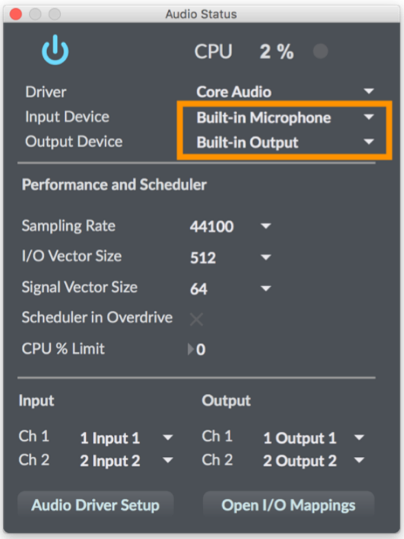
Double click the MAMITechToolkit2.0 application which once opened will look like below

There are 3 sections corresponding to the 3 instruments supplied with the kits.
There is also a button to activate the sound which by default will be on upon opening.

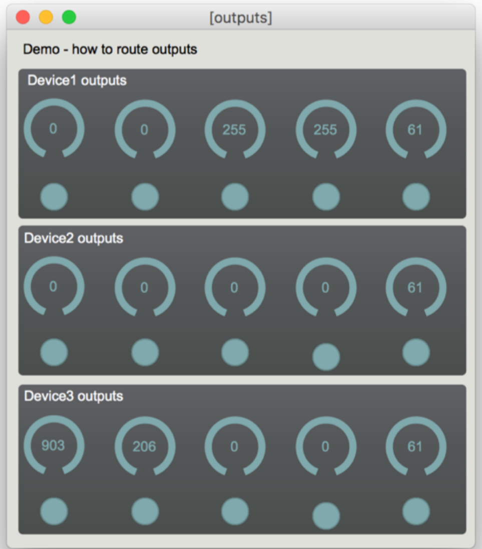
2

There is a button that open settings regarding how the audio is routed

The 'where is the sound?' button can be clicked to show the input and output device for the application. A drop-down menu can be used to select the desired output based on your computer set-up and any microphones or speakers you may have plugged in.

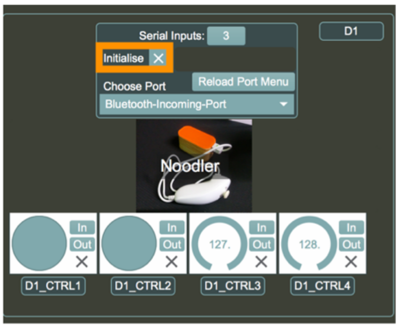


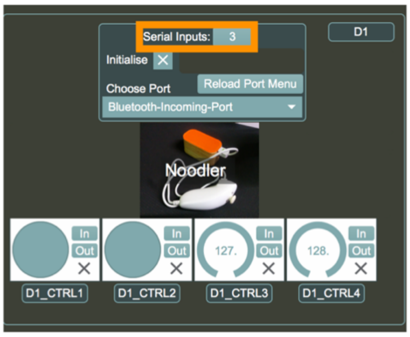
There is also a 'see devices outputs' button that can be clicked to show a pop-up of the output from the instruments that are plugged in and operating. The following 'outputs' window will be activated. When connected Device1 shows the Noodler output, Device2 shows the squishyDrum output and Device3 shows the filterBox output.



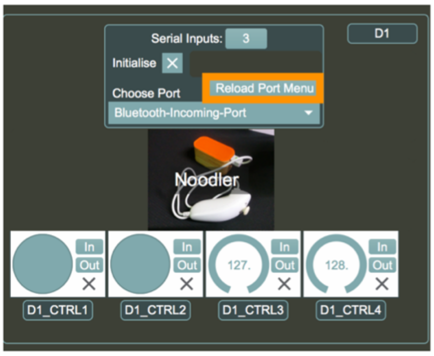
4

Section 1 marked in orange shows settings for connecting the Noodler.

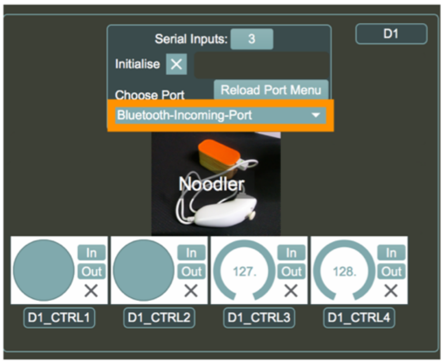




By default, the devices will be initialised upon loading the application. Serial inputs will display 3 and can be ignored.



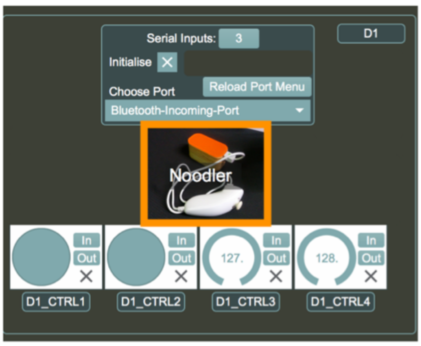
Plug the Noodler receiver into the USB socket on the computer and click the ‘reload port menu button’ to scan for connected devices. Turn on the Noodler device.



Then click the ‘choose port’ drop-down menu and select the corresponding Noodler reciever number (if you are unsure which port this is, try unplugging the reciever, pressing ‘reload port menu’ and then plugging the receiver back in and clicking ‘reload port menu’ a second time to see the a new addition to the menu).

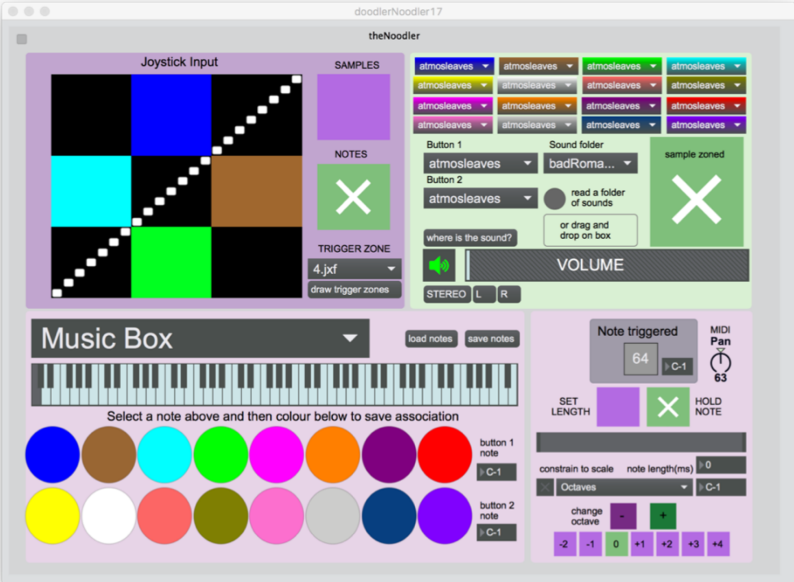
The menu item will likely look something like this ‘wchusbserial1420’, although the 1420 number may differ for each device. This should then enable the connection between the Noodler device and the receiver. Within a few seconds the displays within the Noodler zone (marked in orange below) should be showing input from the device with the red areas lighting up as the values from the Noodler are changed.

The other information within these boxes regarding the in and out are not used in this testing toolkit and can be ignored.

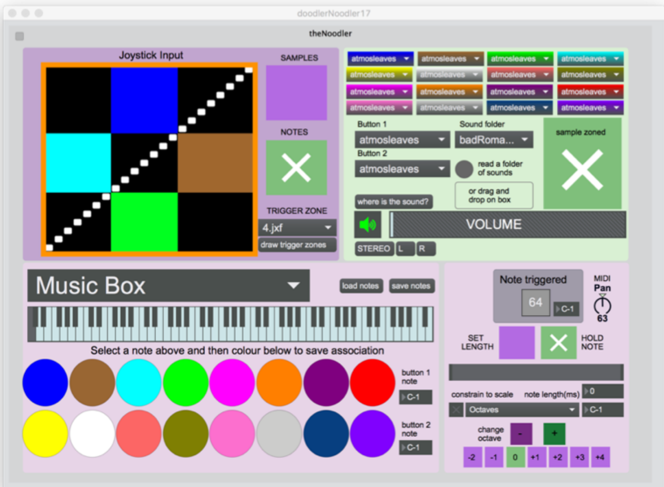


Clicking on the picture of the Noodler will load the Noodler App which will pop-up into a new window.

Noodler App

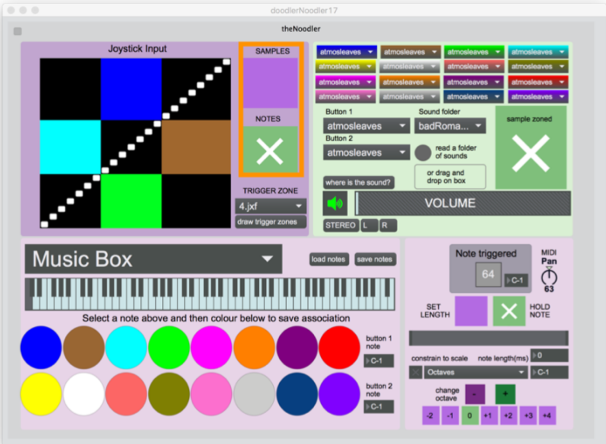


This is the main interface of the Noodler app!

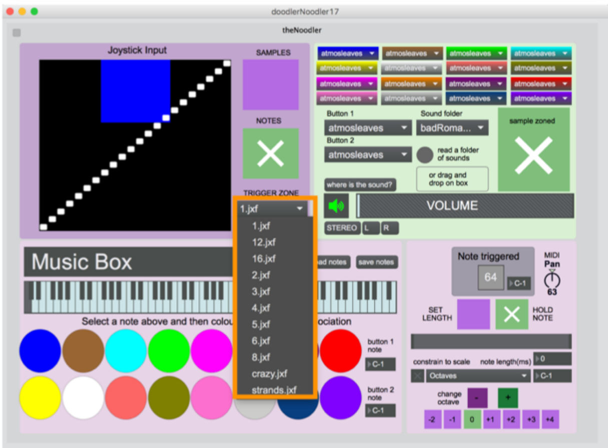


The section marked in orange shows the input from the Noodler joystick (in the form of a white dot that follows the joysticks movement (upon loading and without connection the white line above will be displayed).

7

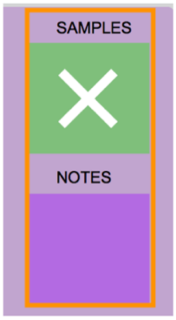


The application works by triggering notes or samples as the joystick moves through the trigger zones. The above is set to have 4 trigger zones (the blue, brown, green, and cyan areas, with the black areas denoting no trigger areas). The trigger areas correspond to the up, down, left, and right motion of the joystick.

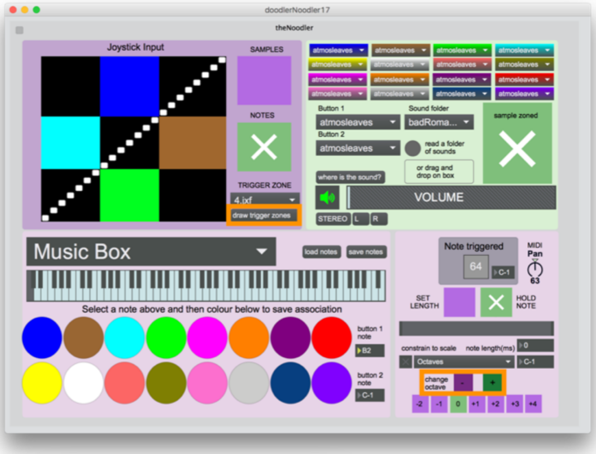


The amount of triggers in the trigger zone can be changed with the trigger zone drop-down menu.

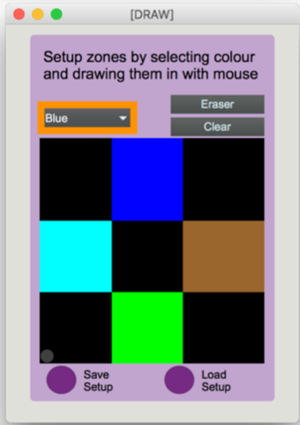
The trigger zones can be used to trigger MIDI notes or samples by clicking the the corresponding box (a cross will indicate which option is selected).



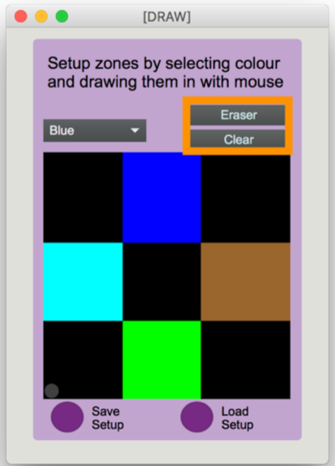
Drawing Customised Trigger Zones



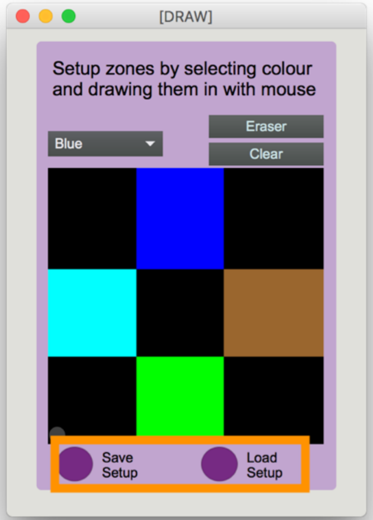
Clicking the 'draw trigger zones' button will allow you to draw customised trigger areas. A new 'draw' window will pop-up to allow this.



A colour (from 16 colours) can be selected from the drop-down menu and the mouse can be used to draw onto the trigger area in this colour.

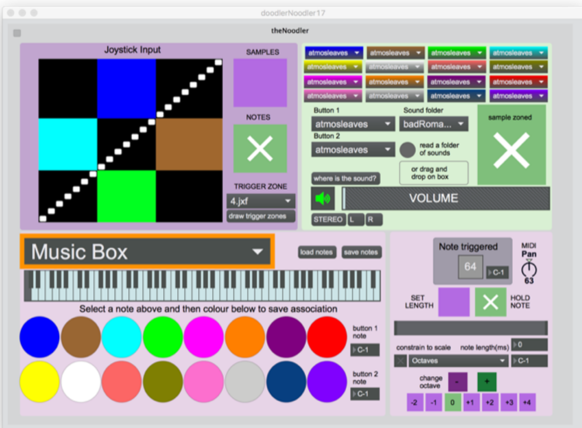


'Eraser' can be selected to erase areas of the trigger zone and 'clear' can be selected to completely clear all colours from the trigger zone.

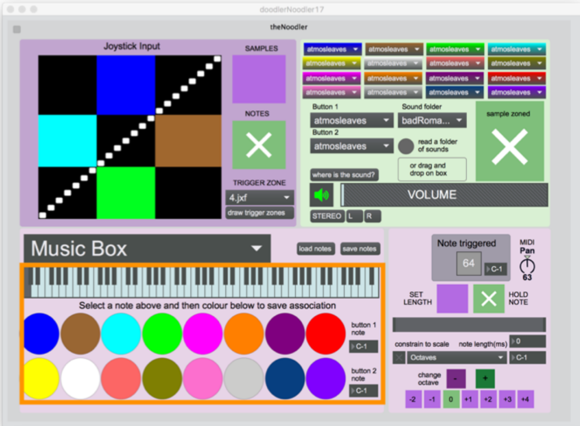


Once a trigger map has been drawn this can be saved using the 'save setup' button. This will create a pop-up box to allow you to navigate and store the file within your computer. Saved setups can then be subsequently loaded using the 'load setup' button.

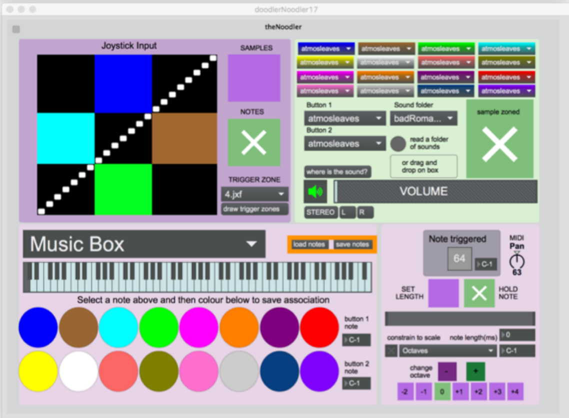
<u>MIDI features</u>



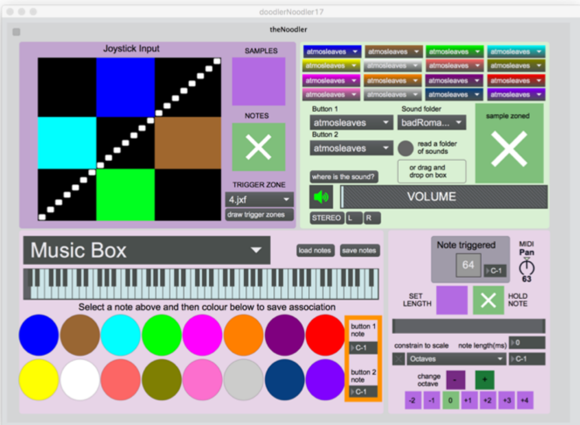
The type of MIDI instrument can be selected from the drop-down menu.



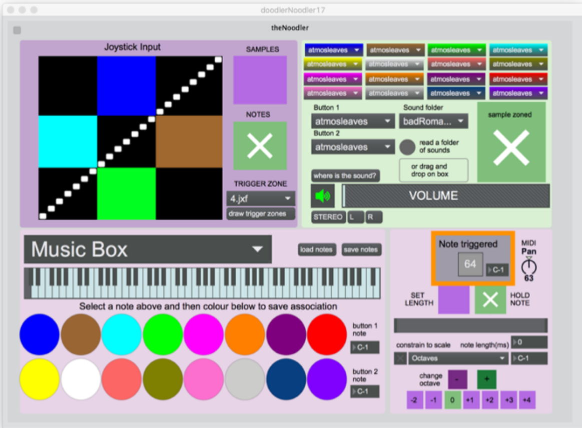
The on-screen musical keyboard can then be used to assign a note to a colour by first clicking the note and then clicking the coloured dot below to save the association automatically.



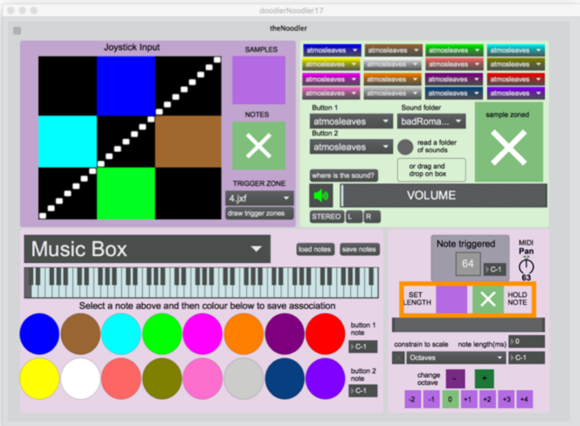
To save the assigned note associations for future the 'save notes' button lets you save a file with the note associations. These can then be recalled using the 'load notes' button. A pop-up will appear to when you click either option to allow you to save or reload the files at a location of your choosing on your computer.



To select a note for each button on the Noodler the boxes highlighted in orange to the left can be dragged or the box can be clicked (the triangle by the value will turn yellow) and a value can be typed in to assign that corresponding MIDI note.

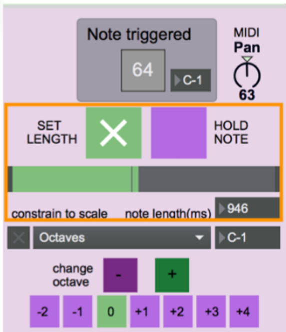


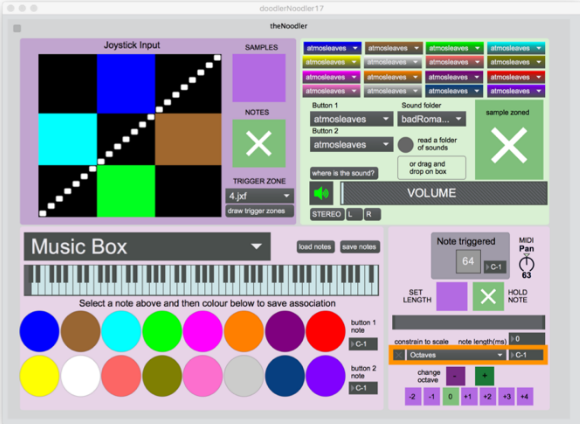
The 'note triggered' zone will display the note that is currently being played as a number and MIDI value.



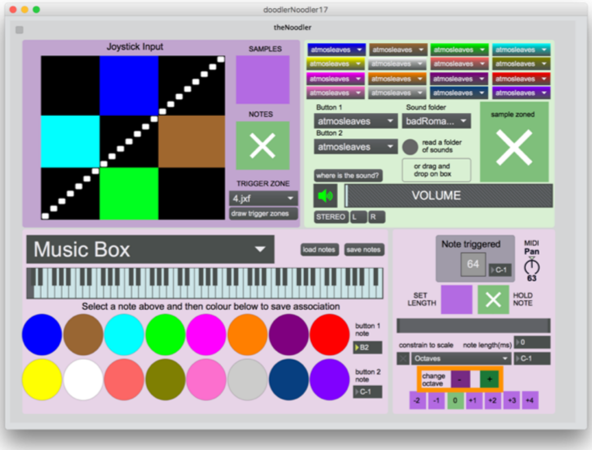
Notes can be set to trigger only while the Noodler stays in the trigger zone or to ring out for a set time by selecting either 'set length' or 'hold note'.

If 'set length' is selected the time bar below becomes active and note length can be changed by sliding the bar. This selected length will then be displayed in miliseconds (ms) in the 'note length' box (946ms in the image below).

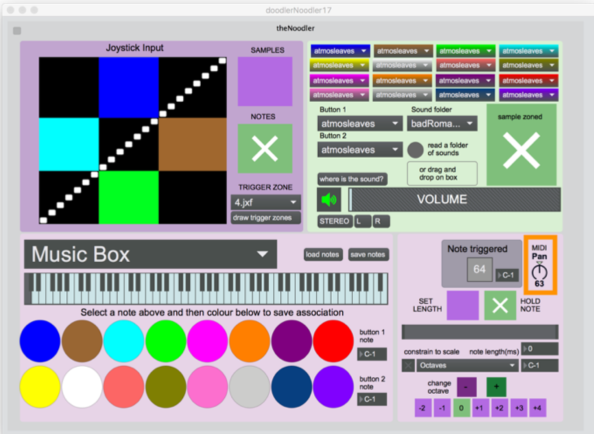




A beta feature of the app is the 'constrain to scale' function. If the small crossed toggle box is clicked to the left of the drop-down menu then the notes played should remain within the scale selected from the drop-down menu.



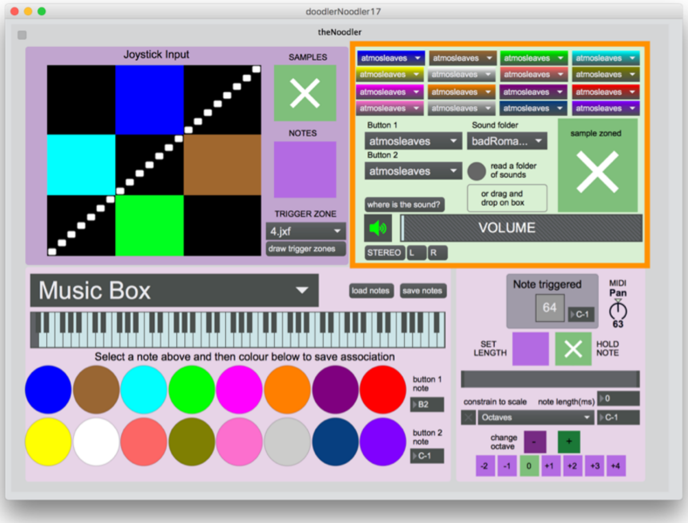
The 'change octave' buttons labelled with the '–' and '+' can be used to move up or down octave with the current selection being displayed in green in the boxes below.



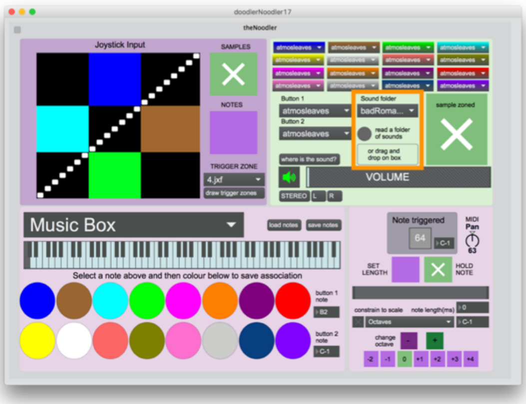
The 'MIDI Pan' dial can be used to send out the MIDI notes via the left or right speaker if a stereo system is being used. By default it will be stereo.

13

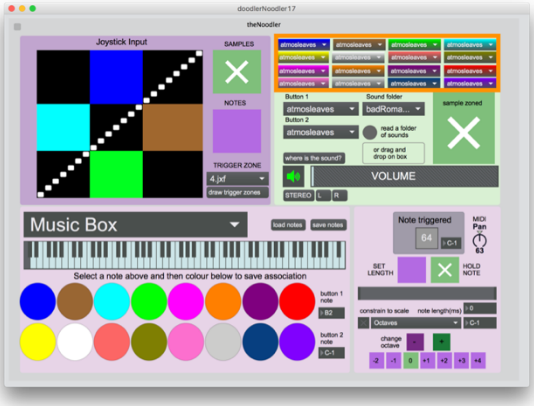
<u>Sample features</u>



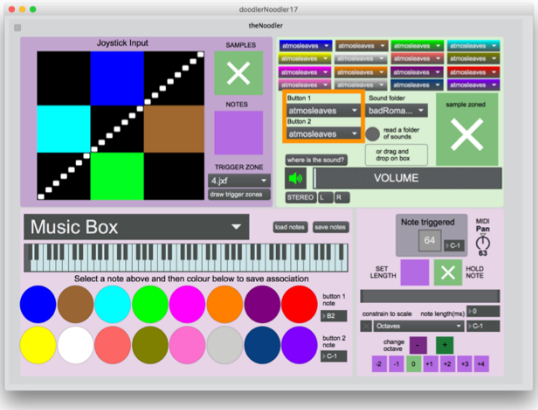
When the ‘samples’ section is selected denoted by the green cross to the right of the trigger zone the area marked in orange becomes active.



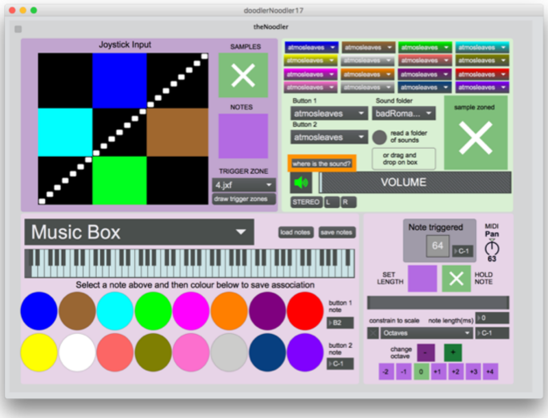
A folder of sounds can then be selected from the drop-down menu. The app comes with several pre-loaded. Using the button next to ‘read a folder of sounds’ allows for a custom folder to be selected or alternatively a folder of sounds can be dragged and dropped onto the ‘drag and drop’ box to auto load.



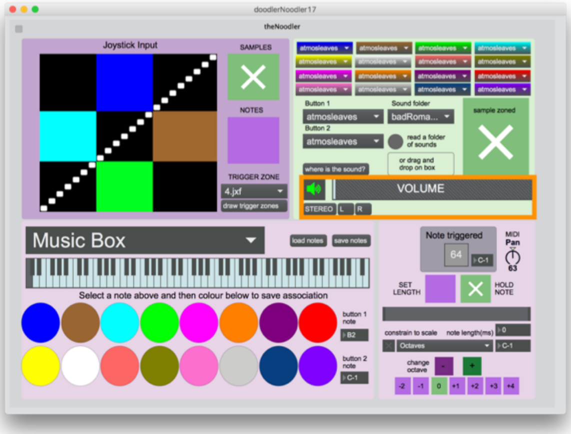
Once a folder of sound is selected the coloured drop-down menus will display the sound files in the folder selected and can be used to assign a sample to a coloured trigger zone.



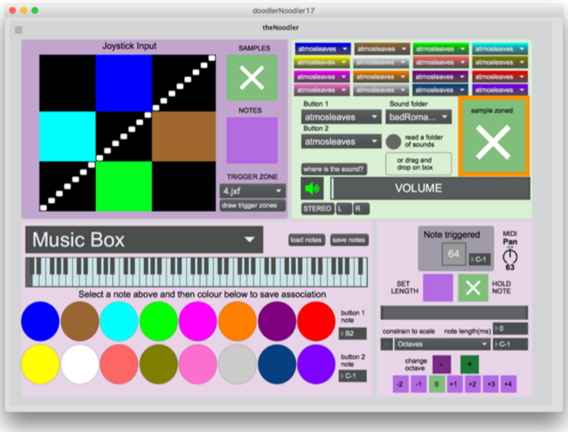
The ‘Button 1’ and ‘Button 2’ drop-down menus can be used to assign a sound file to the buttons on the Noodler.



The ‘where is the sound?’ button can be used to enable the pop-up window that shows how the audio is routed within the computer (the same as the main MAMI Teck Toolkit app).



The sound can be turned off and on with the speaker icon and the volume adjusted for the sample playback with the slider. Stereo playback or playback from the left (L) or right (R) speaker can be selected also.

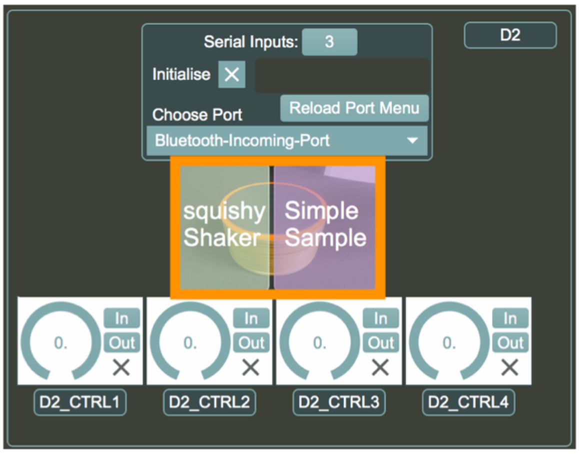


The ‘sample zoned’ area can be selected so that a sample is triggered only whilst the dot remains in the trigger zone and the sample will stop as soon as the dot leaves the trigger zone. If unselected the sample will play fully unless retriggered by re-entering the trigger zone.

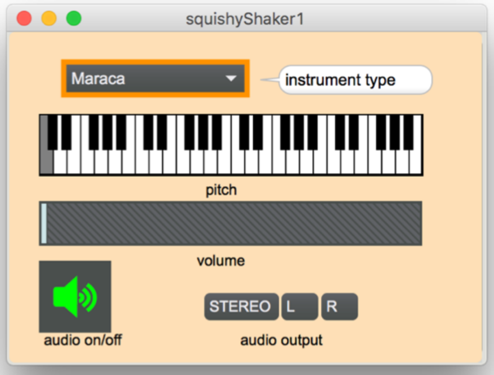
squishyDrum Apps

The middle section of the main app relates to the squishyDrum. To connect the squishyDrum the same procedure can be followed as for when connecting the Noodler. Plug in the receiver and turn on the device. Reload the port menu and select the correct port from the drop-down menu.

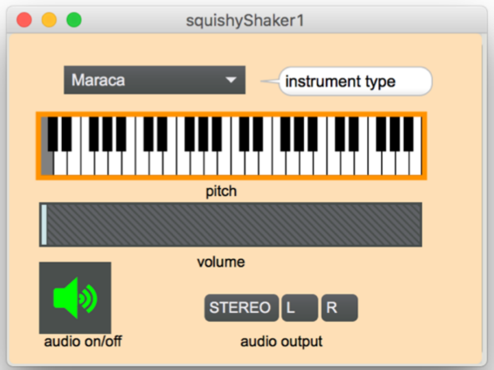
The squishyDrum has 2 available apps, squishyShaker and Simple Sample. squishyShaker creates noise based on the pressing of the 3 pressure pads on the squishyDrum surface and the Simple Sample triggers selected from a folder of sounds or allows you to record 3 sounds using your computer microphone and then playback these samples using the device trigger pads. To start either app click their name over the picture of the device. Once an devices picture has been clicked it will go green and the app will load.



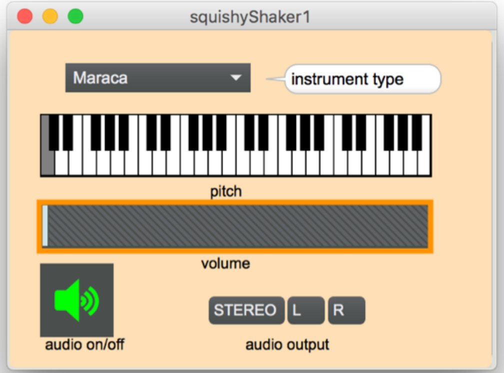
SquishyShaker



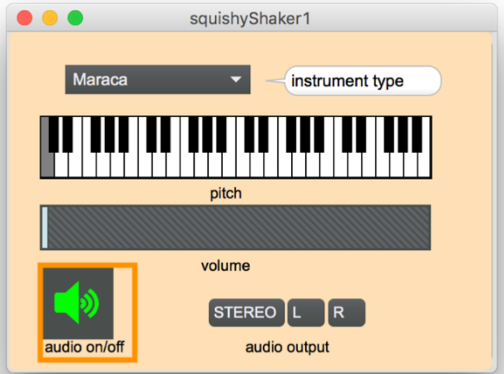
The main interface of squishyShaker features a drop-down menu can be used to select and 'instrument type'. These are based on percussive objects such as coins and stones.



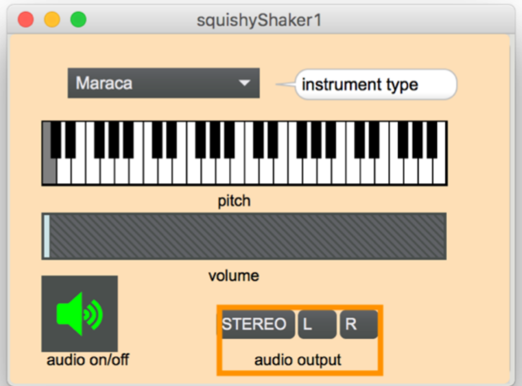
The pitch can be selected from the on screen keyboard.



The volume can be changed with the slider.

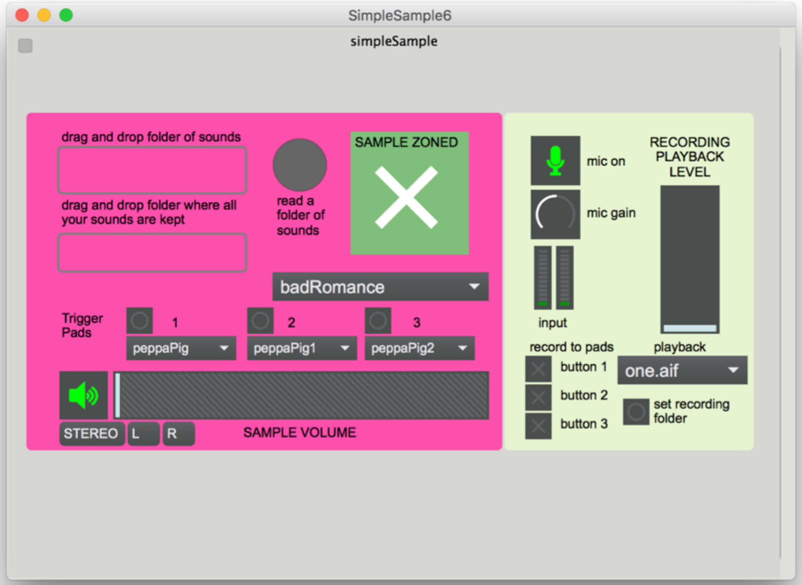


The audio can be turned on and off.

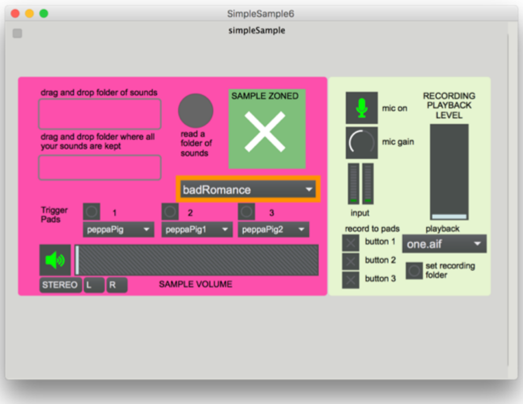


The audio output can be routed to stereo, ledft (L) or right (R).

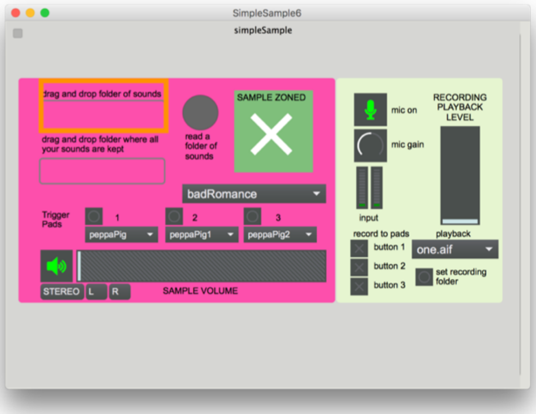
Simple Sample



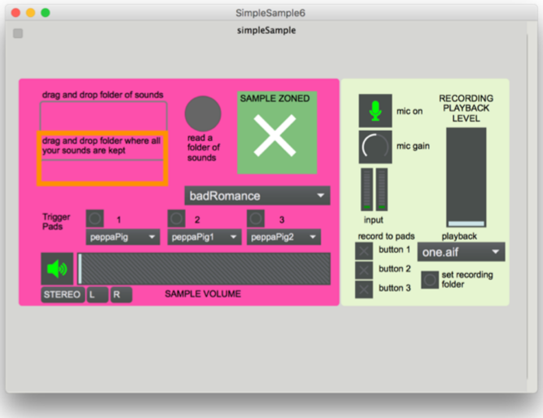
This is the main interface for the Simple Sample app.



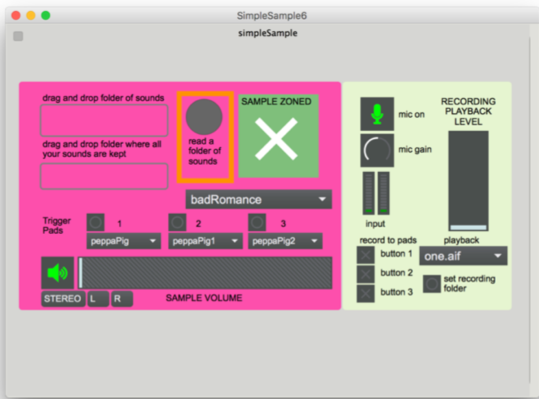
A folder with a selection of sounds is loaded by default which can be selected from the drop-down menu.



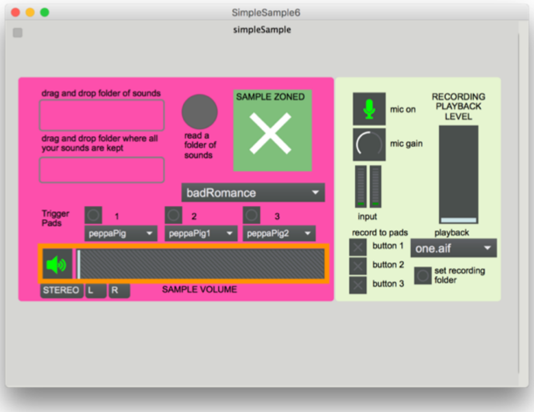
A folder of sounds can be dragged and dropped onto the box to autoload.



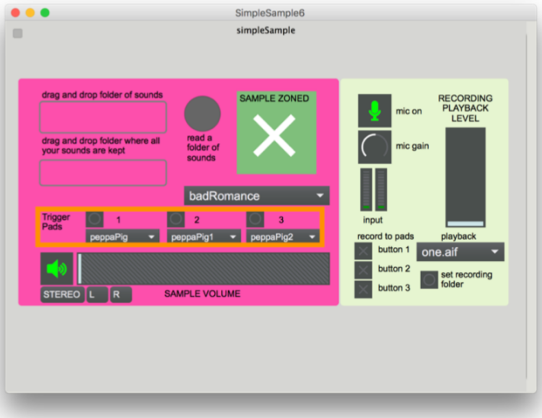
Or a folder can be dragged and dropped that contains folders of sounds to auto load.



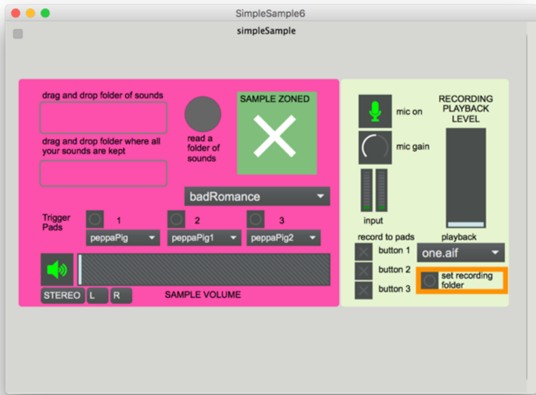
Or a folder of sounds can be navigated to on the computer using the button above 'read a folder of sounds'.



The audio can be turned off and on and the volume of the sample playback can be adjusted using the slider.

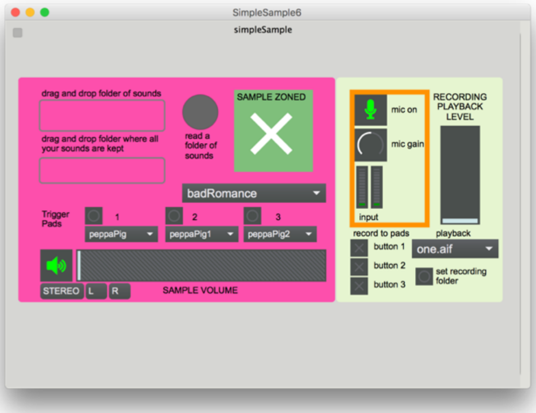


The content of the trigger pads can be tested by pressing the button next to the numbers 1, 2 or 3. The drop-down menu can be used to select the sample that the trigger pad triggers. The audio output can be set to stereo, left (L) or right (R).

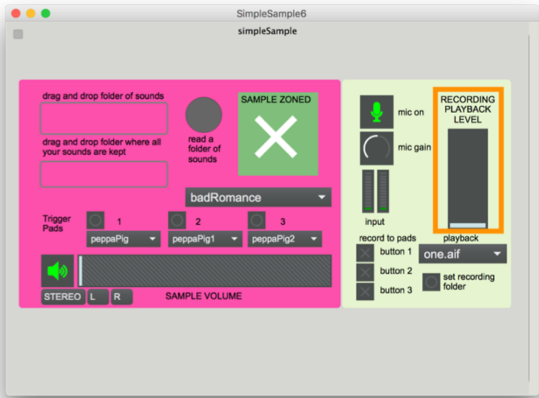


When using the recording function it is important to set the recording folder before recording!!

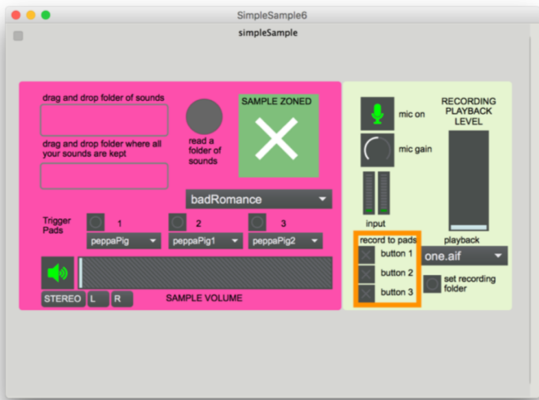
Clicking the button to the left of 'set recording folder' will allow you to create an empty folder for the 3 files that will be created as you record with each pad.



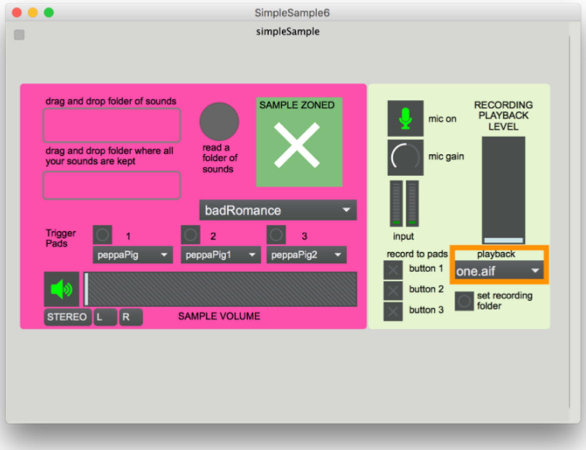
When the audio is armed the microphone selected in the audio routing window with be used for recording the sound. Moving the 'mic gain' dial up will show the input level from the mic in the meters below it.



The 'recording playback level' slider can be used to change the playback volume of the samples recorded.



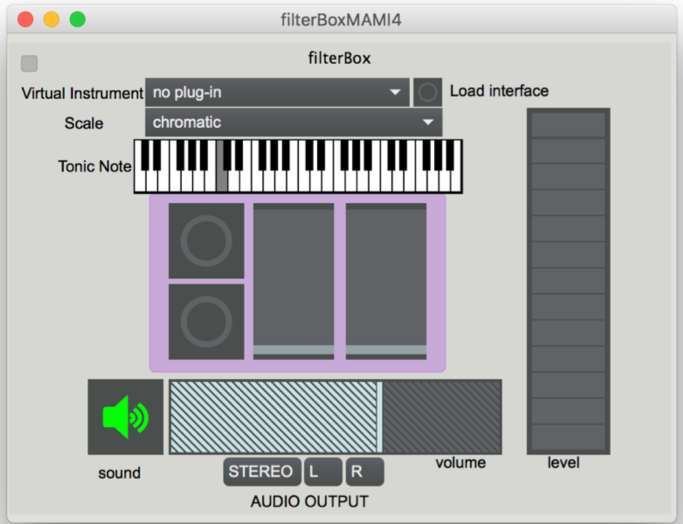
The 'record to pads' area is used to record sounds to the corresponding trigger pads. Clicking the cross box next to the button number will start the recording onto that pad. The recording will continue until the toggle is clicked again and the sound file will then be triggerable.



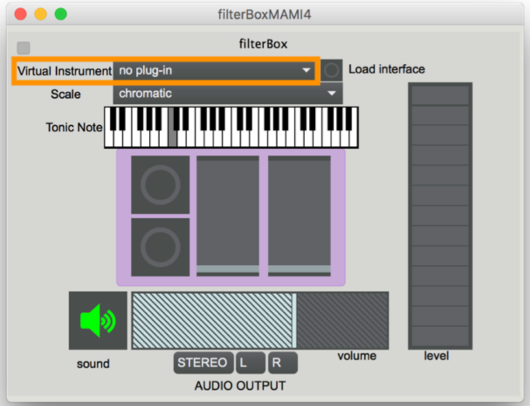
Playback from the pads can be shown in the playback area. The drop-down menu can also be used to play the sound files.

filterBox

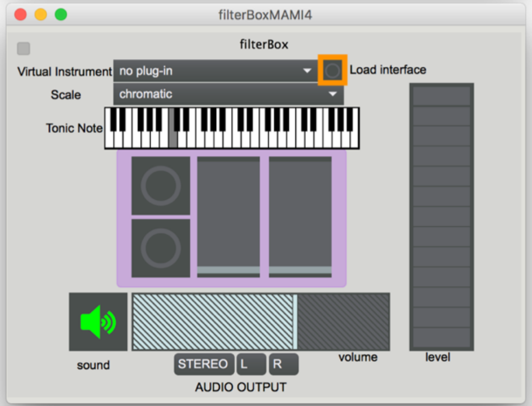
The filterBox can be connected in the same way as the other 2 devices. Plug in the receiver, turn on the device, reload the port menu and select the correct receiver from the dropdown menu. Click the devices picture to open its associated app.



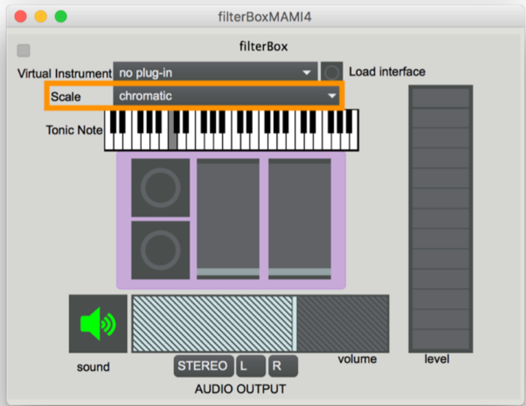
The main filterBox app interface!



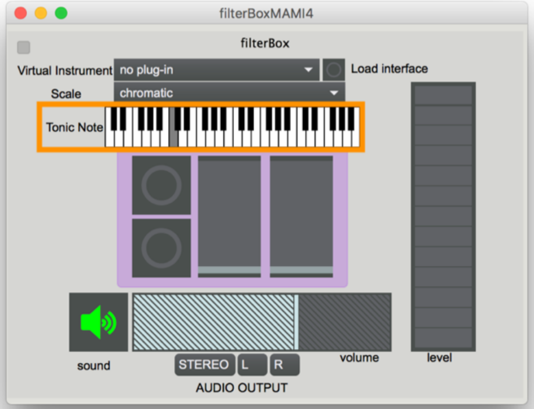
This app allows you to load virtual instruments that are included with the app.



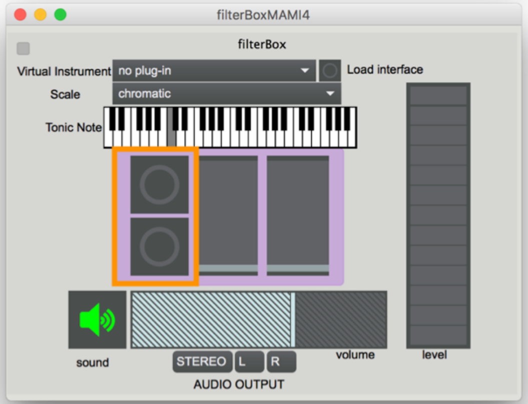
Once a virtual instrument has been selected from the drop-down menu. If you are feeling technical and want to see the interface for the chosen virtual instrument then the 'load interface' button can be used **(note that these are third party and can be very technical!!!).** However sound will be created without loading the interface!



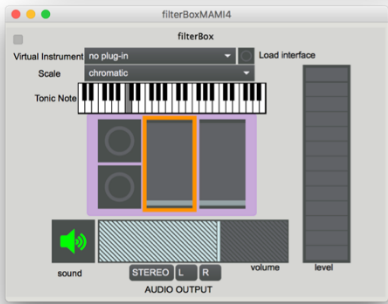
A scale can be selected from the drop-down menu and the notes triggered remain within that scale.



The tonic note for the scale can be selected from the on-screen keyboard.

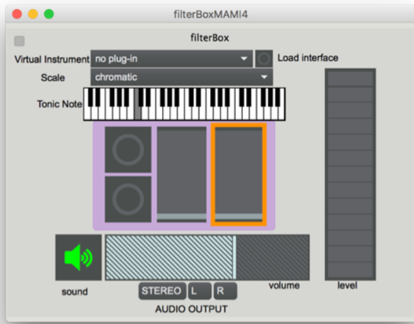


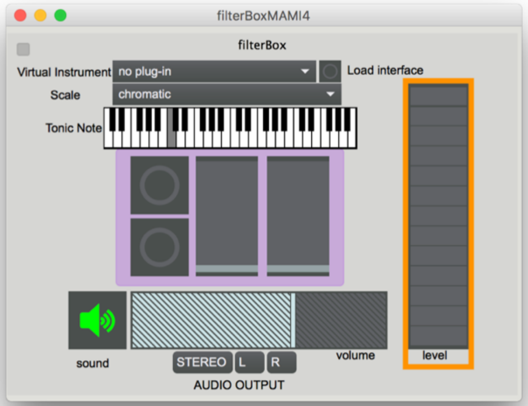
The two buttons will show the incoming button presses on the filterBox device.



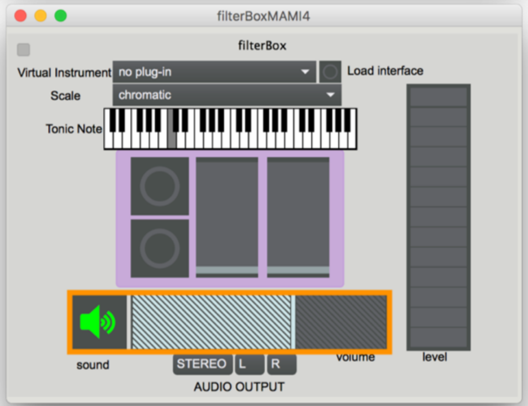
The left slider will show data from the pressure sensors.

The right slider will show the data from the light sensor.

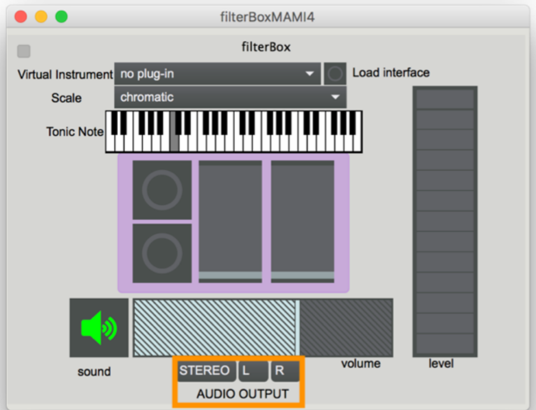




The level meter shows the level of the virtual instruments output.



The audio can be turned off and on and the volume can be adjusted with the slider.



The audio output can be routed to stereo, left (L), or right (R).

O.

Simple Microcycle Template

Plan

What (do you need to do)	
Who (needs to be involved)	
Why (what are the goals)	
When (does it need to be done by)	
Resources (equipment/space/ facilitation/time)	
Ethical/health and safety considerations	
Notes (from researcher/ stakeholders)	

Act

What (was the activity)	
Who (was there)	
How is data captured (field notes/audio recording etc)	
Where (physical location)	

When (time/date)	
Why (related to another activity?)	
Materials (what were there)	
Procedure	
Notes (from researcher/ Stakeholders)	

Reflect

Were the goals achieved	
Were there any issues	
Are there further actions to be taken	
Notes (from researcher/ Stakeholders)	