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A Constructivist Approach to Developing Interactive Digital Technology for Musical Learning

A thesis presented in partial fulfilment of the requirements of the University of Salford for the degree Doctor of Philosophy

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5. Phase 1: Initial Design

Note that most of these figures are screenshots of Pd *patches from the earliest stages development.*

6. Phase 2: Development

Note that most of these figures are screenshots of Graphick Score *in development, or of pupil compositions using the programme. Any figures with pupil names also have an accompanying video file of the piece, which can be found in the digital appendix.*

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Acknowledgements

Research depends on community, and as such, I owe a tremendous debt of gratitude to the individuals and institutions that have supported me in so many ways throughout this project. This research is funded by the Arts and Humanities Research Council and the North West Consortium Doctoral Training Partnership. I will always be proud to have embarked upon my research career with the support of these networks.

I could not have commenced or completed this project without the guidance and friendship of Professor Alan Williams, and I greatly appreciate the time and thought he has given over the past several years. Also, I thank Professor Steve Davismoon for continuing to be a source of support and advice, even after moving on to another university. I am very much obliged to all of the staff and students at the University of Salford who have had such a lasting influence on my life, and who are too numerous to name here. I hope to continue to work with all of these people for many years to come.

I will always be grateful to my network of schools, teachers and other educational professionals for training me, employing me, and letting me conduct my research in their classrooms. Teaching is the most important job in the world, and I count myself exceptionally lucky to have such a varied and valuable time in education among such inspirational people.

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In this and everything else I do, I thank all of my family and friends for their support.

Declaration

This thesis is submitted under the University of Salford regulation for the award doctor of philosophy. Unless otherwise stated in the text, I hereby declare that the contents of this thesis are the result of my own work, and that no part of it has been submitted in support of any application for other degree or qualification at this or other institutions of higher learning.

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Abstract

This study explores the potential added value of interactive digital technology to early-years music education through the development of software artefacts and their application in the primary classroom. The aims of the study are to investigate and identify new designs and approaches for classroom music-making with technology, to integrate educational theory and software development in this field, and to promote musical creativities at the individual and social level. Following a constructivist-interpretivist approach, a range of qualitative methods are applied in the pursuit of these goals. The emerging educational methodology of Software Design as Research (SoDaR) is combined with an emergent model of Grounded Theory, adapting a new methodological approach for the unique purposes of this project, as well as examining how this model could be applied to similar projects.

Findings can be summarised as follows:

i. *Rudimentary and familiar actions can be harnessed, through digital interfaces, as a means of affording creative expression in novice musicians*
ii. *Meaning-making structures are as vital as music-making structures in such activities, allowing creative ownership and communication to emerge through basic narrative elements*
iii. *Through this process of interactive and representational engagement, digitally-supported environments can allow learners to construct musical concepts for themselves, at the individual and social level.*

This research has implications for music education: Appropriate digital technologies and approaches can support the process of musical learning in social settings. Furthermore, such technologies, and the framework for their use in the classroom, can be developed through a process grounded in empirical educational research. Closer working links between educational practice and research, and the development and testing of digital resources, are recommended to ensure that a meaningful and active music education, and the valuable opportunities for personal, social and creative development and expression that this affords, is available and accessible for all learners.

1. Introduction

Figure 1.1

This chapter will frame the narrative of this project, which concerns two concurrent trajectories of development and discovery: Firstly, the development of a software artefact for musical learning and the findings which emerged from its application in the classroom and secondly, the development of my practice as a programmer, researcher and music teacher, and the findings which emerged as I triangulated these approaches into a single mode of practice. I will provide a preliminary overview of the progression of this project from proposal to completion, introduce my experiences, aims and theoretical orientations as the conductor of this research, and explain the form and structure of this thesis.

1.1 About the Project

1.1.1 Overview

The aim of this research project is to investigate an approach for achieving musical learning outcomes with digital technology. 'Musical learning' is defined, within this study, as learning which enhances musical knowledge and skill arising from diverse modes of interaction and engagement in creative environments. This is a practice-led project, one in which creative practice is 'in itself is a form of research and generates detectable research outputs' and where this practice 'can lead to specialised research insights which can then be generalised and written up as research' (Smith & Dean 2009, p.5). In this instance, the practice concerned is the development and application of bespoke digital technology for musical learning, the insights generated from which are used to answer a set of research questions:

- *To what extent have interactive digital technologies hitherto succeeded in encouraging musical behaviour in the classroom?*
- *What conditions prompt musical learning in 'sandbox' environments?*
- *How can constructivist educational theory be applied to software design as a means of facilitating creative musical learning?*
- *How might interactive digital technology be harnessed to facilitate creative expression in the musically untrained?*

As this is an exploratory project, where outcomes are directed, at least in part, by the changes in this practice as it develops and responds to emergences, many of the more specific details are arrived at during the narrative of this thesis. For example, the questions posed here, and answered in the conclusion, are not the questions I was asking at the start of the research project. At that time, I had a single question:

- *How can digital technology be used to facilitate musical learning?*

Compared to those which emerged from it, this question may be smaller, but it is certainly not simpler[1]. It demands answers to a series of qualifying questions: *With what kind of digital technology are we concerned? What constitutes musical learning? Why are these two ideas necessarily mutually relevant? How can I assume that we should we using digital technology for this purpose?* These details, along with the research questions, are addressed in

[1] This distinction is present in the work of Bamberger (1996, p.42; see 6.6) and became a prominent influence in this research project.

subsequent chapters. I will begin, in this chapter, by clarifying my decision to adhere to a specific theory of learning.

1.1.2 The Relevance of Constructivism

In simple terms, constructivism is the idea, originally theorised by Piaget, that individuals develop their understanding (of anything) from interaction between their experiences and their ideas. As such, it has significant implications for the nature of education and instructional design, and is often used as an umbrella term encompassing a wide range of related pedagogies. The various aims, assumptions, adherents and applications of constructivism will be explored in detail in chapter 2. Here, I will just explain how this particular theory came to feature so prominently in my research.

The original proposal for this project, entitled *Educational Applications of Interactive Music Technology*, drew from my experiences of music education, as both a student and a teacher, and my continual interest in using digital technology to support learning. At this time, the Office for Standards in Education (OFSTED) had recently published two reports critiquing the lack of musical opportunities in the classroom, as well as insufficient ICT-related advancements in musical learning (OFSTED 2012, p.54), and efforts to restructure music education provision which were largely failing to address a fundamental lack of music teachers and resources (OFSTED 2013). In my research proposal, I highlighted potential solutions to these issues, and set out a plan for developing new resources for musical learning and testing them in learning environments. Having spent the preceding five years working in education in various capacities, including training and working as a secondary school music teacher, I wanted to ensure a strong educational basis for my research, and so my first semester as a PhD student was mostly devoted to reading education journals. Consequently, I read much on constructivism. The dynamics of active experience and reflection to which it referred resonated with my classroom experience, the outstanding teaching and learning which I had observed, and what I understood to be indicative of best practice in education. Although it has informed numerous pedagogies, constructivism is not by itself a pedagogy but an ontology. If we subscribe to this ontology as a way of supporting teaching, by defining learning structures, planning activities and promoting reflection, then could we not also apply it as a measure of the resources we are using for teaching, to support their design, development and application? In my research, this specifically concerns digital resources for musical learning.

A disparity between the modes of practice I proposed to combine in this project became apparent. When planning a lesson, my training and experience led me to approach it as a constructivist, allowing the students to apply their own skills and ideas and arrive at outcomes in their own way, while also ensuring that this was evaluated against the learning objectives. When programming a musical interface, I did not approach the task with the same attention to reflexivity. My patches were typically based on a single and fixed initial idea, and consequently had a single mode of use and fixed outcome, with little room for variability of input and output. As an example, here is a description of a computer programme, or patch, which I completed in 2013 as part of a collaborative project at the University of Salford with Professor Alan Williams, who would become my supervisor for this research. The project was an installation entitled *Sing to Me and I'll Tell You My Story*:

> A vocal melody is played through speakers, inviting listeners to 'sing to me and I'll tell you my story'. A listener then sings the melody back into a microphone, and the patch analyses the frequency of the audio signal to check if it falls within a given frequency range that can be perceived as an 'accurate note'. A message on a screen informs the listener how many notes they got right, and if they accurately sing all of the notes, a pre-recorded audio file plays, 'telling' the listener a story.

Because the patch has an educative element – learning to accurately sing a melody in order to receive the reward of a story – it came to mind when writing my proposal of how interactive digital technology might support music education. However, though the process works well as a game or installation, it is not a process that I would apply in a music lesson, for a number of reasons: Firstly, the outcome, from the perspective of the listener, is not the ability to accurately sing the melody, but the story it triggers, so they do not necessarily see the value in any learning that may have taken place. Secondly, feedback is minimal, and is only given when the melody is sung incorrectly, as when sung correctly, triggering the story, the melody serves no further purpose for the listener. Thirdly, this involves no repetition or practice of the correctly sung melody; once they have sung it accurately, they are silently listening to the story. Fourthly, there is only one way in which the listener can approach the interface; they sing the correct melody and are told a story, a single mode of input and a fixed output. Looking at the patch as a teacher and not a programmer, I see these deficiencies.

During the first semester of this project, I realised that the approach taken and outcomes generated with this kind of patch contrasted with that of my lesson planning and that I wanted to avoid this contradiction when exploring opportunities for musical learning in digital technology. Therefore, the measure I set for myself in this project – to achieve an ontological reconciliation between my teaching and programming practice, to develop this combined practice, and to use it to produce research insights – was to approach it from a constructivist perspective. Consequently, instead of producing several applications with single modes of input and output, I focused my attention on a single versatile application with multiple modes of use. This artefact, *Graphick Score*, is provided in the digital appendix which accompanies this thesis.

1.1.3 Validation and Dissemination

My research proposal was awarded a three-year scholarship by the Northwest Consortium Doctoral Training Partnership (NWCDTP) with funding from the Arts & Humanities Research Council (AHRC) and I was accepted as a candidate for the award of PhD Music at the University of Salford. I was supervised by Professor Alan Williams and Professor Stephen Davismoon of the School of Arts and Media. I started work on this project in the autumn of 2014, completing this thesis in 2018. This research has been widely disseminated during this time, through its application in classrooms throughout the North West of England, in a variety of national and international conferences and exhibitions, in two published peer-reviewed papers and on social media. I have presented this research at each of the annual NWCDTP postgraduate research conferences and Salford Postgraduate Annual Research Conferences (SPARC) since commencing this project, winning the award for 'Best Interactive Presentation' for two consecutive years at the latter. Other major conferences at which I presented include the International Association for the Study of Popular Music (IASPM) and the Nordic Educational Research Association (NERA).

Just prior to the third year of this research project, Professor Davismoon left his position at the University of Salford to become Head of Performing Arts at Edge Hill University, but remained in my supervisory team. As the university has a noted education department, and given my previous links to the institution (my PGCE was awarded by Edge Hill University) this presented an opportunity to expand my network with regard to education research. I arranged consultations with professors of education Tim Cain at Edge Hill University and Jonathan Savage at Manchester Metropolitan University, both of whom are cited as prominent contributors to the field of music education research in my literature review, and was able to greatly expand my knowledge and practice with respect to this field during this time. This is reflected in my outputs within international conferences and journals within the field of education research in the latter half of the third year.

This research was presented at three major international conferences on education; the 45th and 46th international congresses of NERA in Copenhagen and Oslo respectively, as well as the 19th annual conference on education at the Athens Institute of Education and Research (ATINER). Some of the research conducted for this project has already been published in two open-access peer-reviewed academic journals. *Towards an Effective Freeware Resource for Music Composition in the Primary Classroom* (Hart 2017a), describing many of the central research outputs of this project, was published in the London Review of Education by the Institute of Education at University College London. In what was a new approach for the journal, the article was published with embedded hyperlinks to video examples of music made by pupils using *Graphick Score*, which were uploaded to the journal's *YouTube* account. This novel approach, raising further possibilities for linking to interactive digital media in open-access publishing, was taken by the editor to more effectively disseminate the evidence I provided; the videos and software artefact which are submitted in the digital appendix to this document. I also had *The Tablet as a Classroom Musical Instrument* (Hart 2017b), detailing additional research undertaken for this project, accepted for publication in the Athens Journal of Education, as an outcome of my attendance at ATINER.

1.1.4 Limitations

In order to arrange a consistent series of case studies and produce sufficient results of a reliable quality, this research is limited within certain boundaries. For example, research focuses on music composition at key stage 2, as these were identified as areas on which to focus during the initial stages of the project. It will be useful to extend this study to a wider age group and range of activities in a follow-up project (see 4.3.2). Limitations were also encountered as to where, when and for how long research could take place. Most of the schools who were contacted were very accommodating, and glad to offer a novel musical experience to the pupils, but an appropriate day had to be arranged sufficiently in advance, and several schools had to cancel or postpone due to various circumstances. Due to busy schedules and the pressures of examinations and other projects, most schools had specific periods in mind, such as the weeks prior to the winter or summer breaks. Also, only schools in the North West of England were contacted for this study, due to the logistics of travelling wider distances for short studies, and because most of my school contacts are within this region.

Sessions varied in length, from an entire day of studies, to afternoon sessions of around 2 hours and, in the earlier stages, short 'taster' sessions of around 20 minutes. Ultimately, the length of each study, and the number of pupils involved, was the decision of the class teacher, who was in turn subject to various limitations, though many were happy to accommodate requests. This meant that, in many cases, pupils only had a short window within which to become acquainted with the digital resources used, and the outputs of such sessions are limited in relation to those of longer sessions. It should also be noted that, due to the investigative nature of the research project, and variable availability of equipment that I was able to obtain from the school, university or other sources, the case studies often differ in terms of lesson plan and resources. These differences are highlighted in the account of each case study.

Lessons were primarily conducted by me acting as researcher and teacher, though the class teacher was involved for some of the sessions. Most teachers were naturally more receptive to the idea of a visiting music specialist taking the class than to the idea of delivering a lesson using an unfamiliar resource themselves, though later sessions did see an increased involvement (see 7.6). As such, I decided to focus mainly on the development of these resources and student interaction with them rather than their use by the teacher, though later research should certainly focus on this too. By acting as the teacher, I came to recognise certain other limitations. My own training is largely in secondary school music, though I do have previous experience working with younger children. Consequently, it must be acknowledged that the pupils are working with someone who has a different set of skills from their usual class teacher – a lack of personal knowledge of the pupils themselves, as well as less pedagogical experience, but the additional knowledge of specialist musical training – and the dynamic will not be that of a typical lesson. I must also acknowledge my own biases and orientations with regard to teaching practice, educational theory, and musical ability. All of these considerations are taken into account within this thesis.

Finally, it will be useful to extend this research to examine a greater number of factors which might influence musical creativity. Some details, such as gender, ability, and musical training, were known or became apparent, while other information was not available, either due to ethical considerations regarding sensitive data such as medical or pastoral requirements, or other logistical factors. As an initial study into a relatively new area of research, I hope that this work generates useful findings which lead to a more substantial body of research, in my future work and that of other academics working within similar fields.

1.1.5 Structure and Approach

The conclusions derived from this project have been generated by two modes of research, each supporting the other. A theoretical examination of educational research, focusing on music and technology, but drawing from other possible areas of relevance, provides the initial ideas, substantiates explorations, and gives validation to findings. This inquiry is primarily covered by the second and third chapters of this document, which review the existing literature and research in the field of educational music technology, as well as investigating some technologies with hitherto untapped potential for music education. The second mode of research is practical, involving the design, development and evaluation of software artefacts. It is through this inquiry that the initial ideas are tested, honed and expanded upon. The methodology is outlined in chapter 4, while my programming practice and field research in the classroom is presented over chapters 5, 6 and 7. The conclusions emerging from this research are summarised in the final chapter.

The digital appendix, which accompanies this thesis, contains two main folders. The first, entitled 'Graphick Score'[2] is the principal software artefact, along with a text file of instructions for installation and operation, as well as any auxiliary files required for it to function. The second folder, entitled 'Classroom Research', contains the outputs of classroom studies (see chapters 6 and 7) in a series of sub-folders. Each of these folders corresponds to the study name given in the chapter (e.g. 'Storyboard Composition at School B, June 2016', see 7.2) while the file names correspond to the (anonymised) pupil names used when presenting these findings (e.g. 'Carly', Figure 7.7). These are audio-visual files of the pupil compositions made during these studies; as such, the reader can use the appendix to view any pupil work which is referenced within this document.

This project can be characterised as qualitative, case-study led educational research undertaken within an interpretivist paradigm (see O'Donoghue 2006). The interpretivist position, common within social science research, is that individuals and society influence one another in a meaningful way, and that the researcher should seek to understand this process of mutual influence rather than any quantifiable absolute with which the positivist researcher, by contrast, is concerned. Therefore, interpretivist research focuses on the behaviour of individuals within specific contexts and environments. To a greater extent, this research works towards the definition of theory from active practice and observation, as opposed to research models which test existing theories:

> Qualitative researchers build toward theory from observations and intuitive understandings gained in the field.
>
> (Merriam 1998, p.7)

This involves a prominent component of individual practice stemming from my experience of interface design for composition, meaning that much of this research can be characterised as practice-led research within the creative arts (see Nelson 2013). A mixed methodological model for conducting and analysing this practice and its outcomes is taken from Brown's (2007a) software design as educational research model (SoDaR) supported by grounded theory (see chapter 4). Furthermore, observations are derived from the application of this practice, and its outcomes, in different case studies. These studies are often sequential sessions returning to the same school, but where the emerging outcomes of one session, analysed through a grounded theory-based approach, inform the structure and content of the next. In this respect, the approach has links to the method of action research in education, where issues are addressed dynamically within the learning environment (Mills 2000). To some extent, this situates the findings within specific case studies, and means that the process must be applied to different contexts in order to verify broader hypotheses. Bassey tells us that these 'fuzzy' generalisations are of empirical value, as they can provide insights into the effectiveness of educational practices within specific settings, as well as the understanding that comes from applying these practices across a broader range of settings (Bassey 2001).

1.1.6 Ethics

Ethical approval for this research project was obtained from the College Ethics Panel at the University of Salford during the first year of study. This application detailed the methodology for developing resources and using them to conduct research as a school visitor. At this time, I also obtained new documentation from the Disclosure and Barring Service via the School of Health and Social Care, certifying me to carry out research with children of less than 18 years of age.

Schools were invited to take part in the study by email, and an electronic copy of a leaflet detailing the aims of the project at a key stage 1 reading age was attached. When a school agreed to take part and arranged a date, forms were sent to the school again giving this information and requesting consent from the parents or guardians of the pupils to allow them to take part in the study. These were given to the pupils by the teacher, who then collected them prior to the date of the study. In early studies, surveys were used to gather information on the musical ability of the pupils taking part. No other personal information was collected, and the names of the pupils and their schools are anonymised in this thesis and the other published works emerging from this research.

1.2 About the Researcher

1.2.1 Qualifications and Experience

Merriam (1998, p.205) tells us that one of the ways in which a qualitative researcher can achieve validation is by stating their theoretical orientation and biases at the outset. To this end, I feel that it would be helpful to give some insight into my ideas and experience prior to commencing this research.

I have held some form of educational role for the entirety of my adult life. Several of my immediate family are, or were, teachers in comprehensive schools similar to those in which this research has been conducted, so the discussion of educational practice has been an ever-present influencing factor. Naturally, I have always pursued occupations related in some way to the educational environment, from work experience to later employment and study. While attending university I worked as a peripatetic guitar and keyboard tutor. Upon graduating, I was employed by an educational supply agency and worked in a variety of roles for several years, including teaching assistant, cover supervisor, and individual support for pupils with special educational needs. I also held a long-term position as learning support and intervention for the English department of Prestwich Arts College during this time, which involved the assessment of individual learning needs and tailoring of approaches to meet these requirements. After much experience and development in such roles, I eventually completed a Postgraduate Certificate in Education through Edge Hill University alongside a Schools Direct training programme with the Kingsbridge Educational Improvement Partnership. During this period, I taught key stage 3 and 4 music at Hawkley Hall High School in Wigan, with an additional placement at Manchester Communications Academy. I now teach on the BA Music Production course at the British and Irish Modern Music Institute and the MA Music course at the University of Salford, specialising in interactive and emergent technologies.

Music and interactive technology have both been major components of my academic and professional development. I hold a BA (Hons) in Popular Music and Recording and an MA in Music Composition. Becoming interested in programming languages around the time of my MA, I focused on the design and development of interactive music systems as modes of composition. As previously mentioned, I have written and delivered modules relating to this area of study for BA Music programmes. My main area of interest and expertise concerns visual programming languages such as *Pure Data* and *Max/MSP/Jitter*, though I also have experience working with *Java*, *C*, *Visual Basic* and *Python*. I occasionally made use of these skills when teaching secondary school music, as a way of incorporating interactive games and activities into my lessons. In some respects, this influenced my research proposal for this project.

1.2.2 Theoretical Orientations

As an educational practitioner, I naturally hold certain preconceptions about how learning takes place, rooted in experience, knowledge and instinct. In line with the ideas of constructivism, I feel that people learn best when given opportunities for active experience and reflection, and that, wherever possible, the learner should have opportunities to direct this process for themselves. These ideas are not revolutionary, having been at the heart of educational reform for the better part of a century. However, it is also my experience that they have emerged in different areas of education, manifesting successfully in some ways but not in others. One might expect that a creative subject like music would be one of the prominent areas for constructivist teaching practices, though research tells us that this is not the case (see 2.2). In my opinion, there are certain barriers imposed by resources and musical forms commonly used in music curriculums, which emphasise knowledge and skills that stand in the way of active experimentation. The learning of notation, for example, is undoubtedly an important musical skill, but becomes a barrier if we take it as a prerequisite of active music-making.

The above point raises another question of theoretical orientation. As a classically-trained musician, I have an understanding and experience of traditional musical forms, such as standard notation and orchestral instrumentation. However, as someone who has been actively involved in many varied musical pursuits, I do not believe that being a musician begins and ends with this kind of knowledge. The experiences which have most significantly defined my musicality have all been active and social in nature. My route to these experiences involved traditional musical training, but for others who shared these experiences, this was not the case. Therefore, I tend toward a broader interpretation of what kinds of activity can be considered music-making, and what constitutes a musician. Again, this will inevitably have some influence on the kind of issues I will perceive as problems, and the kind of solutions I will perceive as appropriate.

I also hold certain ethical assumptions surrounding educational research, that the validity of educational research is shown when it is conducted in an educational setting and learning takes place. In other words, educational research is valid when it assimilates into the everyday learning process of a child at school, and results in some form of added value. This is a responsibility not only to the relevance of the research, but also to the wellbeing of the child and the practices of the school. Therefore, as educational researchers, we do not have the freedom to try out a multitude of possibilities expecting different results, especially where the educational benefit of such possibilities is questionable. The ethical considerations of ensuring clear and accurate results through varied testing is inevitably compromised by the more pressing ethical considerations of ensuring that each child has access to quality learning experiences. This is supported in the ethical guidelines published by the British Educational Research Association (see BERA 2014).

2. Research Context 1: Constructivism & Creativity

Figure 2.1

As an interdisciplinary project, the associated research context covers a range of subjects, spanning musical creativity, educational theory and digital technology. Therefore, this part of the narrative is divided up into two chapters; chapter 2 covers broader educational and creative considerations underpinning this research to define questions, while the chapter 3 focuses on a body of existing work, theory and practice necessary to develop practical and methodological considerations.

This chapter will establish the research context for this project. I will provide an overview of the constructivist paradigm, tracing the emergence and continual relevance of the associated theories of learning. This discussion will focus on interactive digital technology and music education, particularly what constructivist perspectives tell us about musical creativity in the classroom, and how this may be supported by digital technology, with reference to key examples from the field. Finally, I will summarise this context as a set of initial research questions.

2.1 What is Constructivism?

2.1.1 Overview

The concept of constructivism, emerging from among the competing paradigms of education over the last century, has come to signify a variety of evolving perspectives on the nature of learning and instruction as an active, student-led, dynamic process, and continues to drive educational reform, as well as informing new strategies for teaching, resource-design and research. Duffy and Cunningham (1996, p.2) summarise these perspectives as 'the general view that (1) learning is an active process of constructing rather than acquiring knowledge, and (2) instruction is a process of supporting that construction rather than communicating knowledge.' If we conceive of knowledge as communicated artefact, something which can be transmitted from a teacher or a book to the recipient learner, like data from one computer disk to another, then learning is the acquisition of this information; the teacher possesses this knowledge and the student does not, so they must follow the instruction of the teacher in order to acquire it, typically involving the recitation of facts or copying of processes, otherwise known as rote-learning. Constructivist educators attempt to accommodate or facilitate the means by which learners build this knowledge for themselves. Despite varying perspectives across the constructivist paradigm, the general consensus within education is that teachers should strive for understanding, and that this is something which is achieved only by the learner, within a context and environment that enables them to do so.

2.1.2 Emergence

> Constructivism does not claim to have made earth-shattering inventions in the area of education, it merely claims to provide a solid conceptual basis for some of the things that, until now, inspired teachers had to do without theoretical foundation.
>
> (Von Glaserfeld 1995, p.15)

Constructivism is not, in itself, an approach, methodology or pedagogy. It is an ontology which recognises the experiential dynamic of learning and understanding, which may be used to direct or understand specific approaches. For example, the seminal pedagogical methodology of Herbart (Ufer 1894, pp.81-7) might be described as 'proto-constructivist', building upon the prior experience or understanding of the learner and abstracting from concrete experiences to form new meaningful and functional processes[3]. The teacher, from this perspective, is a skilled practitioner of education, not just the possessor of knowledge but the facilitator of understanding. With the emerging acceptance of psychology as a science in the late 19th century came the recognition of opportunities for a sound theoretical basis for education (Thorndike 2013). However, such was the weight of behaviourist ideas in psychology for the first half of the 20th century, the primary manifestation of influence in the classroom during this time concerned discipline, or 'learning as response acquisition' (Mayer 1992, p.406-7).

With the latter half of the 20th century, the paradigm of educational psychology shifted away from behaviourism and toward cognitivism, leading to a focus on 'learning as knowledge acquisition' and ultimately 'knowledge construction' (Mayer 1992, p.407-8). The continual influence of Dewey emphasised a view of education as an evolving system, where progress is sustained through preoccupation with the experience of the learner, and therefore reliant upon challenge and change:

> Education is a social process; education is growth; education is not preparation for life but is life itself.
>
> (Dewey 1916, p.239)

Such ideas ultimately drew the trajectory of educational philosophy toward a notion of a system which must grow and develop like the learner, and must therefore be derived from the experience of the learner, as opposed to the maintenance of externally imposed stasis implied by the behaviourist model. Dewey is critical of such prescriptive curriculums of learning where they do not reflect the life-experiences of students:

> A single course of studies for all progressive schools is out of the question; it would mean abandoning the fundamental principle of connection with life-experiences
>
> (1938, p.78)

This questions the coherence of any paradigm which seeks to impose knowledge artefacts as having universal relevance. The content of the progressive curriculum, then, would be open

[3] This taxonomy is comparable to Dewey's ideas on formative life-experiences (English 2013, pp.105-13) and Kolb's experiential learning cycle (1984).

to challenge and change, and delivered with a context of authenticity to the life experiences of learners. Within this emerging paradigm, the focus of attention is not the content itself, but the perspective of the learner.

2.1.3 Cognitive and Social Constructivism

Widely acknowledged as the most influential figure within the constructivist paradigm is Piaget, whose theory of cognitive development proposes that children intuitively employ a different mode of learning from those consciously employed by adults, in that they construct their understanding through a process of experience, assimilation and accommodation, and develop structures (or *schemata*) through their play and explorations (Piaget & Cook 1952). This highlights the importance of the learner perspective, the need to bridge the cognitive gap between the adult teacher and the child who have fundamentally different thought processes, and the recognition of play as an exploratory and developmental component of learning:

> The prevalence of play among children is therefore to be explained not by specific causes peculiar to the realm of play, but by the fact that the characteristics of all behaviours and all thought are less in equilibrium in the early stages of mental development than in the adult stage.
>
> (Piaget 1962, p.147)

It is through this dynamic process that the individual maintains a state of cognitive *equilibrium* between new experiences and environments and those understandings previously acquired:

> Equilibration is not a sequential process of assimilation, then conflict, then accommodation; it is not linear. Nor is assimilation a process of 'taking in information' as it has sometimes been described. Equilibration is instead, a non-linear, dynamic 'dance' of progressive equilibria, adaptation and organization, growth and change. It results from 'coupling' with our surround.
>
> (Fosnot and Perry 1996, p.18)

This contradicts the traditional curriculum model of information as sequentially transmitted artefact, and of the learner as passive ‘blank slate’. The nature of how the learner receives information is influenced by experience, both prior and during the immediate educational process, a factor which shapes the information as well as the learner. Within constructivist theory, knowledge is generally defined as a cognitive and social process yielding an idiosyncratic representation of a new experience or environment; it is the active process of gaining information rather than the abstract end-product (Cunningham & Duffy 1996, p.2; Perkins 1999, pp.7-8; Rieber 1992, p.94; Scott 2006, p.17; Webster 2011, p.6). In educational practice, this has led to a revision of the student-teacher classroom dynamic; the learner must be both active and reflective, and it is the role of the educator to mediate this process through maintenance of the environment and pertinent inquiry (Von Glaserfield 1995; 1996, p.7; Holt-Reynolds 2000; Honebein 1996; Richardson 1997). These ideas are further substantiated by Bruner’s theory of discovery learning (1961), which states that effective learning takes place when knowledge is arrived at independently, leading to a realisation and individual cognitive interpretation on the part of the learner.

While the earliest constructivist theories focused exclusively on the cognitive processes of the learner, a new perspective emerged with theorists such as Vygotsky, who believed that it is through interaction with society and culture that an individual forms a context of understanding for their experiences, thus emphasising the importance of social structures in learning. Vygotsky’s ‘zone of proximal development’ (1978, p.86) distinguishes between what the learner can and cannot do unaided by assistive structures, or ‘scaffolding’ (Wood *et al*., 1976), making completion of a task significantly more accessible**.** The distinction is often made between the camps of *cognitive* and *social* constructivism within academic discussion (Cobb 1996; Palincsar 1998; Powell & Kalina 2009) including criticism of the apparent mutual conflict of these ideas (Phillips 1995). It has been suggested that both interpretations constitute manifestations of the same didactic process, whereby the individual interacts with a changing environment (Scott 2011, p.192) and that the separation of these ideas is pedantic and dualist (Liu & Matthews 2005, p.389). For the purposes of this discussion, it will be useful to establish common ground between these two camps.

In both cognitive and social constructivism, the learning environment is defined as the situation or setting in which the learner constructs knowledge, through interaction with peers or some other external stimuli. To further consolidate these perspectives, Jonassen (1994, p.35) suggests that there are characteristics shared by both cognitive and social constructivist learning environments:

1. Providing multiple representations of reality, reflecting the complexity of real life-experiences.
2. Emphasising the construction over the reproduction of knowledge.
3. Emphasising meaningful and authentic tasks over abstract knowledge.
4. Emphasising open-ended real-world environments over predetermined sequences of instruction.
5. Encouraging reflection on concrete experience.
6. ‘[Enabling] context- and content- dependent knowledge construction.’
7. Supporting ‘collaborative construction of knowledge through social negotiation, not competition among learners for recognition.’

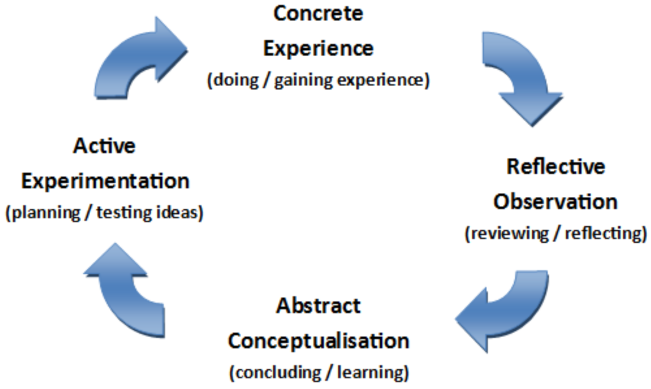


Figure 2.2 – Kolb’s experiential learning cycle

This example of a constructivist framework situated in practice reflects Kolb’s theory of experiential learning (1984), conceived as a four-stage cycle of active experience and reflection (Figure 2.2). Concrete experiences with real-world contexts (in this case, multiple realisations of such) and a process of meaningful reflection are the means by which the learner synthesises new knowledge from environment. The final point is of key importance, highlighting the mechanism by which the learner also influences their environment as well as adapting to it. It is for this reason that collaboration rather than competition is widely viewed as preferable within constructivist models of learning environment; by influencing peers rather than acting against them, the learner has the capacity to challenge and change their zone of proximal development, so equilibrium is maintained not just by the learner but by the environment itself. In modern perspectives on practice, the role of the teacher is to negotiate and manage this environment to ensure that all students access opportunities for experience, reflection and discovery (see Holt-Reynolds 2000; Powell & Kalina 2009, pp.247-8).

2.1.4 Constructivism and Digital Technology

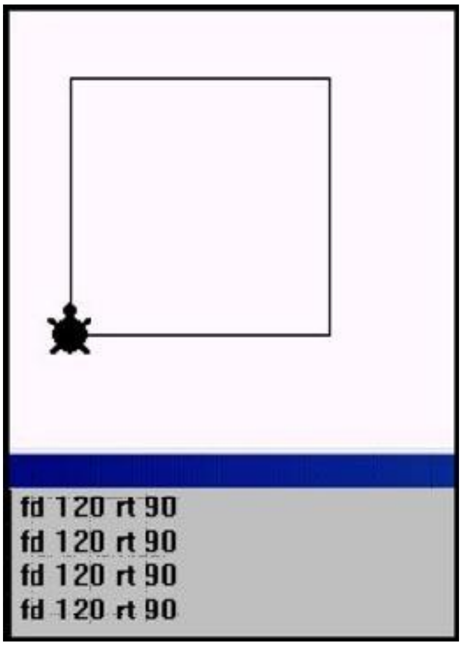


Figure 2.3 – Describing a square in *LOGO*

A seminal convergence of constructivist learning approaches and digital technology can be found in the work of Papert, exploring the potential for meaningful concrete experience adapted from abstract learning materials (see 3.1). This involves virtual immersive playground environments which the user navigates through a process of experimentation, discovery and assimilation (1980, pp.120-136; 1987). Papert's research incorporated the *LOGO* programming language (Figure 2.3), the first programming environment to follow a pedagogical design, with the graphical avatar of a user-controlled turtle aimed at situating the learner in the virtual environment, and facilitating exploratory emergent behaviours:

> My interest is in the process of invention of 'objects-to-think-with', objects in which there is an intersection of cultural presence, embedded knowledge, and the possibility for personal identification.
>
> (1980, p.11)

Papert's theory of learning, *constructionism*, emphasises the need for meaningful creative and social learning outcomes:

> Constructionism… shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe
>
> (Papert & Harel 1991, p.1)

These opportunities arise from *micro worlds* (Papert 1980), software environments which make *objects-to-think-with* – building blocks – out of challenging or abstract ideas.

Constructionism is arrived at by reconciling constructivist theory with emerging technological possibilities, a consistent theme in 21st century interpretations of learning theories, as demonstrated by the 'digitisation' of Bloom's Taxonomy (Churches 2008; 2009) and strategies for web-based learning (Churchill 2009; Duffy 2008; Greenhow *et al*. 2009). Siemens (2006; 2014) and Downes (2008; 2012) present an interpretation of constructivism 'for a digital age' in the theory and principles of *connectivism*:

- Learning and knowledge rests in diversity of opinions.
- Learning is a process of connecting specialized nodes or information sources.
- Learning may reside in non-human appliances.
- Capacity to know more is more critical than what is currently known.
- Nurturing and maintaining connections is needed to facilitate continual learning.
- Ability to see connections between fields, ideas, and concepts is a core skill.
- Currency (accurate, up-to-date knowledge) is the intent of all connectivist learning activities.
- Decision-making is itself a learning process. Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality.
- While there is a right answer now, it may be wrong tomorrow due to alterations in the information climate affecting the decision.

(Siemens 2014, p.5)

This theory recognises the learning environment as being in constant flux due to the changing nature of culture ideas and information exchanges in a digital world. The ability to see connections and make decisions is defined as learning, because the knowledge itself is subject to change. Siemens (2014, p.3) argues that this pursuit of 'fuzzy' learning situates constructivist principles in the modern world:

> Constructivism assumes that learners are not empty vessels to be filled with knowledge. Instead, learners are actively attempting to create meaning. Learners often select and pursue their own learning. Constructivist principles acknowledge that real-life learning is messy and complex. Classrooms which emulate the "fuzziness" of this learning will be more effective in preparing learners for life-long learning.

However, this interpretation is less likely to resonate with the critics who attribute evidence for constructivist approaches as factual relativism (see Boghossian 2007). Phillips (1995, p.5) argues that constructivism has 'become something akin to a secular religion' among its followers. Some educationalists have expressed the view that constructivist researchers can be so blinkered by an ontological stance as to distort empirical evidence (Phillips 1995; Fox 2001). Arguing from a constructivist position, Jonassen (2006) warns against a dichotomy of competing paradigms, where constructivists seek to replace perceived behaviourist methods on principle alone.

In taking on the concerns of critics, it is important that constructivist ideas are situated not just in emerging technological possibilities, but also in measurable outcomes of classroom practice. Drawing from an extensive meta-analysis of classroom practice, Hattie (2009; 2012) emphasises the importance of *making learning visible* so as to demonstrate clear impact. This relates not just to the measurable visibility of what has been learned, but in the capacity of educators to see this from the perspective of their students and thus help them to become motivated evaluators of their own learning. Hattie defines learning as 'the process of developing sufficient surface knowledge to then move to deep or conceptual understanding' (Hattie & Yates 2013b, p.26), where students become self-directed and self-aware knowledge constructors. In measuring impact, then, we must question the extent to which students can demonstrably appropriate new knowledge to different contexts and outcomes. This is often referred to as *deep* learning, defined by Fullan and Langworthy as instances of learning which '[develop] the learning, creating and 'doing' dispositions that young people need to thrive now and in their futures' (2014, p.i). Constructivist ideas may help us to decide how digital technology might be used to support specific learning outcomes, but it is then vital that we provide sufficient supporting evidence of the impact of this approach (for example, the ability of learners to apply their knowledge to new areas). For educational theorists principally concerned with best practice, the researcher who attributes their findings as evidence for their wider ontological stance may be guilty of factual relativism in the pursuit of a theoretical agenda; certainly, this takes the discussion outside of the classroom, and renders it unlikely to contribute to the forum between teaching practice and educational research (see Welch *et al*. 2004, p.270).

2.2 Constructivism and Music Education

2.2.1 Curriculum and Instruction

Constructivism has had a significant impact on music education. In the United Kingdom, the traditions of the conservatoire curriculum (instrumental training, music theory) were the entirety of formal music education prior to the establishment of the national curriculum for the study of music in 1992. This was heavily influenced by Paynter's (1982) arguments for composition as a mode of creative and personal expression and development. Paynter advocates a distinctly constructivist pedagogy, where 'making music is more important than musical information' (p.xiiii) and learners can 'use the skills they have acquired as they acquire them' (p.123). This led to the establishment of a constructivist music curriculum (see Garnett 2013) predicated on fostering creative decision-making and provoking emotive discussion around musical ideas. Paynter's constructivist approach is echoed in more recent ideas with respect to instructional design in music (see, for example, Bower 2008; Brown 2012; Scott 2006; Rinaldo & Denig 2009; Webster 2011). It should come as no surprise that a subject so heavily concerned with both individual creative expression (composition) and meaningful social experience ('jamming') should inspire an affinity with constructivist ideals. Indeed, both cognitive and social constructivism seem highly relevant to musical practices, as separate ideologies and as a convergence, as evidenced in group composition, for example (see Barrett 2006). In an educational paradigm where activity is the precursor to understanding, we should expect to see an inherent experiential feedback cycle of music-making and reflection. However, the 2012 nation-wide report on music education by OFSTED contradicts this:

> Too much use was made of verbal communication and non-musical activities. Put simply, in too many cases there was not enough music in music lessons.
>
> (p.4)

This issue prompts a possible research question: *What does constructivism tell us about the nature of learning that we can use to support specific musical learning?*

Bloom's Taxonomy tells educators to start with basic units of information, build an understanding, and ultimately apply in creative contexts (Krathwohl 2002). If we are working towards a creative learning goal with fixed logical steps, building a website for example, this is an undeniably useful framework, but if we are teaching an inherently creative subject, we most likely want to pursue a range of formative creative behaviours. As such, the delivery of prescriptive and sequential musical curriculums can be something of a stumbling block to meaningful musical learning. Webster (2002, p.4) highlights the importance of enabling students to become self-directing in their music education, and to be able to make creative decisions:

> One obvious gage of how successful we are as teachers is the extent to which our students can make aesthetic decisions about music as listeners, composers, and performer/improvisers and to develop a sense of musical independence. Such independent thinking does not happen if each decision is dictated. Teachers must teach for independent thought.[4]

He proposes that the goal of music education is to teach students to 'think in sound', and that 'this is possible only if students are encouraged to 'create' music through all the available behaviours' (pp.4-5). Studies into effective classroom composing show that educators manage a creative environment by facilitating freedom of choice and making a range of options as accessible as possible, but crucially directing students to consider the reasons for their compositional choices (Berkley 2004; Bolden 2009; Burnard & Younker 2002; DeLorenzo 1989, p.197; Reese 2003).

Improvisation with new ideas plays an important role in facilitating creativity. Burnard (2000) demonstrates how children quickly ascribe meaning to improvised choices and forge further creative decision-making. Borgo (2007) also advocates improvisation in early-years music education, and is critical of the assumption that students must first master lower-level features of music (chords, intervals and durations – the lower-order thinking skills of Bloom's Taxonomy) before attempting higher-level music gestures (melodic, harmonic and rhythmic expression – creative higher-order thinking skills):

> According to this logic, only after the pyramid of processing has been completed, should students expect to achieve the less talked about (and rather more nebulous) goal of improvising, to have conscious or unconscious experiences of a truly musical kind.

[4] For comparable views on independent (or student-directed) learning, see Barrett 2006; Bolden 2009; Brown, J. 2008.

(p.76)

The implication here is that, if a student only finds the determination, inspiration and confidence that are afforded by meaningful music-making experiences after learning the curriculum content, then a passive, abstract and potentially discouraging experience can be expected until the student is has the opportunity to apply this knowledge. Active experimentation with new ideas and approaches may be the most effective precursor to further creativity and understanding:

> Pupils achieved the highest standards when they were given musical and technological information as they needed it.
>
> (Pitts & Kwami 2002, p.69)

This resonates with the findings of OFSTED (2012, p.46):

> Survey evidence showed, very clearly, that pupils made the most musical progress when they were taught in music, rather than about music.

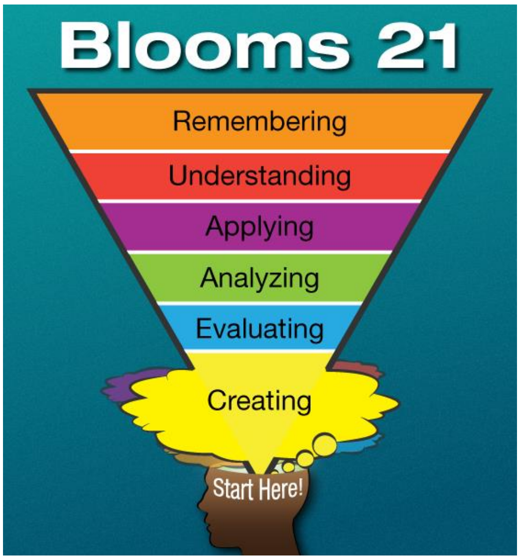


Figure 2.4 – Bloom's 21

If learners construct knowledge for themselves, as constructivist theory claims, then musical information would arise from reflections on active music-making experiences. This is succinctly illustrated by turning Bloom's Taxonomy upside-down ('Bloom's 21', Figure 2.4) and starting with the goal activity. Wright (2012) suggests that learning activities should start with a creative task and ultimately synthesise new knowledge from these experiences, which can then be re-applied, very much reflecting Kolb's experiential learning cycle (1984).

While creative and practical activities can be more easily directed by teachers with specialist musical training, this does not, by itself, lead to high-quality learning. OFSTED found that the best music lessons were conducted by trained full-time teachers with a musical specialism (2012, p.20), but that specialist music teachers also accounted for a large proportion of inadequate lessons where a lack of classroom management or teaching skills were observed (p. 19). Generalist teachers, accounting for two-thirds of music lessons, demonstrated questioning and management skills but made less use of musical activities, and therefore showed a greater degree of consistency in terms of quality of teaching (pp.18–9). We can conclude from these findings that practical music activities only lead to outstanding lessons when coupled with the teaching skills necessary to guide students beyond the 'create' stage of the 'Bloom's 21' model. OFSTED make this a central argument of their follow-up to the 2012 report, declaring that 'performance and enjoyment are not enough' if music is to be upheld as a 'rigorous, academic subject for all' (2013, p.9). It is therefore vital to have a qualified teacher overseeing music lessons.

Generalist teachers, or teachers with limited musical experience, have shown a greater capability to deliver a quality music education than, say, music specialists with limited teaching experience (2012, pp. 18–9), although studies continually address issues about confidence in teaching the subject (Biasutti 2010; Biasutti *et al*. 2015; Garvis 2013; Hallam *et al*. 2009; Hennessy 2000; Mills 1989; Russell-Bowie 2009; Seddon & Biasutti 2008; de Vries 2013). In recent years, government reforms have attempted to address this 'musical skills gap' with initiatives such as the First Access scheme, in which schools employ visiting music specialists from local music hubs to deliver music lessons[5]. A lack of pedagogical training and knowledge of curriculum aims appears to have posed barriers to such lessons (OFSTED 2013, pp.16-8). Modern teacher training is intensively directed at helping students to construct knowledge for themselves, so teachers possess the necessary pedagogical skills, but do not necessarily have the resources at hand to deliver abstract musical ideas as active and experiential learning environments. This would account for the overreliance on explanatory classroom activity described by OFSTED (2012, p.4).

The introduction to the 2013 national curriculum for the study of music in the United Kingdom cites the vital formative influence of creative musical opportunities, describing music as 'a universal language that embodies one of the highest forms of creativity' with the potential to impart 'self-confidence, creativity and sense of achievement' (Department for Education 2013, p.1). The 2011 National Plan for Music Education follows similar rhetoric with a quotation attributed to Aristotle: 'Music has a power of forming the character and should therefore be introduced into the education of the young' (DfE and DCMS 2011, p.2).

[5] OFSTED (2013, p.17) report that, among the schools who were aware of this policy, staff were often relieved to defer wholesale the provision of what is arguably the most cumbersome subject to external specialists. It is another indication of uncertainty around musical teaching that it was so commonly assumed that this would lead to a higher standard of musical learning.

In the original 1992 curriculum, music is presented as a practical subject with composition as a central activity (Swanwick 1992, pp.162–3). At 77 pages, this is a detailed document, providing creative frameworks, sample schemes of work and lesson structures, and specific guidance on SEN and ICT, among other important considerations. The 2013 version consists of 4 pages, two of which are identical, to cover the aims, attainment targets and breadth of study for key stages 1 to 4.

The substantial reduction of the curriculum comes at a cost to the specific guidance on creative pedagogy present in previous versions. We are told that students should 'improvise and compose music for a range of purposes using the inter-related dimensions of music' (DfE 2013, p.2). This refers to what were described in previous versions as the *combined elements of music:* pitch, dynamics, duration, timbre, texture, structure and tempo. The 1999 curriculum encouraged reflection on how these elements are combined to produce musical decisions or impressions, placing emphasis on subjective language of 'mood', 'feelings' and 'intention' (DfEE 1999, pp.16–9). It is clear that, in this curriculum, the recognised value of music education is in its capacity to promote forms of interpersonal and intrapersonal development (p.8). These values suggest a drive to encourage musical reflection as a means of promoting social issues; inclusion, independent thinking, and readiness to challenge immoral or irresponsible ideas. It is perhaps a reaction to OFTSED criticism of excessive verbal communication (see 2.2.1), augmented by the reflexive 'political football match' as responsibility for education passes from one party to another, that the 2013 curriculum dispenses with this line of thinking altogether in favour of an approach that might be described as 'keeping it to-the-point'. The concise targets of the 2013 curriculum suggest a narrowing of focus to the more traditionally academic aspects of music education: developing an understanding of the history of music and great composers through listening and appraising, and being able to 'use and understand staff and other musical notations' (DfE 2013, p.2). Staff notation, in particular, has hitherto not been seen earlier than key stage 3. Previous curriculums have always placed greater emphasis on alternative notations, while the staff system has in the past proved too daunting a prospect for many teachers (see Mills 1994, p.194), and is arguably not an aim to introduce without substantial reasoning and support.

Among the greatest reductions, especially when compared with the 1992 curriculum, is in specific guidance on the use of technology. Though OFSTED reported 'insufficient improvements in the quality of learning through the use of technology' (2012, p.54), the only technological guidance in the 2013 curriculum is that it should be used 'appropriately' (DfE 2013, p.1). The 1992 curriculum, by contrast, contains a section on 'using IT in music and developing IT capability' (DES 1992, p.67), referencing what were (at the time) emerging technological practices, and also containing various detailed references to the use of assistive technology in the music education of pupils with special educational needs (see, for example, pp.1, 57, 70). These points were arguably more pertinent in 2013, as educators pointed out the 'digital nativism' (Prensky 2009) and 'new pedagogies' (Fullan & Langworthy 2014) presented by digital technology in the classroom, and with research suggesting a prevalent culture of digital music activity thriving outside of school life yet largely unexplored in music classrooms (Daubney & Mackrill 2012).

Consider the following example of a music lesson activity, taken from the 1992 curriculum, which follows a framework of guidelines for improvisation, composition and arrangement (p.47):

> Year 9 pupils are set the task of creating a piece called Hiroshima in which the musical depiction of a nuclear explosion is set between a threatening prelude and a reflective epilogue: a given structure. Pupils worked in groups for half an hour and then reassembled to perform their compositions, which were video-recorded. In one group, seven pupils play timpanum, side-drum, tom-tom, cymbal, wind chimes, trombone and electronic keyboard. The piece opened with very quiet chord clusters on the keyboard alongside barely audible wind chimes. Percussion instruments gradually imposed an ominously repetitive rhythm. The trombone added insistent long notes on a single pitch. A fierce climax was reached. There was a long silence. The epilogue echoed the prelude with the rhythm fading away into nothing. The class analysed the outcome with the teacher prior to listening to Penderecki's *Threnody*.

The central components of musical activity, composing, performing, listening and appraising (Swanwick 1979) are all present, though crucially, the example begins with the practical exercises and concludes by inviting reflection. As such, it follows Kolb's (1984) experiential learning cycle. Notice that the activities are a prelude to listening to Penderecki's *Threnody* – a more traditional lesson structure might have the pupils listen to the piece and then create something similar, resulting in a preoccupation with the lower order *recall* and *apply* skills of Bloom's taxonomy. Instead, we have an example of flipped Bloom's taxonomy (Wright 2012), starting with a creative task and relating this to the source content at the end. This is much more likely to result in original, idiosyncratic and unexpected outcomes, and therefore a more varied and meaningful discussion – it is a lesson structure akin to the software development model of *bottom-up design* and *complex systems* (see 4.1.1), demonstrating the interconnected ideas and suggestions present in the 1992 curriculum. Also, the *inter-related dimensions of music* are employed in a truly inter-related and expressive manner in this example, and it notably demands very little in the way of formal knowledge regarding harmony, key signature, staff notation, music history, and other more traditionally-academic aspects of musical education while presenting, in the conclusion, opportunities to engage with these aims. The 2013 curriculum is, by contrast, akin to the *top-down design* model (see 4.1.1). It presents its outcomes in the abstract, focusing on *what* students should learn but neglecting the question *how* they could learn it. Garnett (2013, p.169) argues that this constitutes a return to learning as response acquisition:

> [Year 9 students] were learning how to perform a task correctly – essentially a piece of behavioural learning – rather than experiencing an encounter with music that prompted them to engage and expand their own concepts of how musical material can be organised. The constructivist curriculum was thus taught in a behaviourist manner fuelled by conceptually driven learning objectives.

2.2.2 Musical Creativity in the Classroom

Jonassen (2006, p.44) is critical of educationalists who 'claim that constructivist solutions should replace behaviourist methods', though he also argues that effective solutions may be founded on constructivist principles (p.43). Constructivism is not a way of teaching, but a view of learning, and therefore offers no solutions by itself, but may bring to light instances of learning which may benefit from new approaches. We may apply this lens to musical creativity, and see an aspect of musical learning that has hitherto proved troublesome (Shively 2015, p.129). Specialist, as well as generalist, teachers of music report uncertainty on how to teach composition (Winters 2012). The curriculum gives us a framework of musical devices, and we may direct students to apply these devices, but how do we argue that they have done so creatively? Set against this question, in successive curriculums, is the benchmark of the 'great [Western] composers', and the principle of developing a discerning appreciation for their works, 'to listen with discrimination to the best in the musical canon' (DfE 2013, p.1). Burnard (2012) refers to 'myths of creativity' which disseminate an unrealistic notion of composition:

> [Musical] creativity is rarely, if ever, a matter of the lone composer, or self, composing in isolation. Rather, it is a matter of composers working and playing with and with respect to others, intentionally or unintentionally... Creativity is not the product of single individuals, but of social systems making judgements about individuals' products.
>
> (p.24)

Myths such as the one identified here contribute to an idea of creativity that is wholly unquantifiable; we might call it *inspiration*. This is not traditionally viewed as something which can be taught, but which must emerge from the gifted individual. However, the same can be said of *understanding* within the constructivist paradigm (see the start of this chapter, for example) and yet this is not seen as a scarcely-attainable abstract but rather the very objective of every lesson. When we view musical creativity through the lens of constructivism, we may see through the veil of myth and observe something which is very much attainable; even, part of an experiential process.

Burnard's explanation of compositional process here resembles a social equilibration; collaboration not just in the direct sense, but also in terms of indirect influence – reaction, response, cultural ideas – all of the ways in which our social environment is engaged in a dynamic interplay with our creative efforts. Borgo (2007, p.71) argues that, if we are shaped by our social environment and 'perceived place' within it, then 'all musical encounters… are inherently social, since other listeners are always either present or imagined.' While we know that musical creativity can be fostered by a vast range of personal, social and cultural circumstances, research is needed to contribute toward a framework for understanding how this occurs. Previous research provides us with some insight into this field.

A study by Gall and Breeze (2008, p.35) found that students with less musical training were discouraged from contributing to the task when grouped with more experienced musicians, as they felt 'less ownership of the final product' due to the more experienced students '[taking] control of the compositional process.' In such scenarios, the more experienced students are seen to be skipping the 'exploratory phase' of the activity, to the detriment of its educational value for their less musically-confident peers[6]. The research suggests that bridging this gap between students who are inclined and disinclined to

[6] Research by Odam (2000, p.118) also suggests that more musically-confident pupils tend to find shortcuts through the compositional process, and should be challenged with alternative approaches.

experimentation is an important consideration in the design of any resource aimed at supporting creative-decision making. Also, this may be of particular relevance to the transition between primary and secondary education (key stage 2 to 3) where differences in provision of key stage 2 music education lead to potential disparity in skills and understanding at the start of key stage 3.

A study on the student interaction with compositional computer programmes by Scripp, Meyaard and Richardson (1988) found that students with no formal music tuition were more exploratory in their use of the programme than those who had received musical training. Mellor (2008, p.453) suggests that 'those participants with musical training produced responses which 'fitted' their self-perception of the 'musical' expectations inherent in the task' thereby diminishing their need to experiment. These findings are further substantiated in several other studies (Folkstad *et al*. 1998; Hewitt 2002; 2009; Seddon & O'Neill 2001; 2003; 2006). A study by Hewitt (2009, pp.19-20) concludes that students with musical training tend to spend less time in the 'exploratory phase' of a music-making activity, and proposes further determining factors: The older children in the study were also less prone to exploration and experimentation (the age range of the group was between 7 and 12 years), as were those who were more familiar with the activity. This suggests that the factors which encourage exploratory musical learning should be further examined.

Researchers have observed a need for case studies which examine the individual experiences of students engaged in the music-making process, to understand how intuition and personal perspective affects creative decision-making (Hallam in Welch *et al*. 2004, p.250; Higgins 1992, p.491; O'Neill in Welch *et al*. 2004, pp.257-8). Hewitt (2009, p.21) recommends that there is a need for research which focuses on both the macro- and micro-levels of analysis; that is, the music-making experience of the individual and the wider social process. What is clear from this discussion is that the social environment, be it present or virtual, should be a key consideration in any research into pedagogical creativity and music technology. The value of what teachers and other educational practitioners can bring to this discussion should not be underestimated; Welch (*et al*. 2004, p.270) identifies the need for a 'symbiotic research environment' formed by closer links between researchers and practitioners and is critical of the 'ongoing 'conservative' influence of music conservatoire curricula… largely untouched by pedagogic innovation' (p.269; see also Cain 2004, p.220; Savage 2007, p.72).

2.2.3 Supporting Musical Creativity with Digital Technology

One of the functions of this chapter is to generate research questions. I have stated that this project does not aim to supplant behaviourist methods with constructivist ones, but rather to view musical learning from a constructivist perspective to evaluate where a new approach may produce successes. Similarly, digital technology should not be assumed to be inherently preferable, and it is not to be taken for granted that any aspect of learning should be digitised, but many aspects of the curriculum have been supported by digital technology with empirical success (in the work of Papert, for example). This prompts further questions:

- *To what extent have interactive digital technologies hitherto succeeded in encouraging musical behaviour in the classroom?*

And if we are concerned, like Paynter, with supporting creativity in the first stages for formal music education, we may ask:

- *How might interactive digital technology be harnessed to facilitate creative expression in the musically untrained?*

Burnard (2012, pp.252-3) suggests that implementations of digital technology for musical creativity has new implications for collaboration, assessment and the role of the teacher in digitally-augmented creative environments. Digital technology, then, has implications for music education beyond merely 'modernising' existing structures. The importance of a curriculum inclusive of relevant technology and informed by empirical research is further highlighted by Cain (2004, p.291):

> Curriculum change is necessary if the world of the classroom is to keep pace with the world outside. And it is also necessary to have a clearly defined theory which allows teachers to commit themselves intellectually to the change.

Similarly, Savage (2007, p.75) warns of the ongoing need to implement relevant technologies into effective teaching practices:

> If educators fail to grasp this major cultural shift, music as a curriculum subject will become increasingly alienated from young people's lives and they will find their music education elsewhere.

There is a clear need for further research examining student interaction with new technologies, the possibilities of integrating social networking in the interest of meaningful engagement and wider social participation, and of course, close dialogue with students and teachers.

Figure 2.5 – *jam2jam*

There have been many software solutions aimed at assisting both specialist and generalist music teachers in delivering a more creative and experiential curriculum. The most prominent example of this in the United Kingdom is Charanga (see 3.2.2), which offers a suite of sequential virtual lessons based on the music curriculum. Many promote collaborative learning in digital environments. In an age where technology and virtual networks are increasingly significant, there is a demand for music education to extend beyond 'the constraints of classroom and curriculum', as 'schools and colleges cannot be musical islands' (Swanwick in Welch *et al*. 2004, p. 242). The same metaphor is used by Dillon (2009, p.297):

> Musicological research tools provide a bridge between these islands [of virtual and present music-making environments] and have the potential for directing the development of educational software that enables learning within both contexts.

Much has been written on the educational benefits of collaborative music-making with respect to digital technology (Barrett 2006; Blaine & Fels 2003; Dillon 2003; Hewitt 2008; Savage & Challis 2001; Sawyer 2008; Wiggins 1994). Emerging technology provides opportunities to extend the benefits of collaboration beyond present and virtual 'islands' through networked jamming and composing, as seen with *jam2jam* (Brown 2007a; Brown 2007b; Dillon 2004; Dillon 2009; Figure 2.5) and *Networked Drumsteps* (James & Stanton 2011; McCarthy *et al*. 2005; Figure 2.6). These systems provide accessibility to both music-making experiences, through the undemanding human-computer interface, and to wider social experiences,

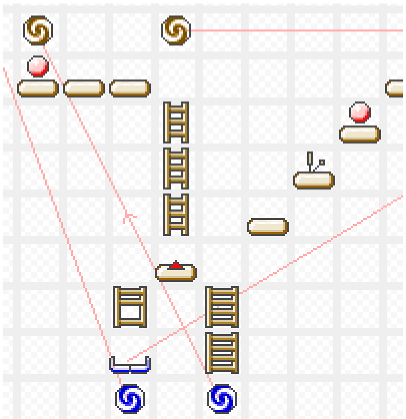


Figure 2.6 –*Drumsteps*

through virtual networks of interaction and collaboration. Brown (2007b, p.296) suggests that such opportunities are key to the development of personal *schemata:*

> The ways in which [computer music systems] are used for musical activities teaches students about how musical activities are conducted, for example whether or not music is a private or social activity, individual or collaborative, interpretive or inventive, unimportant or important, and so on. The integration of computer music systems into the music program is, as with all other activities and resources, not simply about the provision of a tool or about the transference of ideas; it is about situating the student in a musical culture.

The sharing of compositions, over social networks for example, also appears to have highly positive pedagogical implications regarding confidence and creativity (Kardos 2012, p.150; Maag 2006; Partti & Karlsen 2010, p.375; Salavuo 2008).

Educationalists have also written about the potential of digital technology to support new modes of musical interaction in the classroom. Savage and Challis (2002, p.2) express concerns over the limitations imposed by the omnipresent MIDI-keyboard workstation:

> MIDI is a highly flexible and powerful system for controlling all aspects of electronic sound. However, within schools MIDI seems to have become synonymous with keyboards linked to sequencing software. Recent research by the Fischer Family Trust suggests that for 75% of high school pupils this is their primary means of performing and composing with ICT. In this example pupils are relying on a 400-year-old interface (the keyboard) for accessing the sounds contained within a computer!

Their research project *Dunwich Revisited* (Savage & Challis 2001; 2002) afforded a range of compositional approaches, including modern electroacoustic methods, as well as diverse stylistic genres, as part of a concept-based classroom composing activity:

> The ways of working that pupils adopted when composing with the various technologies represented a significant change from what might be called ‘notation-based’ compositional tasks. This encouraged a greater sense of freedom both in composition and performance… Even those performers playing the more conventional parts in the final performance ‘improvised’ within the structures they

> had decided to adopt… The uses of different technologies empowered the majority of pupils. They provided tools to engage in this sense of play through speculating, affirming, selecting, rejecting and evaluating musical ideas both individually and corporately.
>
> (2001, p.147)

The feedback suggests that the range of familiar and unfamiliar approaches prompted a highly democratic and exploratory social learning process[7], with even the more experienced musical performers being compelled to experiment. The inclusion of sound design and manipulation technologies are identified as highly influential in the development of a creative vocabulary among the students (Savage & Challis 2001, pp.142-3; Savage 2005, pp.171-2)[8]. As an educational project, *Dunwich Revisited* is an effective response to Qualifications and Curriculum Authority (QCA) recommendations made around the same time:

> Teachers need to choose a context of relevance to young people's lives, select an interesting challenge and ensure that pupils have the necessary artistic skills. Providing choice, ensuring autonomy, encouraging teamwork, allowing experimentation and encouraging perseverance are key components of fostering creativity within the arts.
>
> (QCA, 2000, p.9)[9]

However, OFSTED's 2012 report on the quality of UK music education found 'insufficient improvements in the quality of musical learning through the use of technology' since their previous assessment (p.54), and found no evidence of exploring electroacoustic music-making techniques in the 194 institutions inspected, 'even at key stage 4 and A-level' (p.55)[10]. The findings of OFSTED suggest that the implementation of the most recent technologies, which may in themselves present opportunities for emerging musicalities relevant to the lives of young people, have gone largely unexplored (see also Daubney &

[7] For another study on collaborative music-making projects maximising student potential by allocating a variety of roles, see Tobias 2012.
[8] For further ideas on the importance of sound design within the evolution of musical language see Théberge 1997, p.188.
[9] A project similarly involving electroacoustic methods, cultural relevance and collaboration, also with promising implications regarding engagement and teamwork, though less pedagogically-focused, can be found in Freeman *et al*. 2011.
[10] It has been suggested that there is a general deficiency in compositional software incorporating electroacoustic methods (Eaglestone *et al*. 2001).

Mackrill 2013). More detailed empirical evidence is required on how children of different age, gender and experience respond to a range of music-making technologies (Webster 2012).

The availability of a range of music technologies not only encourages experimentation and versatility, as suggested by the research of Savage and Challis (2001; 2002) but creates an environment of accessibility for students who may otherwise struggle to develop a musical identity:

> Technology provides pupils with access to a musical environment that is not dependant on their own performance skills
>
> (Hodges 1996, p.77)

Several studies have focused upon the effectiveness of the sequencing software *eJay* on promoting musical creativity in schoolchildren (Dillon 2003; Gall & Breeze 2008; Mellor 2008; Figure 2.7). The software employs pre-programmed ‘tape loop’ structures, which the user arranges, thus providing an accessible environment for exploring form, structure, style and texture:

> For some, especially those without musical keyboard skills or without experience of playing a traditional musical instrument, the experience of using Dance eJay not only opened up a possibly for seeing themselves as a musician with music technology as a main instrument, it also opened up the possibility to see themselves as a musician.
>
> (Mellor 2008, pp.468-9)

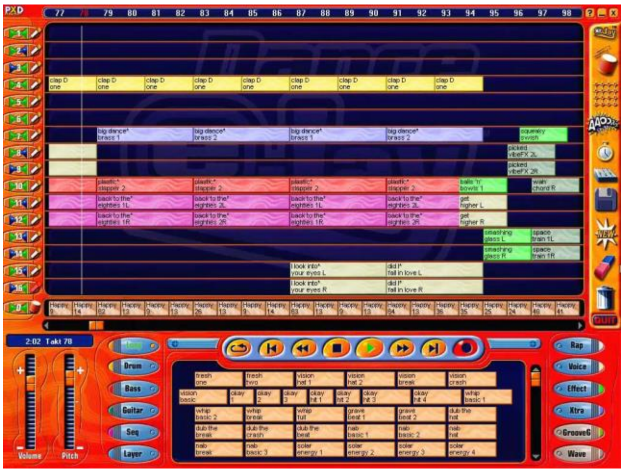


Figure 2.7 – *eJay*

Furthermore, such alternative approaches may offer certain students the possibility of a uniquely personal creative identity, through the application of methods which traditional resources do not permit (Wise *et al*. 2011, p.125). There is limited room for such emergences if classroom compositional approaches continue to be generally prescribed:

> …our results show that the ways in which music is created varies between individuals, and between different kinds of music. An important implication of this is that there is no such thing as 'right' or 'wrong' with the respect to method or strategy by which music should be created, and consequently that school should not teach the method of composition, but rather create a context in which the pupils can explore their own ways into music composition.
>
> (Folkestad *et al*. 1998, p.95)

In order to support creativity, educators must ensure that students have access to approaches that they consider meaningful and authentic (Crow 2006). This may be something that emerges in the classroom, or it may already exist outside of the context of the classroom in the ever-growing proficiency of young people in their use of personal communications technology. It seems a logical progression to assimilate this proficiency into learning environments (Gouzouasis & Bakan 2011; Norris *et al*. 2011; Zhou *et al*. 2011). Prensky (2001; 2009) asserts that the 'digital native' (or 'digital wisdom', to use the more age-inclusive updated terminology) demands an educational environment which reflects the context within which they have come to understand and interact with the wider world, and argues that educators must acknowledge and embrace this need in order for students to see their learning experience as authentic. Recognition of this ideal may be seen in the recent emergence of 'bring your own device' policy in some schools, despite a tradition of conservative resistance to schoolchildren using personal communications technology onsite, for educational purposes or otherwise (Tierney 2012). In any case, if educators are to create an environment in which creativity is truly supported, it will be necessary to be open to approaches which may prove to hold a context of authenticity to young people (Custodero 2002, p.6).

In promoting a context of authenticity, and also ensuring that students have an understanding of the musical concepts they are applying, successful digital environments may involve some form of student-directed instruction (Brown 2008). A more open-ended format may allow students to build their own framework of musical concepts, addressing the issue of suppressed experimentation in more experienced musicians, and allowing creating an environment for improvisation non-dependent upon the prior mastery of low-level musical skills (Manzo 2010). Rudi (2007, p.140) is critical of instructivist interface design which relies on sequential information processing, and advocates systems based upon a nonlinear learning model. Savage (2005, p.175) expresses a similar view, exploring the potential of the computer programme as a ‘meta-instrument’ which can be customised to meet individual needs. This may also have promising implications concerning the role of interactive technology in meeting specific barriers to learning (Anderson & Smith 1996; Collins 1992; McKnight & Davies 2013, pp.24-44) and in providing opportunities for cross-curricular learning (Lehrman & Ryan 2005).

The apparent suitability of customisable interfaces to classroom applications is reflected in the anecdote of a teacher consulted in a study by Savage (2007, p.70) whose students ‘found more interesting things to do within the technology’, subverting the prescribed learning outcome (see also Mills & Murray 2000). These unexpected occurrences, *pivot points*, may provide valuable opportunities for student-directed learning:

> A constructivist classroom is one in which the teacher welcomes learners to enter with the teacher into the learning process, as full participants in exploring our, their, and others’ musical worlds.
>
> (Shively 2015, p.133)

As students become increasingly accustomed to experimenting with digital technologies, perhaps this should be reflected in the use of ICT in the classroom (Prensky 2001; 2009; Beckstead 2001, pp.48-9). Teacher attitudes to these occurrences are examined by Savage (2007, p.70):

> A number (39 percent) spoke of their pupils knowing more than they did about a particular piece of technology. This did not threaten the majority of the teachers (57 percent of this 39 percent), who saw it as a positive opportunity to encourage pupils to move towards a greater degree of independence in their learning. They described this shift from teacher-dependence to learner-independence as accompanying a shift in their teaching role from instructor to facilitator.

The views expressed have significant implications for interface design, but are far from unanimous. Clearly, this student-teacher dynamic and its relationship to emergent technology demands further study.

The usefulness of visual representation in pedagogic music-making activities cannot be underestimated (Gall & Breeze 2005, p.429). Savage and Challis (2002, p.1) distinguish the *intrinsic* act of composition from its *extrinsic* aspects (score representation, notation etc.)

Within a constructivist framework, the extrinsic aspects of composition should not pose barriers to the intrinsic act:

> In my opinion, we only err when we place the cart of music theory before the horse of musical experience…
>
> (Borgo 2007, p.78)

Supporters of traditional notation have suggested ways of using active composition to instil knowledge of its formation, using MIDI for example (see Brophy 1996). The dynamic creation of score material from alternative and highly original methods of input has also been explored (Farbood *et al*. 2004; 2007; Jennings 2005; Kelly 2011). The pedagogic value of alternative notational methods has been examined in some detail (Jennings & Tangney 2001; Jennings 2006; McCarthy *et al*. 2005) as well as the use of abstract graphics in supporting engagement and focus (Blaine & Perkis 2000). From a constructivist perspective of the dynamic nature of knowledge, it may make sense to make use of different modes of representation for different modes of musical learning. Brown (2012, p.31) advocates a choice of notational representations, and offers examples of software which uses none whatsoever, such as *jam2jam*. Bamberger's (2010) explorations into 'student-invented notations' prompt questions regarding the development of personal understanding, and calls for further research into the scope for implementation of these strategies in educational resources (p.35). In terms of facilitating the intrinsic act of composition, many researchers favour intuitive and tangible input methods, which rely upon familiar actions such as drawing (Farbood *et al*. 2004; 2007, Raffle *et al*. 2007; Rosenbaum & Silver 2010), moving physical items (Bean *et al*. 2008; Catala *et al*. 2011; Costanza *et al*. 2003; Marshall 2007; Zuckerman *et al*. 2005) and bodily gestures (Bevilacqua *et al*. 2007, Fischman 2013; Ip *et al*. 2005). As commercially-available interfaces become more technologically sophisticated, there is a growing interest in the re-humanisation of the interactive process through recognisable metaphor, a concept referred to as *transparency* (Fels *et al*. 2002; Gadd & Fels 2002). However, such aims must also be reconciled with reasonable expectations as to what can be made available in the music classroom and harnessed by the generalist teacher.

2.3 Summary

This research project aims to investigate a constructivist approach to the development of interactive digital technology (i.e. user-friendly software resources) for supporting specific musical learning. The context established in this chapter should further outline what is meant by ‘a constructivist approach’. Constructivism is not an approach or method, but a lens through which to view teaching and learning, and to provide some insight into the effectiveness of specific methods with respect to learning impact (Shivley 2015, p.129). Therefore, we can apply this to existing practices and resources to identify an area in which we may support musical learning through digital technology:

- *To what extent have interactive digital technologies hitherto succeeded in encouraging musical behaviour in the classroom?*

In this chapter, I have partially answered this question. Research suggests that real musical behaviour is lacking in the classroom, most directly stated in the reports of OFSTED (2012; 2013). The pursuit of more experiential musical behaviours is therefore desirable, so it is appropriate that we should consult a constructivist perspective on this matter. I have explored an interpretations musical learning in this context, and some of the barriers currently facing music educators. To further address this question, I will now examine, through the constructivist lens, the range and effectiveness of interactive digital technologies widely used in music classrooms (see chapter 3).

Earlier in this chapter, I posed a question: *What does constructivism tell us about the nature of learning that we can use to support specific musical learning?* The research that I have cited indicates that musical learning is effective when students are engaged in active music-making as part of a social dynamic. However, certain barriers become apparent, such as disinclination to experiment among more experienced students, and limited accessibility among those with less experience. Then there is the suggestion of a deficiency in the creative use of technology in music classrooms. Most students’ interaction with composing technologies is limited to the standard MIDI keyboard and sequencer workstation. However, studies indicate that access to a range of technologies and methods may encourage creative collaboration. It is also suggested that the need to understand low-level musical concepts and traditional modes of representation is not an effective precursor to creative progress, when compared to more active, dynamic and student-directed learning structures. Research is required to explore how alternative modes of representation and dynamic, open-ended learning environments facilitate creativity, through both accessibility and the possibility for subversion of standard musical practices. We have discussed how creative activities providing opportunities for meaningful reflection might be made accessible to the musical novice by encouraging improvisatory, creative musical behaviours. If we follow the 'Bloom's 21' model, we make a creative task the starting point for discovery of abstract musical ideas, which will then have a context of relevance and understanding to the learner, rooted in concrete experience, according to the theories of Bruner (1961) and Kolb (1984). Therefore, we must ask what role interactive technology plays in formulating such opportunities:

- *How might interactive technology be harnessed to facilitate creative expression in the musically untrained?*

This is a further aspect of design and application within the classroom, and may involve considerations of transparency in interface design, as well as ensuring the visibility of musical learning (Hattie 2009). In primary music education, we are faced with not only a skills gap, but also a difficulty in translating abstract musical concepts to meaningful activities, often leading to an overreliance on verbal communication as a means of addressing curriculum aims (OFSTED 2012, p.4). Where discussion is present, we must ensure that it is a reflective response to real musical behaviours, and that which effectively communicates musical ideas as part of a reflexive and social creative process.

Having explored and consolidated perspectives on constructivist theory, we have begun to address some of the implications for facilitating musical learning. Just as there are numerous perspectives on educational theory, what constitutes musical learning may be interpreted in many ways, and there are many approaches we could take. In this project, we are concerned with interactive technological solutions which extend possibilities for learning beyond that of existing musical workspaces. While constructivism is not a method for design, we must consider how the relevant ideas contribute to an informed method of design:

- *How can constructivist theory guide interface design as a means of facilitating creative musical learning?*

By applying this view of learning in this project, we are examining two aspects of development and impact: Firstly, we are investigating the extent to which interactive digital technologies support musical learning within the classrooms that we visit as part of this research project. This will be achieved by evaluating the musical outcomes of these sessions (see chapters 6-7). Secondly, we are investigating my own practice as a teacher, programmer and researcher, and the extent to which this practice develops and is successfully applied in this project, in recognition of my own position as a learner in this process. This will be evaluated by the outcomes of this project, and a key measure of this is the musical outcomes produced by the students.

The next chapter will further explore the role of digital technology as part of a musical learning environment, aiming to provide answers to the questions posed here, and to further establish how my design practice may support musical creativity in the classroom.

3. Research Context 2: Environment & Interaction

Figure 3.1

We have established that the constructivist perspective of learning concerns maintaining equilibrium through interaction with our environment. What this learning environment is, and how we interact with it, are increasingly technological considerations. Late 20th century perspectives on the constructivist paradigm, such as constructionism, focused on the new educational dynamics presented by virtual learning environments, and present day ideas such as connectivism are wholly situated in a context of e-learning. This chapter will continue to answer some of the research questions previously established:

- *How might interactive technology be harnessed to facilitate creative expression in the musically untrained?*

To do this, I will explore the extent to which digital technology forms our environment and directs our interactions in the interest of experiential learning, and will examine the wider dynamic considerations of instructional technology within educational environments. I will also discuss how digital media has influenced music education, and look at the existing software resources used in the classroom:

- *To what extent have interactive digital technologies hitherto succeeded in encouraging musical behaviour in the classroom?*

Finally, I will discuss the gamification of digital learning resources, and the implications for formulating a design strategy, in order to address the question:

- *How can constructivist theory guide interface design as a means of facilitating creative musical learning?*

3.1 Digital Technology in Creative Learning Environments

3.1.1 Visible Learning

Students often look for a context of relevance in what they are expected to learn. '*When will I ever need to know this?'* they may ask themselves, their peers or their teacher when faced with some unit of learning that possesses no apparent significance to their lives. Instructional technology has, in many cases, allowed curriculums to evolve beyond the rote-learning of abstract knowledge. For example, the teaching of mathematics was restricted to 'pure maths', with limited application in real-world circumstances, before the advent of computer modelling and subsequent focus on problem-solving from the 1970s onwards (Puhlmann 2014, pp.78-9). While this ultimately led to the development of more meaningful curriculums, a great deal of attention to design was required before teachers could confidently incorporate these technologies into their lessons, and scaffolding tools such as the calculator faced opposition from conservative voices who felt that this constituted a 'dumbing-down' of mathematical processes (pp.77-8). This is a good example of the educational importance of scaffolding: Square roots are immensely difficult and tedious to work out on paper but easy to do with a calculator. The only reason not to use a calculator is if the method serves some purpose applicable to our lives, but if we have calculators in our lives and in our pockets, then it makes sense to use them. When we do, more complex problems with a context of relevance to our lives, such as calculating distances, become accessible. This allows us to take mathematics out of the classroom and into the real world, or alternatively, we could work with virtual representations of locations and their respective distances on a computer. Either way, we have a much more experiential lesson with clear and valuable outcomes. Our students are now much more likely to develop an interest in mathematics and see how square roots can be useful in their lives, and if that is the case, they will find out independently how to calculate square roots on paper should the need ever arise, being equipped with perhaps the knowledge but, more importantly, the motivation to do so. In this circumstance, technologically-augmented learning environments have made the learning aims visible to the learner.

Hattie (2013) tells us that learning is made visible when 'teachers see learning through the eyes of students and help them become their own teachers.' This means facilitating a clear understanding on the part of the student of not only *what* they are learning, but *why* they are learning it. Collins (1991, p.5) identifies the educational advantages of computer modelling as connecting *how* and *why* with visible representations of processes which would otherwise remain unseen, allowing us to synthesise concrete experiences from what would otherwise be abstract cognitive processes. From a perspective of experiential learning, if we understand why we are doing something, the dynamics of how become clear, because we see, or perhaps actively seek to understand, how these processes ultimately connect to the goal we already have in sight. Papert (1980, p.74) clarifies how this occurs within the *LOGO* virtual learning environment:

> In the *LOGO* environment new ideas are often acquired as a means of satisfying a personal need to do something one could not do before. In a traditional school setting, the beginning student encounters the notion of variable in little problems such as:
>
> *5 + X = 8. What is X?*
>
> Few children see this as a personally relevant problem, and even fewer experience the method of solution as a source of power. They are right. In the context of their lives, they can't do much with it. In the *LOGO* encounter, the situation is very much different. Here the child has a personal need: To make a spiral. In this context the idea of a variable is a source of personal power, power to do something desired but inaccessible without this idea.

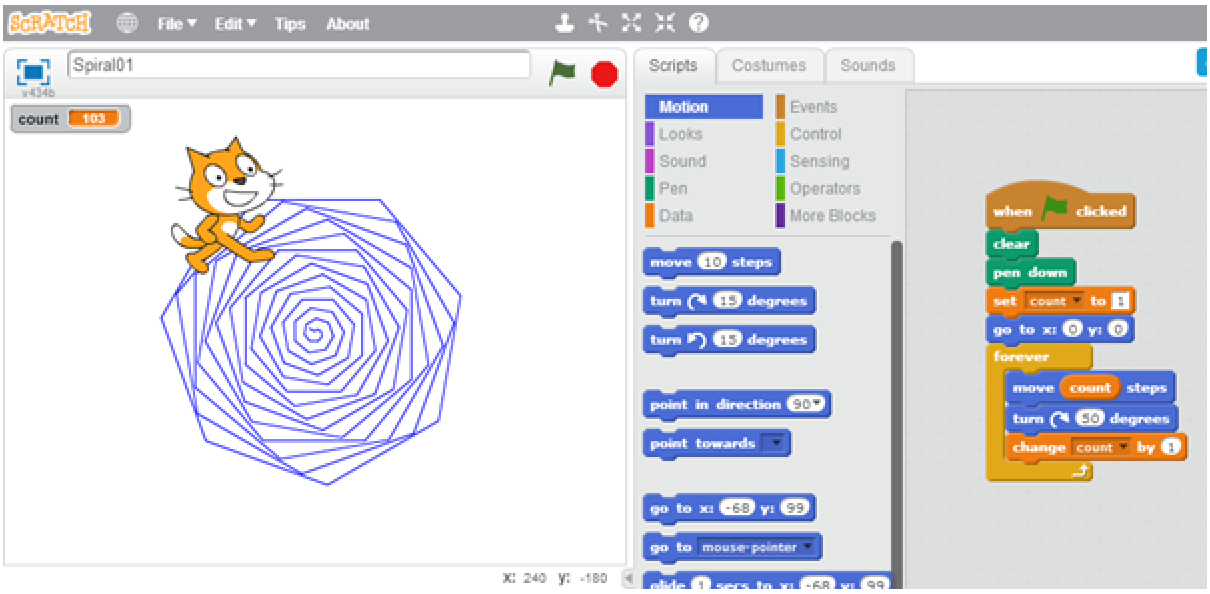


Figure 3.2 – Generating a spiral structure in *Scratch*. Notice the use of an anthropomorphic cat avatar as a cursor, a version of the pioneering 'turtle graphics' of *LOGO*.

This point is still relevant to modern pedagogical programming environments such as *Scratch* (Figure 3.2), and highlights what Ackerman (2001, p.8) describes as the situation-dependent definition of intelligence within constructionism, where 'being intelligent means being situated, connected, and sensitive to variations in the environment.' Because the virtual learning environment can be modified, customised, and interacted with in a multitude of ways, the capability of the learner to engage with the learning materials is defined by the suitability of the environment. To 'dive into' such an environment, the learner must have a clear understanding of what their objective is, and how changes within the environment, or responses to their interactions, constitute movement in the direction of this objective. Collins *et al.* (1991, p.3) advocate an experiential mode of learning designed for intrinsic motivation and impact, where teachers make processes visible and relevant to students. Scaffolding tasks, which allow the learner to engage with simpler units to build a 'conceptual map' and thus understand the wider global objectives before focusing on local skills, are used in various forms of apprenticeship:

> In tailoring, apprentices learn to put together a garment from precut pieces before learning to cut out the pieces themselves. The chief effect of this sequencing principle is to allow students to build a conceptual map, so to speak, before attending to the details of the terrain.
>
> (p.15)

This approach mirrors the use of pre-composed structures in music resources such as *eJay* (see 2.2.2) which allow the user to engage with global musical skills such as structure and texture. The idea of 'global before local skills' is also analogous to the notion of *Bloom's 21* (see 2.2.1) where the higher order thinking skills of Bloom's Taxonomy are used as a creative starting point. In all of these models, the environment, often through technological augmentation, provides a 'conceptual map' which promotes more specific 'local' outcomes through less instructive processes, such as active experimentation and discovery learning. The students then have other opportunities to learn or transfer what is learned as the situation or environment diversifies (pp.15-6).

3.1.2 Tangible ('Hands-on') Learning

From a perspective of experiential learning, the construction of a conceptual map by the learner is the product of enhanced modes of interaction with the learning concepts within the environment. Papert's term 'objects-to-think-with' (1980, p.11) implies a hands-on approach to cognitive processes, where otherwise abstract ideas are made not only visible but tangible through interactive technology. Through the construction of 'meaningful public entities', students, peers and teachers have a clear manifestation of learning as it takes place:

> For a while, I dropped in periodically to watch students working on soap sculptures and mused about ways in which this was not like a math class. In the math class students are generally given little problems which they solve or don't solve pretty well on the fly. In this particular art class they were all carving soap, but what each student carved came from wherever fancy is bred and the project was not done and dropped but continued for many weeks. It allowed time to think, to dream, to gaze, to get a new idea and try it and drop it or persist, time to talk, to see other people's work and their reaction to yours -- not unlike mathematics as it is for the mathematician, but quite unlike math as it is in junior high school.
>
> (Papert & Harel 1991, p.4)

This suggests an alternative to the modular and sequential approach to learning, instead advocating a structure more commonly found in artistic subjects, which emphasise the choices and decisions of students and allow them to apply skills in a variety of cross-curricular contexts[11]. Though the structure employed within classes like the one which Papert observes is, at least in part, a consequence of the less rigid control imposed on them as 'non-core' subjects (auxiliary to the traditional Western educational triad of English, science and mathematics) he values this structure as unrestrictive to the personal development of the students, and seeks to incorporate it into his own subject, mathematics. By producing learning materials which the student can see and 'sculpt', in this case, computer-generated, Papert pursues a mode of learning rooted in 'problem-creation', where continual acquisition and application of knowledge that is driven by the choices and orientations of the individual learner (Harel & Papert 1990, p.24).

Consider the practice-based research model: The practitioner-researcher begins not with a problem, but with their individual creative process, from which some knowledge is extracted. They then apply this to a new creative process, and so the reflexive cycle progresses:

---

[11] Such an approach, termed project-based learning, is common in the Finnish educational system. See, for example, Helle *et al.* (2006).

> The innovative and critical potential of practice-based research lies in its capacity to generate personally situated knowledge and new ways of modelling and externalising such knowledge while at the same time, revealing philosophical, social and cultural contexts for the critical intervention and application of knowledge outcomes.
>
> (Barrett & Bold 2014, p.2)

This model has afforded a rigorous mode of inquiry to the creative arts, one that allows the practitioner-researcher to investigate how context shapes their practice and vice versa. In social constructionist theory, this awareness is termed ‘reflexivity’ (Cousin 2016) but has a clear parallel to the constructivist theory of equilibration, that of ‘coupling with our surround’ and ‘[acting] on new experiences and information’ (Fosnot and Perry 1996). Reflexivity can be thought of as an analysis of this process, a constructed awareness of how it happens. It seems, then, that this model has central relevance to educational practice within the creative arts.

The crucial distinction in this form of learning is that it is not a matter of an individual changing as they absorb an unchanging body of external information. It concerns interaction with an environment (setting, context, task, resources, other people etc.) and the feedback of this experience. This feedback is itself a dynamic process, something which the learner has an influence over. It is shaped by their perspective, the mechanisms by which they internalise it, assimilate it, or possibly reject it. This then manifests in some practical change, the means by which they re-interact with their environment. But, in doing so, it is not just the individual undergoing change, but also the environment with which they are interacting. This is the archetypal mode of observation for the practitioner-researcher: *How and why does my practice influence my environment? How and why does my environment influence my practice?* We might say that the practice-based researcher is engaged in constructing (or perhaps re-constructing) their own conceptual map through these practical interactions and reflections, and this allows them to challenge concepts from their field and contribute new knowledge.

The extent to which young learners can engage with the creative modes of enquiry here described depends upon the provision of a suitable environment, in which they can apply their existing skills to negotiate new concepts, allowing them to venture further still (i.e. express creativity):

‘[Children’s] willingness to improvise and compose is a function of creating an environment where children can express their creativity. By starting with activities that are not too far removed from the child’s immediate experience, creativity becomes integrated with the child’s existing musical experiences and skills. Furthermore, by locating children in a range of musical settings they come to recognise the multidimensional nature of what they already know, think and can do.’

(Burnard 2000, p.21)

This suggests maintenance of a ‘flow state’ (see Czikszentmihalyi 1996) in which present challenge should increase in proportion to acquired skill; a change in environment in response to the needs of the learner, or an environment which adapts to the learner, mirroring the cognitive dynamics of equilibration. How might interactive digital technology contribute to such an environment?

3.1.3 Augmented Learning

In e-learning, designs which change in response to the learner are referred to as ‘augmented learning environments’. Augmentation in virtual learning environments may constitute, as we have discussed, visualisation and concretisation of ideas, something as simple as an assistive onscreen menu or as complex as a system which learns from the learner[12]. However, reliance on this kind of ‘big data’ has led to criticism among educationalists wary of a ‘de-humanisation’ of teaching and learning. Rouvroy and Berns (2013) refer to as ‘digital behaviourism’ where our learning experience is defined by a codex of numerical ‘truths’. Education is about emotional as well as cognitive connections, which occurs and is interpreted on a person-to-person level. If we lose sight of this, we may see a revival of the Pavlovian behaviourism that preceded the emergence of constructivism, albeit veiled by the sheen of technological augmentation.

In order to help students to become actuators of their own learning, technology has to form a scaffold which ultimately affords them more control, as opposed to directing their interactions. Also, because we are primarily concerned with creative outcomes, we should consider how our interventions augment the human element of learning along with the

[12] This kind of technological responsiveness is present in emerging examples of highly software-oriented education, such as the *AltSchools* educational start-up (see Robinson 2017) and AI teaching assistant (see Backchannel 2017).

technological. Augmented learning environments may rely disproportionately on digital technology to provide a dynamic component which could be achieved through social interaction. For Collins *et al.* (1988, p.26) sociology is a 'critical dimension that is often ignored in decisions about curriculum and pedagogical practice.' Modes of co-operative learning feature exclusively within the instructional technology-oriented model of cognitive apprenticeship (Collins *et al.* 1988; 1991). De Corte (1990) defines a 'powerful' problem-based learning environment with reference to *LOGO*, but establishes methods centred around human interactions such as expert modelling, guidance, feedback and reflective observation, placing particular emphasis on any techniques which enable students to articulate what they have learned (pp.12-3). This is echoed in more recent writings on new pedagogies driven by technology:

> The future of teaching may ultimately center in deeper relationships built between teachers and students, developed through creative, collaborative, socially connected and relevant learning experiences. Technology can enable and accelerate these deep learning relationships — both between teachers and students and between students and other "learning partners" such as peers, mentors, and others with similar learning interests. Technology as a platform for more connected social learning experiences is a far cry from the notion of technology supplanting teaching.
>
> (Fullan & Langworthy 2013, p.14)

When augmented learning with technology, we should consider that which legitimately and quantifiably augments the learning experience, or presents new modes of learning, and to question that which is used for the sake of novelty and mere efficiency, especially where this diminishes the effective social components of education.

3.2 Digital Technologies in the Music Classroom

3.2.1 Overview

Fullan and Langworthy (2013, p.4) argue that digital technologies present 'new pedagogies… enabled and accelerated by technology' and promoting deep learning, which they define as that which 'develops the learning, creating and 'doing' dispositions that young people need to thrive now and in their futures' (p.i). This can be seen not just in the inherent engagement and links to the extracurricular activities of students, but in the vast range of unique modes of use across almost all subject areas. Relatively recent technologies such as touchscreen tablets have been widely incorporated into the teaching of core subjects, such as literacy and numeracy. We are only just starting to gather evidence on how tablets and other personal devices may be beneficial within non-core subjects such as music: Riley (2013) documents the various uses of the iPad in music lessons. Criswell (2011) examines teacher perspectives on using the iPad for performance and composition. Most reports focus on the practices of innovative teachers, on an individual case study basis. Riley (2016) suggests six apps that may be used for classroom composition with young children, and provides sample lesson plans. Some of these apps offer intuitive interactions with the touchscreen as ways of manipulating timbre, such as Singing Fingers and Brian Eno and Peter Chilver's *Bloom* app (Figure 3.3). Ruismäki *et al.* (2013) document the use of the iPad for practical learning in a Finnish music class, noting the scaffolding possibilities of *GarageBand* (pp.1091-2).

Figure 3.3 – *Bloom*

Technology is always subject to change, and the commercial software resources used at the time of writing may not still be in use in years to come. Nevertheless, it will always be useful to have some record against which to compare new resources, so I will now examine the different types of software and applications which may be employed in the music classroom currently. In order to categorise these resources as coherently as possible, we can consider the type of musical activity they facilitate. Swanwick's (1979) influential definition of a music curriculum focused on three central activities; audition (or listening and appraising), performance and composition. These are the three basic strands of activity on which music education is founded; we are either perceiving (usually, though not exclusively, by listening) and describing, playing or writing music. There is, of course, a great deal of crossover of these approaches within the available digital resources.

3.2.2 Listening and Appraising

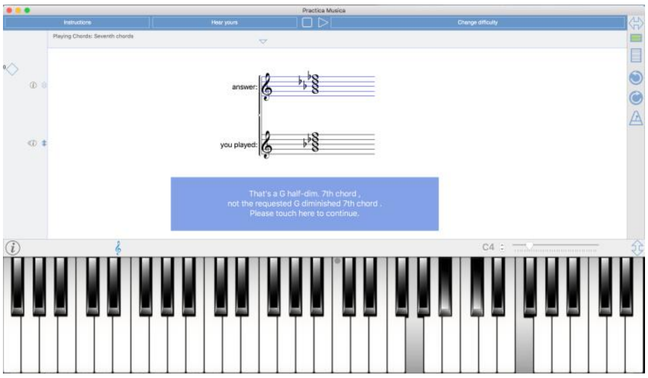


Figure 3.4 – *Practica Musica*

Digital resources for audition of musical examples, such as listening exercises or sight reading musical text such as staff notation or tablature, often comes in the form of software packages. These packages are generally aimed at increasing musical knowledge across a broad sequence of activities. However, many focus on specific curriculum or assessment content, of an awarding body such as the Associated Board of the Royal Schools of Music (ABRSM) or the GCSE Music curriculum. As such, these packages are outcome-oriented, designed to be used by an individual and making it easy for them to track their own progress, and imparting a broad range of musical information through quizzes and other exercises. However, this does mean that such packages tend toward a prescriptive and instructive format. Software such as Ars Nova *Practica Musica* (Figure 3.4) and Rising Software *Musition* is based on music theory, with questions and exercises addressing the identification of musical features. These are often available as part of packages containing other types of music training software. Aural training resources such as Rising Software *Auralia* (Figure 3.5) are also common, which advertise as helping users to develop perfect or relative pitch by identifying notes and intervals.

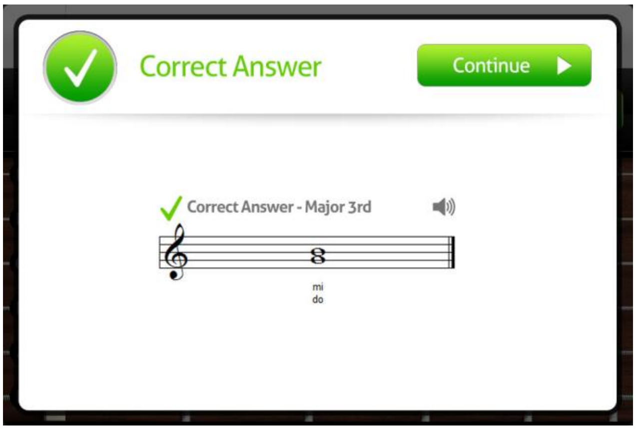


Figure 3.5 – *Auralia*

There are a number of software packages aimed at assisting teachers to deliver the music curriculum. By far, the most prominent example is *Charanga Music World*, which offers a sequential and learning outcome focused set of activities closely following the curriculum. *Charanga* draws from research in music education, with the structure following Swanwick and Tillman's (1986) sequence of musical development, where learners alternate between personal and social musical experience (Figure 3.6). It offers a range of activities as pre-planned lessons drawing exhaustively from the curriculum, with music history and listening exercises alongside performing and composing tools (Figure 3.7). *Charanga* therefore has a much more collaborative and perhaps less instructive format than the other software packages discussed.

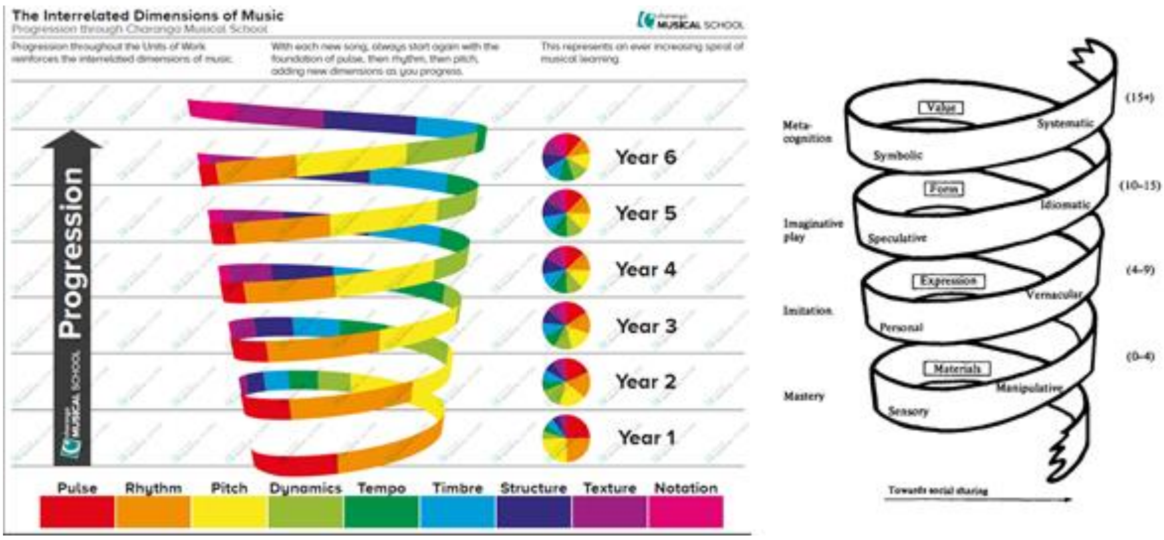


Figure 3.6 – The sequence of progression in *Charanga Music World,* alongside the sequence of musical development (Swanwick & Tillman 1986)

Figure 3.7 – Assistive tools for composing and performing in *Charanga*

3.2.3 Performance

Assistive digital resources for musical performance have tended to focus on tracking accuracy and highlighting errors, such as timing issues and incorrect notes, so have been designed around some means of digitising musical performance. As such, most have used

MIDI, with input devices such as the electronic keyboard or drumkit (Figure 3.8). Advances in frequency analysis and pitch detection, as well as motion tracking with web cameras, has led to the capacity for computer analysis of more complex and discrete features of musical performance. Some researchers have explored the possibilities of a *de facto* digitisation of the classical music tutor in the interest of enhancing performance scrutiny and accuracy (Yin *et al.* 2005; Fober *et al.* 2004; 2007). Other packages utilise similar methods of input to produce a more fun and casual format aimed at the novice learner, for whom the purchase of a piece of software might prove more cost effective than ongoing lessons (Figure 3.9).

Figure 3.8 – *Home Concert XTREME* for iPad

Figure 3.9 – *Yousician*

The gamification of musical performance using interactive digital media was no doubt propelled by the commercial success of *Guitar Hero* with the levels of dexterity and 'virtuosity' among habitual players arguably comparable to the results of legitimate musical practice (Arsenault 2008)[13]. The onscreen interface of falling notes which must be synchronised by the player using the connected hardware has been adopted by other performance tools such as *Synthesia* (Figure 3.10) and popular pedagogical apps such as *Piano Tiles*. Other assistive performance

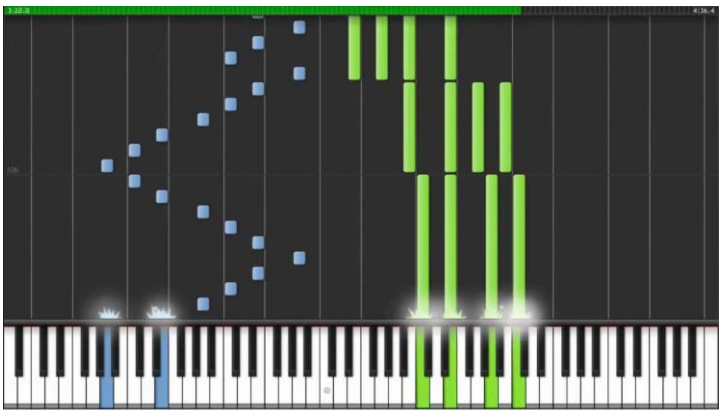


Figure 3.10 – *Synthesia*

[13] Further musical credibility is lent to the ability to skilfully operate a computer game controller or other commercial input device by the possibility and widespread practice of mapping such devices to musical outputs using audio-oriented programming environments such as *Max/MSP*.

resources take on a less linear format, such as Eno's *Bloom* app and Brown and Dillon's *jam2jam* (see 2.2.3). The latter offers the freedom of 'jamming' in a collaborative virtual environment by arranging musical ideas using a touchscreen, and as such offers much more capacity for exploratory and creative performance than the more instructive resources previously discussed.

3.2.4 Composition

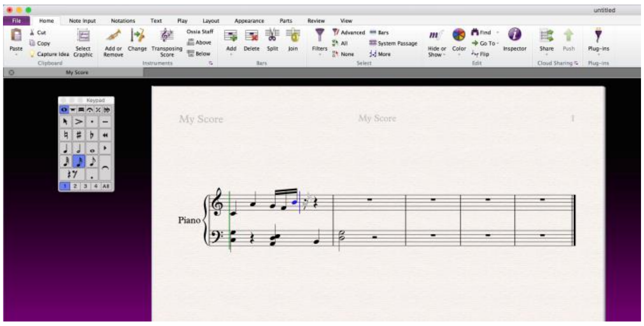


Figure 3.11 – Staff notation in *Sibelius Ultimate*

The majority of commercial software for music composition falls within two categories; scorewriters and multitrack sequencers. Both types tend to use MIDI for note identification, instrument classification and imitation, as well as the control of various musical parameters, such as volume and pitch-bending. Scorewriters (Figure 3.11) are based upon the system of staff notation used in the Western classical tradition, allowing users to create, edit and print musical scores. Such programmes tend to be aimed at trained musicians, offering a sophisticated lexicon of musical representations but little in the way of assistive support to the novice user. Multitrack sequencers (Figure 3.12) draw from studio technology, offering the direct recording and processing of audio, and often a set of virtual instruments (Virtual Studio Technology, or VST) which are typically modelled after popular hardware synthesizers, drum machines and effects units. The usual linear timeline and commands ('cut', 'splice', 'loop') draw from the traditions of audio tape recording and studio practice, and therefore are also fairly demanding for the novice user, though some examples of digital audio workstations have taken on a more assistive format with scaffolding tools, such as *eJay* (see 2.2.3) or the drum mixing matrix within *GarageBand* (Figure 3.13).

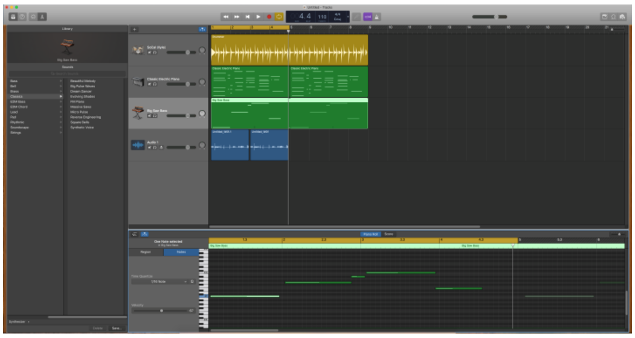


Figure 3.12 – Arranging clips in *GarageBand*

Composing software aimed specifically at children tends toward a more straightforward mode of arrangement, where musical ideas can be easily differentiated from one another. These are often built around the concept of a more child-friendly activity, such as painting (see Rosenbaum & Silver 2010; Figure 3.14). Bamberger's research pioneered the use of 'tune-blocks' (Bamberger 1996; Bamberger & Hernandez 2000), providing melodic fragments to explore composition as a form of puzzle solving (Figure 3.15). This scaffolding approach has been shown to facilitate an intuitive creativity in musically-untrained students, who were then able to provide well-reasoned responses as to their creative decisions (Bamberger 2003). Brown (2012) cites Bamberger's work as influential to the development of *jam2jam*.

Figure 3.13 – Arranging drums in *GarageBand*

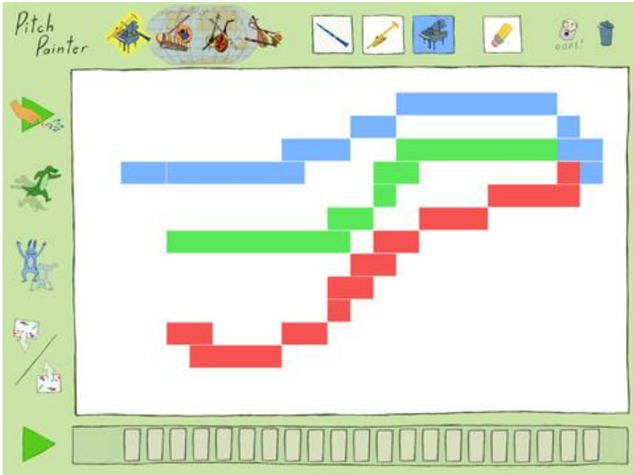


Figure 3.14 – Morton Subotnick's *Pitch Painter*

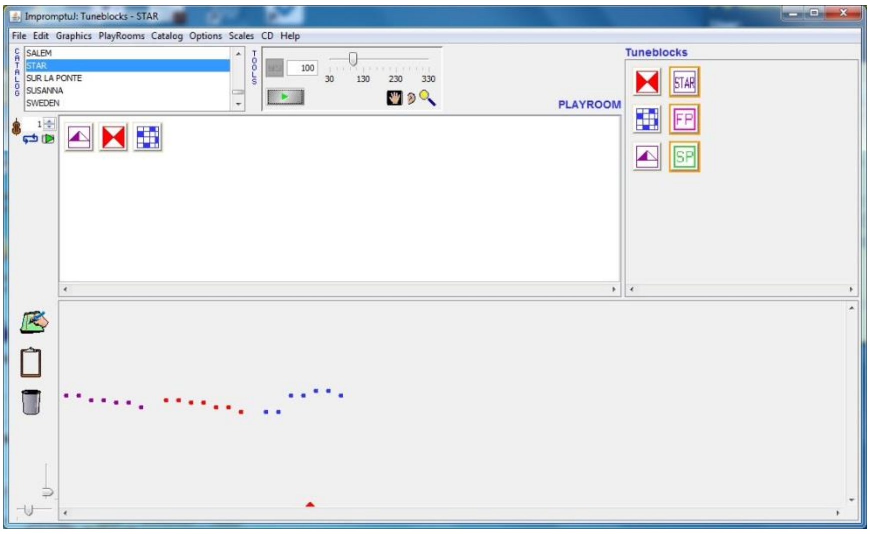


Figure 3.15 – *Impromptu*

3.3 Learning from Games

3.3.1 Sandbox Games

Games have long been recognised as an effective learning impetus. Teachers have been gamifying learning materials with quizzes and other competitive challenges throughout the history of the profession. When Piaget established play as a significant component of educational discourse, the value of games beyond merely measuring knowledge or provoking competition became apparent – The child playing in a sandbox, in developing skills and ideas, however rudimentary, which this environment facilitates, is engaged in learning. Papert and Harel (1991, p.1) compare the process of building a sandcastle to building a 'theory of the universe', acknowledging how creative interactions with our environment underpin the lifelong process of learning. We have discussed how, in modern constructivist approaches, the virtual or augmented learning environment may be designed for and adapted by the learner. This type of environment may be thought of as a sandbox, where the learning materials are, in some sense, directed or 'sculpted' by the learner, but where imagination and personal objective are the vital ingredients which the learner brings to the process.

Figure 3.16 – *Sim City*

In the commercial gaming industry, 'sandbox' refers to a type of gaming environment, where the player sets their own objectives and defines their own outcomes. The educational potential of sandbox games is not necessarily inherent. Rather, the link is derived from their usefulness as resources in the kinds of open-ended learning context that are valued by constructionist educators. The term fell into use with the growing popularity of *Sim City* (Figure 3.16) and *The Sims* – open-ended games which involve the maintenance or development of a state as the sole objective of gameplay. In *Sim City*, for example, the player initiates development which they can then observe as it unfolds further – They may build a hospital, upon which the autonomous sprites of the game add roads and houses around the structure. Other generative aspects are entirely out of the player's control, such as natural disasters, and must be mitigated through protective or restorative measures. However, 'sandbox game' has been generally applied as an umbrella term for any open-world platform which does not follow the linear game format whereby the sequence of events is always essentially the same. From this perspective, first-person shooter or open-world games such as *Grand Theft Auto* might be categorised as sandbox games, though the context of creative exploration implied by the term is largely absent.

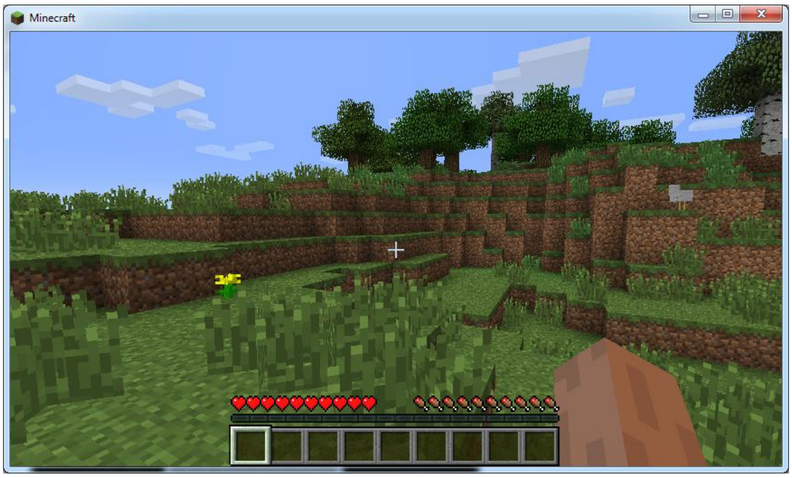


Figure 3.17 - *Minecraft*

As a demonstration of how sandbox environments might support or motivate the novice user, let us consider the gameplay in *Minecraft.* The primary objective is to build structures using a catalogue of resources, most of which are represented as 3-dimensional blocks, and other items with specific properties or functions. The simple cubic graphics allow for the easy construction of basic structures, such as small houses, while more complex designs can be achieved by scaling up the number of blocks used, or the range of different items, so a vast range of possibilities are present. When we begin a game as a new player, there is no apparent objective or instruction in place. We find ourselves in one of several landscapes – a field, a beach, a forest – with a number of onscreen status bars giving indication as to our present condition (Figure 3.17). As we explore these surroundings, we will find that we can collect some items, and combine them to craft other items, but that others are unavailable to us until we obtain more resources. As these possibilities grow, we set further objectives for ourselves. These objectives often have a sequential format, with some wider goal being dependant on the fulfilment of a set of smaller goals; e.g. *I need to find A so that I can make B so that I can accomplish C…* As such, the player acquires skills as they move through the game, setting their own objectives for gameplay.

Figure 3.18 – *Minecraft* players often build and share complex structures

Minecraft is a particularly pertinent example of a sandbox game due to the varying levels of complexity and possibilities for social and personal creative activity. The player is both an explorer and master of a virtual world[14], which they can customise with built structures of endless complexity (Figure 3.18). There is therefore a certain creative ownership and personal identification in such gameplay, and the possibility of world-sharing and networking, whereby players can enter and explore each other's worlds, qualifies this as an example of social creative practice. To use Papert's term, the player is 'constructing a meaningful public entity' (see 3.1.1).

3.3.2 Educational Applications


Figure 3.19 – A class of children, potentially across multiple schools, explore a teacher-generated world in *MinecraftEdu*

There is a growing body of research concerning effective classroom implementation of the commercial open-ended games discussed here (see, for example, Bos 2001; Denis & Jouvelot 2004; Gaber 2007; Brand & Kinash 2013; Ekaputra *et al*. 2013; Schifter & Cipollone 2013; 2015). The possibilities for engagement and development afforded by *Minecraft* have led to an unprecedented level of commercial computer game integration with educational practices (Schifter & Cipollone 2013). Joel Levin's blog *The Minecraft Teacher*, which started in 2010 as a way of demonstrating applications for the game in various school subjects, eventually grew into *MinecraftEdu* (2011; Figure 3.19), an officially-supported version designed for teachers. This format allows the teacher to take the class into a virtual world, whereby they can use curricular content to produce something meaningful. This is the same premise described earlier by Papert, where variables were used to graph a shape in the *LOGO* programme.

[14] Procedural generation in modern open-world games such as *Minecraft* means that the player explores a theoretically infinite space, as the virtual landscape is determined not by direct manual design but by a generative algorithmic procedure.

Through *MinecraftEdu*, and other similar online communities such as *Massively Minecraft*, educators share lesson plans and even *Minecraft* worlds (which can be shared as with any other digital file format). The game has also been used to produce various modifications of an educational nature. *Circuit Madness*, posted by user *deco2000* on the forum *Planet Minecraft* in 2012, harnesses the circuit-building functions of the game to pose a series of challenges. With the block-breaking functions disabled, the player must rely on logic and knowledge of circuitry to navigate the space and complete the game. This demonstrates how sandbox games such as *Minecraft* have the potential not only for discovery learning and development within an open-ended virtual environment, but also the capacity for problem creation. Case studies exists of the game being used to teach programming skills (Repenning *et al.* 2014; Roscoe *et al.* 2014), scientific concepts (Short 2012), mathematics (Bos *et al.* 2014) and collaborative artwork (Overby & Jones 2015). Bos (2001, p.3), using *Sim City* as an educational tool, suggests that feedback should be instrinsic, relevant to accomplishment of the task at hand, rather than extrinsic, such as scoring points or winning prizes. Where students are engaged by a task and have an inherent desire to do better at it, effective teachers are able to reconcile learning outcomes with motivational feedback. Again, this relates to Papert's idea of 'constructing a meaningful public entity'.

3.4 Summary

In this chapter, I have suggested that interactive technology best aligns with the constructivist paradigm when it can be used to present an active and exploratory scaffolding environment, and where it promotes the social functions of learning. Within this context, digital resources which present musical concepts sequentially are less relevant than those provide a visible and tangible means for interacting with such concepts at a global level, and opportunities to apply these skills in a variety of open-ended settings. Resources like *Charanga* are very useful for illuminating curriculum content, and for being accessible for generalist teachers and novice learners. However, the open-ended format of digital audio workstations, not being prescriptively focused on specific examples or exercises, present further opportunities for discovery learning and creative ownership on the part of the student, where they can be effectively utilised as part of a socially-driven educational environment.

While there are many music applications aimed at the very young, there are far fewer music-making programmes specifically designed for school-age children (see 3.2). It is likely that the reason why we have seen an insufficient impact of technology on music education is because there is not enough music software designed specifically to support curriculum learning, or to assist less musically experienced students and teachers. My own background is principally in secondary school education, where I have found that each school tends to have a subscription to a commercial composing software package, such as *Logic* or *Cubase,* which is then used for all ICT-related music activities. Because these programs are not aimed at children, new students face a difficult task in learning how they work, and such lessons often focus disproportionately on the operation of the program rather than the wider relevance of the music activity. This is perhaps an explanation for the ineffective applications of technology that OFSTED (2012, p.54) criticized:

> While they were kept engaged by the tasks and enjoyed working with the sounds, most found it difficult to explain the reasoning behind their choices. Opportunities were missed to develop understanding of the musical syntax, form or the sampling processes that underlay the creation of the pre-composed loops and riffs that the students were using. Even where pupils were creating their own musical ideas in step-time or in real-time, limited evidence was seen of them going beyond the initial inputting of notes to shape the dynamics, articulation or subtleties of tempo for their ideas.

In this example, the students are unable to reflect upon their musical activity because the structures being employed did not effectively communicate the musical concepts in question, and the experiential learning cycle is un-propelled. Hence, further levels of sophistication in shaping musical ideas remains unexplored.

The arrangement of 'pre-composed loops' can provide an accessible means to 'select and combine sounds' (DfE 2013, p.2) that produces a coherent musical result. However, to move beyond this rudimentary key stage 1 skill, we must explore how the approach functions at different levels. We might 'zoom out' and ask, 'How do these building blocks form a verse, a chorus, an overall song structure?' Conversely, we might 'zoom in' and ask, 'What are these building blocks made of, and can we alter them for some intended purpose? What are these sounds? Can we cut them up into smaller blocks?' Such an approach is employed in the sequencing software *eJay* (see 2.2.3). To paraphrase the music curriculum, these examples can be thought of as 'other musical notations' through which the 'inter-related dimensions of music' (DfE 2013, p.2) may be made apparent, or may become interactively attainable, providing that there are opportunities for students to further explore the shape and subtleties of musical materials. There are several well-established examples of composition using larger, meaningful structures that are later broken down into constituent components. Notably, rhythm is traditionally introduced using word-rhythms that allow children to easily conceive and memorize rhythmic groupings. Drink names are typically used: tea (one crotchet), coffee (two quavers), lemonade (two semiquavers and a quaver) and so on. Simple rhythmic compositions are then easily represented. Once a system of rhythmic patterns has been established through musical activity, the concept of duration has some context of relevance to the children, and the groupings can be further broken down into smaller durational components. This approach has an empirical basis in Bamberger's *tune-blocks* (see 3.2.4).

Reflecting on the questions already established, I have asked how interactive digital technology may support creative expression in novice learners, and how constructivist theory may inform an effective interface design for musical learning. In summarising the ideas around interaction in digital learning environments that we have addressed in this chapter, I propose the following principles for a creative music interface. It should:

- Be based on meaningful experiential activity
- Allow students to perceive, interact and engage with fundamental musical concepts
- Yield evident outcomes in terms of what is learned (in curricular terms), but also in the production of a personally relevant creative achievement
- Be open-ended in format and encouraging exploration
- Facilitate social and collaborative learning
- Facilitate meaningful musical dialogue
- Support students in reflecting upon their musical work
- Have an accessible user interface for novice learners and non-specialist teachers

The kind of interface with which we are concerned would provide an environment in which students can interact with musical concepts in an active, meaningful and social way.

We have also discussed how certain open-ended platforms, termed 'sandbox' games, have been harnessed for educational purposes. This prompts a new principle for interface design, as well as a new question:

- *What conditions prompt creative musical learning in 'sandbox' environments?*

When the term 'sandbox' is used in this project, it refers to learning environments which are open-ended, exploratory and creative, but also accessible. In this type of environment, the starting point is the improvisatory ideas of the user, and the learning materials are *objects-to-*

think-with, which allow the learner to produce a *meaningful public entity* and to form their own conceptual map. Just as the child in the sandbox has tangible materials to shape according to their imagination, so the learning materials provided in a sandbox environment should allow the user to manipulate the creative concepts in play.

4. Methodology

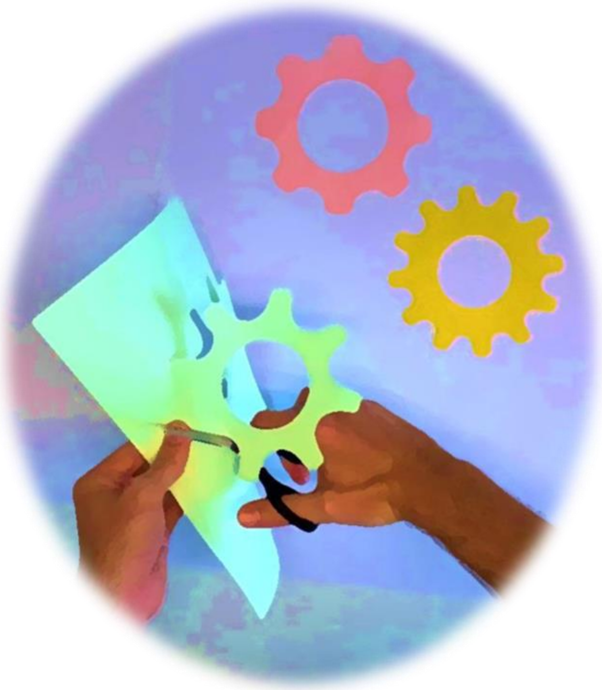


Figure 4.1

This chapter describes the research model adopted in this project. This is informed by two methodologies: A newly-proposed model for software design as educational research, supported by the established methods of grounded theory, which also contribute to the wider questions and theoretical outcomes. An overview of the research tools, timeline and process is also described.

4.1 Choosing a Methodology

4.1.1 Considerations

Through our examination of constructivism in music education, and within digitally-augmented learning environments, we have arrived at a set of initial design principles (see 3.4). It is important to clarify that in this context of instructional design, we are concerned not just with the production of a software artefact, but also a consideration of how this can be applied in a music lesson, the cognitive and social dynamics of such application, and its place within a wider framework of class and curriculum. Jonassen (1999, p.222) discusses this kind of constructivist design as defining a 'problem manipulation space [which] provides the objects, signs, and tools required for the learner to manipulate the environment' as learners 'cannot assume any ownership of the problem unless they know that they can affect the problem situation in some meaningful way.' This further illustrates the definition of *sandbox* as it is used in this thesis; a space for creative ownership over the problem itself as well as its solution, such that the outcomes are intrinsically relevant or valuable to the learner. Such a space must also employ what Jonassen (1999, p.222) terms *authentic representation* or that which is 'personally relevant or interesting to the learner', akin to the *capacity for personal identification* Papert describes in his *objects-to-think-with* (see 2.1.4). This is an important form of scaffolding, as it helps the learner to engage from the point of first use by building upon their existing comprehension.

This project requires a design methodology that will allow us to address these considerations. Methodologies for design and development, for software but also as a general rule, can be categorised as either top-down (starting with the goal design and then refining the constituent details) or bottom-up (an emergent process of piecing together from developing components). This model can also be applied to instructional design; Borgo (2007, pp.85-6) refers to this dichotomy when comparing rote-learning of musical concepts with discovery by improvisation and experiential learning:

> Complicated systems tend to involve a top-down model of organization that requires a strict hierarchy and the unerring execution of many sequential operations… Complex systems, by contrast, tend to involve bottom-up or 'self-organizing' dynamics that rely on extensive communication throughout a network of highly interconnected

> parts… In short, complex systems can produce ‘emergent’ behaviours; they offer the possibility for surprise.

The constructivist orientation of this research project aligns it with the idea of complex systems, or bottom-up design. We have a set of considerations, principles and initial target outcomes, which we will bring together and measure in a learning context, to achieve equilibrium between these component ideas and thus produce a meaningful solution.

4.1.2 Software Development as Educational Research

Reflecting on the developmental process of *jam2jam* (see 2.2.3), Brown (2007a, p.4) proposes a methodological model which ‘is concerned with deliberately employing designed systems that embody a hypothesis about educative experiences, in order to illicit new research findings.’ Software Development as Educational Research (SoDaR) situates software design in a context of constructivist educational research (see Brown 2012), an iterative process which draws directly from student experience and learning outcomes. The methodology aligns with complex system design, recognising the validity of emergent behaviours and rejecting the notion of absolute faithfulness to the initial design specifications present in top-down models:

> An important SoDaR feature should be the maintenance of a healthy skepticism about the degree of control the researcher has over outcomes. In this way control is understood as improvisation rather than direction and there should be a view to generating knowledge by capturing the opportunities that arise…
>
> (p.10)

This sensitivity to learning opportunities comes from testing and developing the resource in an experiential and educational setting[15].

Brown defines the approach as having three stages, and suggests possible research questions for each stage:

[15] Brown (2007a, p.10) notes how the text messaging component of *jam2jam* became a prominent design feature after its unexpected popularity among the students was observed.

Stage 1: Define the activity

- How will the activity lead to the desired learning outcomes?
- What educational value would be provided by the software?
- Why is software the best medium for providing this experience?
- Is the activity described at an appropriate level of detail?

Stage 2: Software Design and Production

- What data structure best supports (technically and pedagogically) the domain knowledge being represented?
- How does each software feature reinforce the design objective?
- What software platform will best enable production and deployment?
- Has the design and production process limited or expanded the educational implications?

Stage 3: Usage and Refinement

- Are the activity and software mutually reinforcing?
- What are the differences between the expected and actual behaviour of the students?
- How can the software and its use be improved?
- Are the students achieving the desired learning outcomes?

(Brown 2007a, pp.5-7)

This can be characterised as a qualitative research process which seeks to determine specific added value from the application of developing software in educational settings. Being situated in and emerging from particular environments and contexts, SoDaR is undertaken with an interpretivist perspective that the experience of individuals and the influence of their surround should be evaluated:

> Research findings generated using the SoDaR approach are limited to the studied contexts in the same way as other methods used within qualitative research studies. While this can be alleviated somewhat by studying multiple sites or classes, generalizations should be made with caution and context dependency taken in to account.

(p.9)

The process has clear links to action research in education (see Mills 2000; Carr & Kemmis 2003). The working environment, in this context, may be taken to be the school environment or the virtual environment. Receptiveness to unforeseen possibilities is emphasised within the SoDaR method (Brown 2007a, p.10). Though generalisations are to be viewed with caution, significant results demand further examination and should be presented in context. This is in line with Bassey's recommendations regarding 'fuzzy' generalisations (1998; 2001).

4.1.3 Grounded Theory

Grounded theory is a research methodology originally proposed by Glaser and Strauss (2017) which has been described as compatible with the constructivist ontology (see Charmaz 2014; Mills *et al*. 2006) and the work of educational practitioners, among other social fields. As the grounded theory researcher collects data, often supported by the writing of memos, they look for *codes*, or recurring units of qualitative data (words, ideas, etc.), which form *concepts*. These are then grouped into *categories*, from which the theory ultimately emerges (Breckenridge *et al.* 2012). Due to the exploratory and flexible nature of grounded theory, a number of variations have been proposed. For Glaser (1992), an emergent approach, characterised by an essentially consistent application of coding methods at micro and macro levels of analysis, is favoured. This argument is made in his *Basics of Grounded Theory Analysis*, a response to the methods elaborated by Strauss (1988). Charmaz (2000) proposes that the grounded theory researcher acknowledge and examine his or her own perceptions to mitigate bias. Glaser (2002) argues that pattern received by the researcher, and resultant theory, are all part of the data and methodological process.

4.1.4 Mixed Methodology

SoDaR is a suitable model for this project, but also one which was only recently proposed, and which has not undergone substantial testing. I therefore decided to base my practical research model on SoDaR, but to combine this with grounded theory. This serves two purposes:

1. This research is practice-led, and therefore has two main outputs; a practical output – in this case, the software artefact – and also a theoretical output emerging from the application and examination of this practice. While SoDaR enables me to produce the

practical output, this requires support from a more theory-oriented methodology to analyse and comment upon the process. The combination of these methods therefore allows me to fulfil both aims.

2. Again, because I wish to comment upon my practice, grounded theory allows me to step back and review the process at every stage, including critical analysis of the methodology itself. I can therefore analyse in turn the effectiveness of this methodological approach.

By combining SoDaR with the analytical coding methods of grounded theory, I aimed to follow a complex system of design that is responsive to emergence and inclusive of the interconnected considerations of software development, musical creativity, and educational practice.

4.2 Research Tools

4.2.1 Programming Platform

The programming platform is a research tool which provides the software artefact, or practical outcome. This in turn becomes a research tool for producing a theoretical outcome, through application in educational contexts. The software platform used for developing this resource will be *Pure Data* (*Pd*), an open-source, object-oriented programming language suitable for audio interfaces. *Pd* presents a number of advantages over other possibilities:

- As an open-source language, it is freely available and developed by a supportive online community. This allows for the production and sharing of a freeware resource which can be further developed and customised by the wider user base (see Hart 2017a, p.414).
- Object-oriented coding languages allow processes to exist as manageable structures, making the programme easier to edit in response to outcomes emerging from its use. This makes it more suited to bottom-up programming than pure text-based languages such as *C* or *Python*. It also allows me to design, develop and deploy software artefacts using a single platform.

- *Pd* has many user-developed external libraries for a range of purposes. One of the most widely used is the graphical processing library *GEM* (graphics environment for multimedia) which will be useful for generating our objects-to-think-with.
- *Pd* runs on all major operating systems, and can be used as a processing platform for mobile interfaces and apps.

However, there are also disadvantages to using *Pd* over other software platforms: As an open-source platform with no commercial interest, developments can be unreliable, and unstable releases are occasionally encountered. The platform *Pd-extended*, which combines the core language with external user libraries to extend the functionality, was used for much of this research project. The final stable release of this platform was in 2014, after which it was abandoned by the community. Many users (including myself) continued to use *Pd-extended*, as the same range of possibilities was not immediately available within *Pd-vanilla* (the core language). Later releases of *Pd-vanilla* allow the user to install and connect these external libraries. The developed version of the software artefact produced for this research was eventually migrated to *Pd-vanilla*, to allow for further continual development. However, this means that the external libraries have to be added by the user in order for the programme to work, where in *Pd-extended* they were immediately available.

4.2.2 Additional Software

Besides *Pd* and the software artefacts produced in this platform, a number of other software resources were used in this research. Bespoke applications were made using *MobMuPlat,* a mobile music platform for building graphical user interfaces with audio engines made in *Pd* (see 7.4; 7.7; 7.8). *Ableton Live* was used as a sound source in early exhibitions (see 6.1; 6.2). Finally, the digital audio workstation *GarageBand* was used as a counterpoint to the earlier research in a final series of studies (see 7.8).

4.2.3 Hardware

Many of the hardware resources used for this research could be provided by the schools; percussion instruments and keyboards were typically available, as were headphones. Electronic resources, such as laptops and touchscreen tablets, were often also offered by schools. However, due to the need to develop bespoke applications, all laptops and tablets were sourced prior to the studies taking place.

A stock of iPads was available for loan at the university, and were borrowed for some of these studies (see 7.4; 7.8). A sufficient supply was available to provide one per pupil, even when working with entire classes. Laptop computers presented a greater challenge to source; several second-hand laptops were purchased and restored specifically for this project, while others were borrowed temporarily. Consequently, the maximum number of laptops used in this research was limited to eight (see 7.6). This issue was often resolved with smaller group sizes, so headphone splitters were also frequently used (for iPads as well as laptops). A set of eight 6-way headphone splitter units were obtained to enable group work on laptops.

4.3 Research Model

4.3.1 Timeline

In SoDaR, the software artefact is continuously weighed against learning outcomes to identify the criteria for its refinement; the extent to which the desired outcomes are achieved, the presence of any unexpected outcomes, and the question of whether software and activity are ‘mutually reinforcing’ (Brown 2007a, p.7). As such, the developmental relationship between the software and learning activity can be thought of as a form of *equilibration*. Brown acknowledges the links to reflection-in-action (p.6), Schön’s (1987) model of reflexive practice, which has parallels with the cycle of experience and reflection proposed by Kolb (1984).

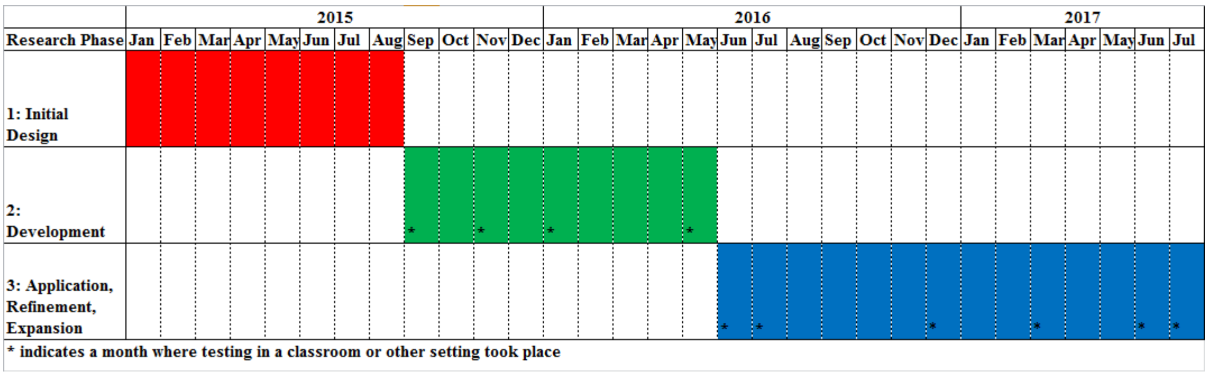


Figure 4.2 – Gantt chart of phases 1-3

This research project was characterised by distinct phases (Figure 4.2):

Phase 1: January – August 2015

During this phase, the activity was defined through analysis of relevant literature (including the National Curriculum for Music). This also led to the formation of the research questions (as documented in chapters 2 and 3). Initial developments and designs were explored to produce a prototype software artefact, *Graphick Score*.

Phase 2: September 2015 – May 2016

During this phase, the software artefact was presented as a working prototype at exhibitions and some initial classroom settings. These focused on the programme itself, with participants being asked to complete some simple task with it, and then comment upon how it might be improved. Questionnaires were also briefly used during this period, asking participants about their own level of musical ability, as well as their opinions of the programme. A number of studies were conducted:

- September 2015: Exhibition at University A (referred to as the pilot study)
- November 2015: Exhibition at University B
- January 2016: Focus group at School A (Year 7)
- May 2016: Focus group at School A (Year 7)

Phase 3: June 2016 – July 2017

During phase 3, the software had reached a state of sufficient user-friendliness that it could be used as part of a music lesson without the need to acknowledge that it was a developing prototype. Consequently, the focus within these sessions shifted from the software itself toward the learning activity and outcomes. The extent to which these successes were present in the lesson became the criteria for the refinement of *Graphick Score,* so development occurred alongside being fully deployed for its intended purpose. It was during this phase that the most valuable unexpected outcomes emerged, as the users were applying their creative ideas and intentions to the environment, and looking for ways of doing what they wanted to do, rather than their activities being bound by the limitations of what the programme could do. It became apparent during this phase that *Graphick Score* was aligning with the definitions of a sandbox environment described in chapter 3, and that the software and activity were undergoing a process of mutual reinforcement.

During the later stages of research, I began to use touchscreen tablets in the classroom, utilising both commercial and bespoke apps to examine the implications for musical performance as well as composition. These studies are interconnected with the research on *Graphick Score*, contributing to the same research questions, or acting as a counterpoint to earlier research. As such, these studies are included in phase 3, and presented in chronological order.

All the studies conducted for phase 3 all took the form of music lessons rather than exhibitions or focus groups. Some of these were single lessons, while others were split into two sessions, or spread over an entire school day. The specific context of each study is indicated in chapter 7:

- June 2016: School B (Year 6)
- July 2016: School C (Year 5 and 6)
- December 2016: School B (Year 5)
- December 2016: School B (Year 5) (re-visit)
- March 2017: School D (Year 5)
- June 2017: School C (Year 3)
- July 2017: School C (Year 6) (2 days)

The research model, indicating phases, individual studies, and data collection and analysis, is described by Figure 4.3. A diagram of codes and concepts emerging from this research, as well as the analytical process, can be found in section 8.1.2 (Figure 8.2).

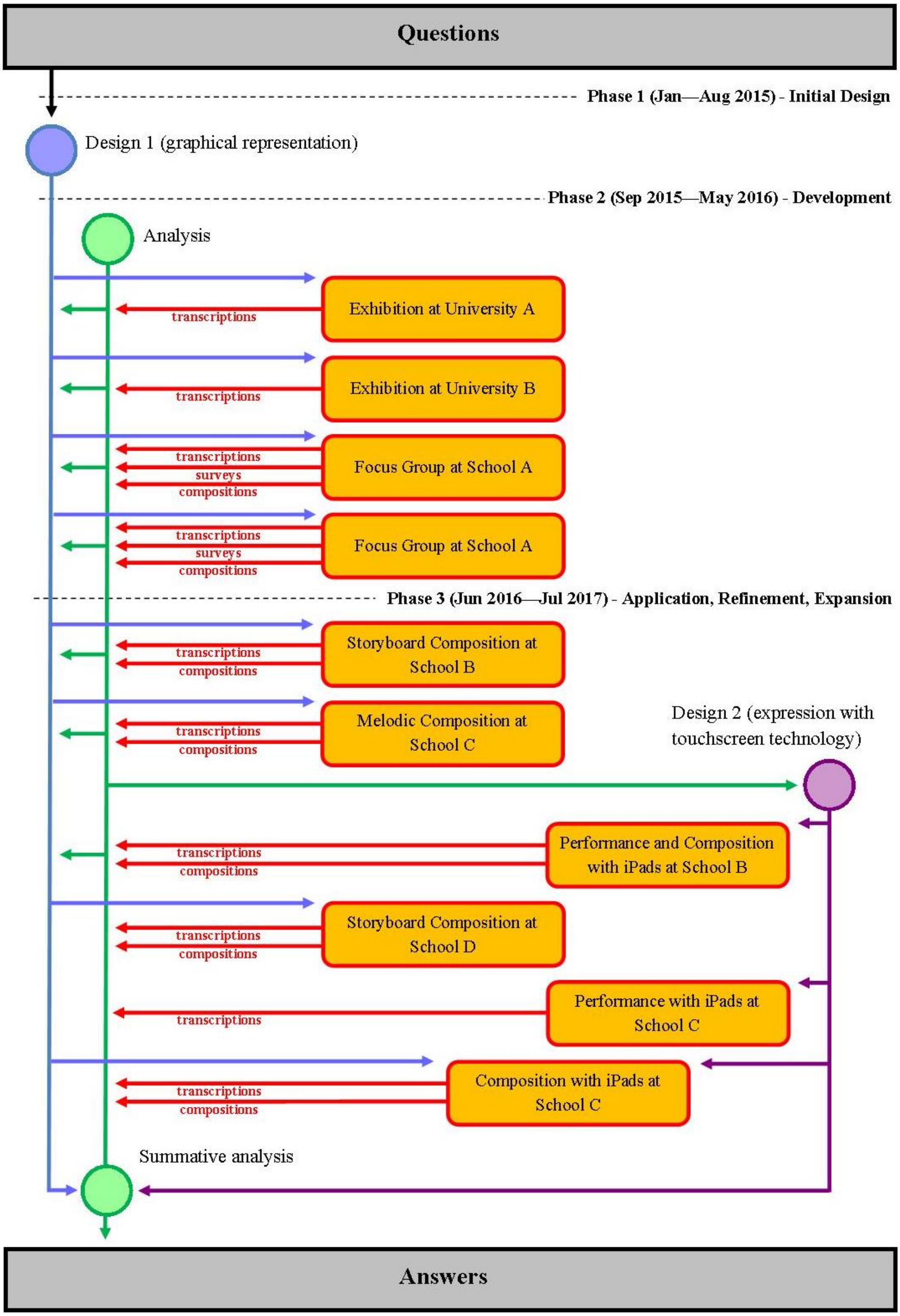


Figure 4.3 – The research model for data collection, analysis and application. Studies across phases 2 and 3 are indicated, along with the emerging data types.

4.3.2 Data Collection and Analysis

A range of data collection methods were consistently applied; audio recordings were made during studies, and later transcribed, and memos were also often written to record observations. A single notebook was used throughout the entire research project, to consolidate observations on literature review, programming and testing. This allowed emerging codes to be identified through continual consultation of notes. All work produced by pupils during phases 2 and 3 was saved and analysed, in addition to being sent back to the school for distribution to the pupils. This mostly consists of files made with *Graphick Score*, video exports of which can be found in the electronic appendix.

In accordance with the recommendations of Glaser (1992), a process of coding for emergence was applied at all stages. Various data types are therefore analysed using the same process:

- Audio transcripts
- Written memos (during reading, programming and testing)
- Software artefacts (produced through programming)
- Musical artefacts (produced by the pupils using the software)
- Unstructured interviews with pupils and teachers

This led to concepts being established, which are presented through the reflective summaries at the end of each study (see chapters 5-7). Further coding of these concepts produced wider conceptual categories, presented at the end of each phase of research. This ultimately led to the formation of a theory grounded in this research data (see 7.9).

In total, the studies conducted during phases 2 and 3 involved approximately 200 participants, though a wider audience has been reached through dissemination at conferences, and casual observers taking part in the earlier exhibitions. This is within the target sample size given in the research proposal and ethical approval form. While it should be noted that this constitutes a small sample size in relation to other qualitative research projects, other considerations particular to this type of research model should be taken into account. In this project, I have acted as a solo researcher and programmer to undertake an interdisciplinary practice-led investigation. The value of this approach has been described in this chapter, but is also recognised by Brown (2007a, pp.7-8):

> Research is often a solo venture, where the researcher undertakes all tasks from literature review, to data collection and analysis, to presentation of findings. In

educational research this is reinforced by the culture of 'solo' teacher. As a result, the software engineering skills required by SoDaR may seem a prohibitive boundary to many researchers… It is worth emphasizing the benefits of developing software engineering skills for those so inclined. Learning to program a computer changes the relationship between the person and the computer, such that the person can create what they need rather than having to accept only what features the machine provides. Also, as a mode of expression, computer languages provide both an alternative mode of thinking and opportunity to communicate ideas. These advantages apply to software development as they do to developing skills in other modes of expression, such as water-color painting, calculus, rhyming couplets, or music notation.

This acknowledges the creative and expressive nature of the practical programming component of SoDaR, and its relevance to pedagogic considerations such as communication. Also, Brown seems to suggest here that the educator undertaking all or part of the programming task, even from a relatively amateur position, is gaining a relevant creative and pedagogic insight, therefore presenting an opportunity for personal and professional development. Adopting this model has necessarily restricted the number of studies – and subsequently participants – compared to non-practical projects, as a proportion of research time is dedicated to the programming task, which forms a prominent part of the narrative of this project.

It should also be noted that issues of small sample size and subsequent concerns around generalisation are common in educational research, and many theorists have proposed allowances for this apparent deficiency (see Bassey 1998; 2001). Where the solo teacher conducts research focused on their practice and outcomes, the sample is inherently restricted to the local demographic of their school and students. If the experience of such a practitioner is of value to research communities (see 2.2.2) it must be taken into account that these outputs have a contextual dependency upon the particular practice of that individual; this is seen in action research, for example. Bridges (2003, p.190) argues that educational principles must be grounded in experiences of classroom practice or this presents a generalisation in itself:

We probably do not even fully understand our educational values until we have seen them implemented or seen the conflicts which arise in practice between different principles to which we ascribe in general abstract terms. We can come to understand

> our philosophical principles differently by seeing them realised in practice, and hence experience can come to change the principles we hold as well as being informed by them. We can evaluate our experience by reference to our principles: and we can re-evaluate our principles by reference to our experience of their realisation in practice.

This seems to describe an equilibration between practice (and emerging experience) and educational principle, an idea to which the constructivist grounded theory-informed approach adopted for this project conforms. Where this practice is part of the research model, as in this case, a limited sample size may be expected. However, this type of focus has its own particular value, according to some researchers:

> Generalisations derived from much educational research based on large samples may be positively misleading, since findings derived from large scale studies are not necessarily reflected in the much smaller numbers that teachers are concerned with
>
> (Foreman-Peck & Murray 2008, p.145)

With a close focus on specific situations and emerging outcomes directing practice, this qualitative model, with its smaller sample size, is akin to the complex dynamics of my chosen programming model (see 4.1.1) and therefore appropriate to an exploratory and creative project. Findings may be used, albeit with caution, to make wider recommendations for further research. As Pring (2000, p.131) notes, 'no one situation is unique in every respect and therefore the action research in one classroom or school can *illuminate* or be suggestive of practice elsewhere.'

I have combined the areas of practice in this project to define an approach which is exploratory yet has reasonable expectations and outcomes, with respect to the work which can be achieved by the sole researcher and the reliability of the results. This requires certain changes in situation and setting to define certain key variables, in line with the emergent grounded theory model proposed by Glaser (1992). Therefore, I address concepts which are 'fuzzy', yet of value in informing further research; Bassey (1998) argues that such generalisations are inherently valuable if situational dependency is taken into account in the presentation of results. His approach is summarised by Mejía (2009, p.7):

1. Suppose that in a situation s1, the carrying out of action x leads to result y.
2. The fuzzy proposition is drawn that in other situations like s1it is possible that x may lead to y.
3. Suppose that a couple of replications are carried out in chosen situations s2 and s3 and it is found that in both, x leads to y.
4. The fuzzy generalisation is drawn that in other similar situations x is likely to lead to y.
5. Suppose that in a further replication at s4 it is found that x does not lead to y.
6. The researchers examine in detail not only what happened in s4, but go back through s1, s2 and s3 and try to modify the description of x to find an x' such that in s1, s2, s3 and s4, x' leads to y.

Similarly, Brown (2007a, p.9) recognises that this is likely to be a concern, and advises recognition of contextual dependency (see 4.1.2). Therefore, results can be presented by providing an account of the situation and considering the circumstances under which identified codes emerge. Concepts, too, are situated in these contexts, but are reinforced by emergence from multiple situations.

In order to account for any situational dependency and mitigate generalisation, presentation of each study is divided into three sections:

1. Context: *What was the purpose/background of the study?*
2. Method: *How was the study carried out?*
3. Results: *What findings emerged from the study?*

A discussion of the findings is combined with the results in each case, as the coding process is drawn from a variety of outcomes, including pupil work, transcriptions of audio and general observations. Wider discussion on emerging concepts observed in multiple situations occurs at intervals. These results produce a refined software artefact, but also a theoretical outcome grounded in this practical research. Crucially, this model can be replicated by other researchers using the same software artefact, or with comparable resources.

5. Phase 1: Initial Design

January – August 2015

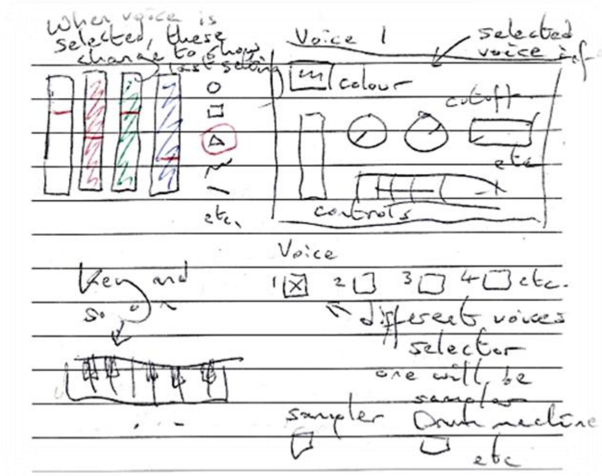


Figure 5.1

Phase 1 of research concerned the defining of an activity where digital technology can provide added value and producing a prototype artefact from these considerations. This process was grounded in the review of literature, including the National Curriculum for Music. As such, it should be noted that this process is partly concurrent with the development of the research context outlined in chapters 2 and 3, though I focus in this chapter on the influence of these wider theoretical ideas in shaping my practice. An account of this exploratory process of developing an interface in Pure Data is given, culminating in a prototype composing environment, Graphick Score*.*

5.1 Defining the Activity

5.1.1 Overview

The first step of the SoDaR method is to identify a learning situation which can be supported by a new software application. This should be a situation where digital technology presents a clear added value (see 3.1). I concluded chapter 3 with a list of design objectives for the resultant artefact, noting that it should:

- Be based on meaningful experiential activity
- Allow students to perceive, interact and engage with fundamental musical concepts
- Yield evident outcomes in terms of what is learned (in curricular terms), but also in the production of a personally relevant creative achievement
- Be open-ended in format and encouraging exploration
- Facilitate social and collaborative learning
- Facilitate meaningful musical dialogue
- Support students in reflecting upon their musical work
- Have an accessible user interface for novice learners and non-specialist teachers

We are concerned here with creative processes, resulting in a 'meaningful public entity' (see 3.1.1). This should lead to outcomes which are 'intrinsically relevant' (see 3.3) to the interests and motivations of participant students. Furthermore, digitisation of these processes should result in an added value. From an experiential perspective, this involves minimising the need for non-musical activity (explanatory verbal communication), and maximising the amount of real musical behaviour in the lesson. Digitisation should also support the reflective process; Students should be able to refer to the musical activity with clarity, and use this to progress on to further musical activity. The musical concepts in question should be visible (clearly communicated through digital representation) and tangible (able to be manipulated in an experiential manner, in order to further understanding of these concepts).

5.1.2 Experiential Composition

In chapter 2, I discussed perspectives and examples of how improvisation can lead to musical creativity, and suggested that inspiration may be thought of as part of an experiential process. The curriculum tells us that pupils at key stage 1 and 2 should compose with the 'inter-related dimensions of music' (see 2.2.1). However, this implies a paint-by-numbers approach to composition that is not reflective of creative process. These concepts are the result of compositional process, not the tools which are used to engineer it. They are useful musical descriptors, providing a framework for dialogue, but as isolated abstract concepts, they have no inherent creative value; hence, *inter-related*. This accounts for what research tells us about composition in education; even among specialist music teachers, it is a source of uncertainty (see 2.2.1).

These musical dimensions result from creative process, from intention effectively enacted in some way. This too is a nebulous idea, but the teaching of composition must involve creative modes of interaction where some scaffold is provided, which enables students to see the link between their creative intention and a musical result. If 'compositional thinking' is to be able to conceive of ideas as musical possibilities, then we teach this by providing an environment which supports that connection, where interaction is more likely to result in this construction of meaning on the part of the learner (see 3.1.1). For the novice learner, this involves improvisation with new ideas or processes which have some recognisable significance to what they can already creatively accomplish; *what creative processes does the learner already understand, and how can this be related to a new compositional process.* Transparency is the added value that interactive digital technology can provide in this process (see 2.2.3).

Gall and Breeze (2005, p.416) suggest that compositional process (in general, as well as in education) is inherently shaped by the affordances of the available software environments. They quote Trouche (2003, p.2), who suggests that 'tools shape the environment', and that the learner may in turn shape these tools to meet their creative intentions. This provides an example of creative interaction. A tool may be used, and a result obtained. Differentiation or progression occurs when the tool is shaped to achieve a different conceived possibility, exerting control over the 'problem manipulation space' (see 4.1.1). Evidence for this is provided through reflection on this process.

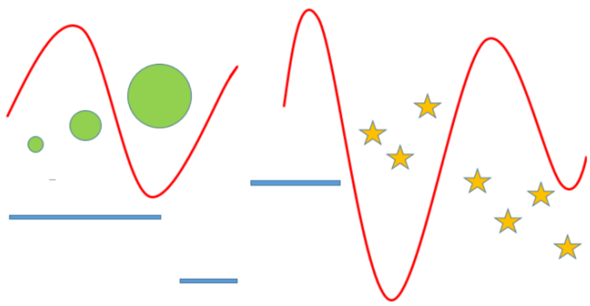


Figure 5.2 – An example of graphic notation, where symbols represent musical dimensions

The key stage 2 curriculum tells us that students should compose with alternative notations (DfE 2013, p.2). As a teacher, I make use of graphic notation to clarify musical dimensions (Figure 5.2). These notations, and the means of producing them or manipulating them, may provide a scaffold for compositional processes. These can be the tools which the learner shapes, making abstract learning aims such as the inter-related dimensions of music more visually and tangible accessible (see 3.1.1; 3.1.2).

5.1.3 Expected Outcomes

The expected outcome of phase 1 was a sandbox interface for making a graphical score, allowing students to immediately engage with a music-making task and to reflect upon their decisions with reference to a visual score which clarifies musical concepts. The activity was conceived to build an understanding of the inter-related dimensions of music by allowing students to engage with these concepts experientially, to see them as a result of their creative decisions rather than being exposed to these ideas in the abstract.

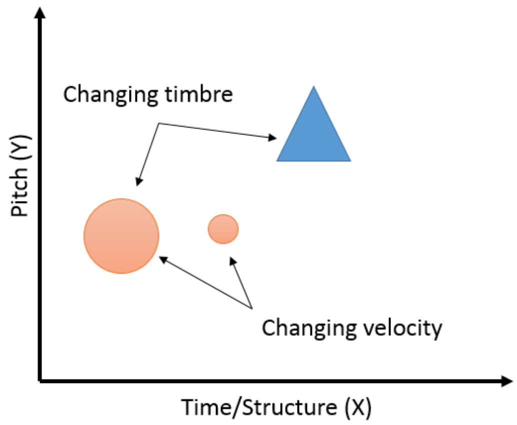


Figure 5.3 – A suggested initial framework for mapping musical dimensions to graphic notations

Graphic notations can provide accessible representations of musical concepts, so allowing students to access these ideas through a software interface can provide a visual, audible and kinaesthetic mode of interaction with otherwise abstract concepts. Staff notation, it should be noted, is itself a graphical system, albeit highly codified and, consequently, more amenable to behaviourist teaching methods than open-ended systems. With software, these representations have the capacity to become interactive and responsive; a user can move a representation of a sound vertically on a screen, or across the Y axis, to hear it change in pitch (Figure 5.3). This reinforces the language we use to describe changes in pitch; up and down. Similar representations can be explored for other musical concepts. As such, this provides the possibility for objects-to-think-with, from which students can synthesise their understanding of abstract concepts through experiential learning.

The wider aims of this research directed me toward an open-ended sandbox approach and a bottom-up design (see 4.4.1), so I reasoned that the dynamics of learning, within this activity, would become clearer as the software was developed, applied and refined, as long as an area in which digital technology could provide added value had been identified. This is in line with the emergent methodology described in chapter 4. At this stage, it was appropriate to describe the activity as follows:

> Students will be set a composing task using the software which directs them to make a simple musical decision (a quiet or loud sound, a high pitch or low pitch etc.) By being guided to reflect upon the connection between the musical result and the creative intentions, further decisions will be reached, leading to the construction of a graphic score which communicates a story through music. This will allow students to reflect upon how specific musical features communicate this meaning, illustrating how the dimensions of music function in combination.
>
> (from my notes, January 2015)

5.1.4 Domain Knowledge and Data Structures

Brown (2007a, p.6) suggests that the SoDaR researcher, upon commencing the development stage, ask how the software platform supports the domain knowledge. In software engineering, domain knowledge refers to the specific area of knowledge that the software aims to address. In this instance, our domain knowledge can be summarised as follows:

- Pedagogical representations of the inter-related dimensions of music; pitch, dynamics, duration, timbre, texture, structure and tempo
- Creative interaction in sandbox environments
- Experiential musical learning

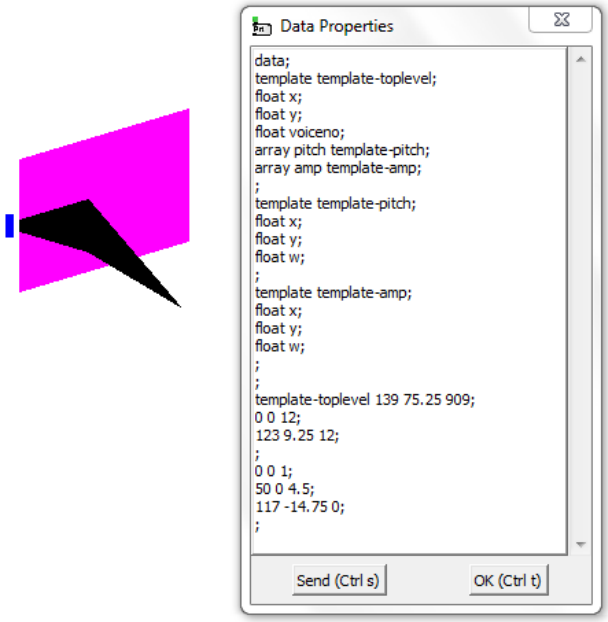


Figure 5.4 – Data structures in *Pd.* Three graphical values (*x*, *y* and *w*) are used to create envelopes for the musical dimensions of pitch and amplitude

The most important element of domain knowledge here is the consideration of how to present the dimensions of music in a way that makes them accessible to novice learners within this sandbox environment. I have discussed how graphic notation can effectively represent these concepts in pedagogical contexts, so the question that follows is how best to apply this understanding to an interactive digital format, or, in simpler terms, how to move from the stage of defining activities to the stage of pursuing a solution through programming. In commercial software engineering, programmers do not typically possess the domain knowledge in question, and consequently often work with highly detailed specifications in order to accurately address this knowledge during the development process. One of the advantages of the approach I have adopted is that it allows for reflexive interaction between the intended outcomes and the domain knowledge, and is therefore more suited to bottom-up design.

The domain knowledge can be represented by data structures; ways of combining and representing data in order to make it more accessible. In *Pd*, lists of data corresponding to different parameters can be represented as geometric *scalars*. This allows the user to alter the scalar directly with the mouse, which changes the parameters of the sound. In the example (Figure 5.4), the pink and black polygons represent pitch and amplitude envelopes of the sound event represented by the blue rectangle. The values *x*, *y* and *w* (the co-ordinates and width at any point) seen in the properties window denote variables, corresponding to both the dimensions of the polygon and the sound envelope. Interacting with the scalar, rather than the code in the properties window, offers a much more intuitive and accessible mode of control over these values, which may be thought of as a form of scaffolding.

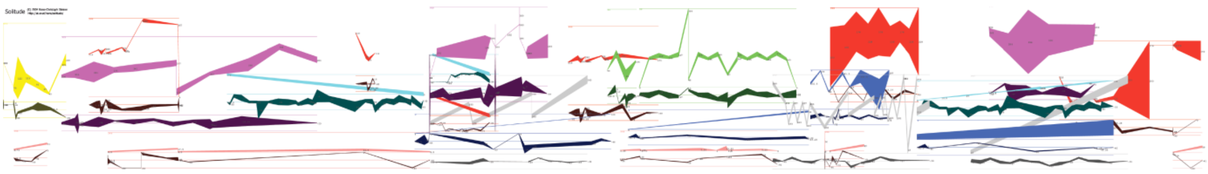


Figure 5.5 – *Solitude* by Hans-Christoph Steiner

This approach may be used to engineer a direct link between visual and musical representation, where data structures can be copied, pasted, dragged and resized, resulting in corresponding changes to the musical output. An example of this is *Solitude* by Hans-Christoph Steiner, an interactive piece composed in *Pd* which consists of a complex sequence of envelopes which can be edited and reassigned (Figure 5.5). In this project, my aim is to make an interactive graphic score environment that is more suitable for pedagogical applications, and where a clear relationship exists between the data structures and the domain knowledge (the inter-related dimensions of music).

5.2 Initial Development

5.2.1 Glossary

The following basic *Pure Data* (*Pd*) terms are used in this account, so they are briefly explained here for convenience:

- *Patch* – A *patch* is a computer programme made in *Pd*. This may contain patches within patches, which are known as *sub-patches*.
- *Object* – Patches are populated by *objects*, each of which fulfils a specific purpose. Objects are combined to build complex processes.
- *Message* – *Messages* are sent to objects to alter their behaviour.
- *Bang* – A *bang* is a basic message which serves as a trigger.
- *Argument* – An *argument* is additional data which defines how an object behaves. It may be sent in a message.
- *Variable* – A *variable* is a non-constant value, which may be altered via messages. In *Pd*, variables are represented by dollar symbols ($).
- *Abstraction* – An *abstraction* is a type of patch which is recalled, often to be used many times with changing variables. These may be *dynamically created* (see A.2.4).
- *Library* – A *library* is a set of inter-related *Pd* objects. The open-source development of *Pd* means that many external libraries other than the basic core library are available. The now defunct *Pd-extended* collated many of these libraries, while in *Pd-vanilla* these must be added manually.
- *GEM* – *GEM* (graphics environment for multimedia) is an external library for graphics processing. *GEM* is used extensively in the development of *Graphick Score.*

Graphick Score, as well as most of the alternative designs described here, consists of the following main components:

- *Canvas window* – The *canvas window* is the window in which *GEM* graphics are displayed. It is the primary means of interaction by the user. The canvas window is most often read from left to right. The X axis may or may not be divided into a metric grid of bars of beats, while the Y axis may or may not be divided according to a musical scale.

- *Geo* – A *geo* is a geometric *GEM* object displayed in the canvas window. It may be a simple shape or a more complex 2- or 3-dimensional design. The visual characteristics of geos, such as their size and position, are linked to musical variables.
- *Painting/drawing…* – Interaction with the canvas window, to create or manipulate geos, is variously termed *painting, drawing, sketching, sculpting,* or any other suitable term which suggests kinaesthetic, exploratory and creative behaviour.
- *Scene* – The user composes in different *scenes*, which can be looped or sequenced. Each scene stores geos and settings to be recalled, allowing the user to switch between them.
- *Graphics menu* – The *graphics menu* is usually located to the right of the canvas window. It is the means by which the user makes selections relating to graphics, which also alters musical variables.
- *Instrument menu* – The *instrument menu* is usually located below the canvas window. It is the means by which the user chooses sound sources, such as VST or general MIDI instruments.

5.2.2 A Note on the Programming Process

The following is an account of the programming undertaken during phase 1. This was a largely exploratory process, based on the principle of manipulating graphics to achieve a musical result, with transparency between mode of interaction and outcome. Ideas were recorded in a notebook, alongside reflections on the literature review. Patches were saved in a repository, and archived at present state whenever significant changes occurred. This was typically at a rate of once per week, though in later phases, with less frequent programming changes, archiving was undertaken at a rate of approximately once per month.

Brown (2007a, pp.10-11) suggests that 'examples of computer code will not be useful to most educational audiences' but that they are still 'likely to be a significant part of examinable thesis presentations of work done using [SoDaR].' The most prominent changes to programming are given in this account, while later phases contain shorter summaries of developments alongside field research. Incidentally, only patches and examples of programming which in some way relate to phases 2 and 3 are presented here. Consequently, many options were explored during this phase which have ultimately not been included as part of this narrative; only those with significance to the educational outcomes of this project are presented. Furthermore, due to the size of the resultant programme, the processes are mostly presented for a non-specialist audience, with reference to the user-friendly interface rather than the code underpinning it. However, the entire artefact is available in the electronic appendix, along with an explanatory file describing how the code may be viewed.

It should be noted that patches were named on an impulsive basis, as is my usual process when programming, as this helps me to recall their specific details. The names of these patches became the name of the interface, where used for field research. This often involves a simple description of the process (‘sound painting’). Where possible, I avoided any names that might be difficult to locate in search engines; hence *Graphick Score* is deliberately mis-spelt. The patch was originally one of several possible variations, but ultimately emerged from this phase as the central research outcome. All titles are working titles only, and are subject to change after this research project, where a new name may be chosen for any artefacts which continue to be developed.

Finally, I have stated that *Pd* is an open-source platform, and that the software outcomes of this project are similarly open-source (see 4.2.1). I have maintained this standard at all stages of programming by using only royalty-free images and sound files. Therefore, all external images and audio files used in the construction of *Graphick Score* are royalty-free.

5.2.3 Sequencing in GEM

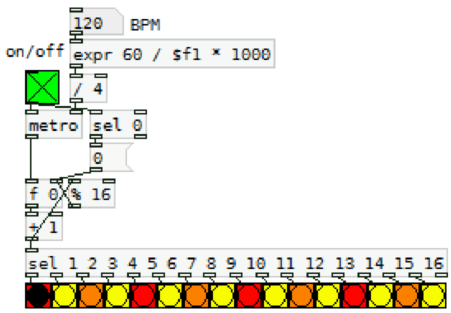


Figure 5.6 – A basic 16 step sequencer

My early experimentations for composing environments in *GEM* were based upon 16 beat sequencers, with a cycle of 16 sequential bangs (Figure 5.6). These patches consisted of a canvas window in which different geos could be set at different present positions by clicking (Figure 5.7). Turning on a geo opened a gate in a sub-patch for each of the 16 steps, allowing the bang message of a particular step through the gate, and triggering a corresponding sound. These were often audio files, or sine waves with basic amplitude envelopes (Figure 5.8). Each geo ‘lit up’, by momentarily increasing RGB values, when its position in the cycle was reached.

These patches were conventional in design and offered little in the way of originality or creative exploration. Later versions allowed the user to switch between different canvas windows to build larger structures of sequential 16 beat loops, and offered more sound design possibilities. However, the creative possibilities at this stage remained limited.

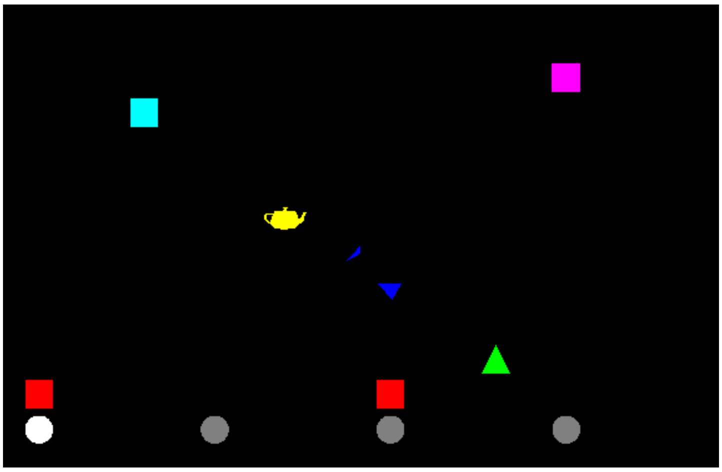


Figure 5.7 – The canvas window in my earliest patches

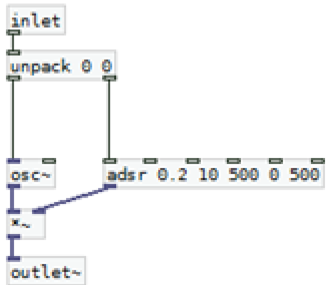
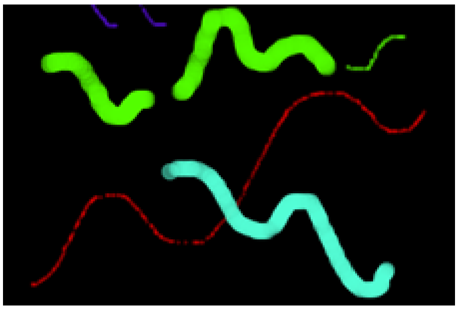


Figure 5.8 – A sine wave oscillator and amplitude envelope, used as a sound source in early patches

5.2.4 'Painting' Sound



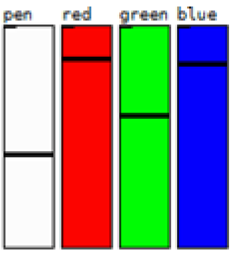


Figure 5.9 – 'Painting' in the canvas window

Wanting to move away from the metronomic format of sequencer interfaces and toward a more open-ended layout, I began to explore how 'painting' might be achieved with *GEM*. Alpha blending allowed geo 'trails' to be drawn in the canvas window, by following the path of the mouse position with the left button held down, giving the appearance of brush strokes (Figure 5.9). The width and colour of these lines could be altered with sliders mapped to the size and RGB values of the geo (Figure 5.10). The right mouse button was used for clearing the buffer in *GEM*, clearing the canvas window. Sound was achieved by mapping the Y axis of the canvas window to pitch and the geo size to amplitude, with the left mouse button opening a gate so the oscillator could be heard; this meant that drawing in the window produced the corresponding changes in pitch.

My goal at this stage was to find a way for the user to 'paint' musical gestures in the canvas window and play back the contents. This became the basis for much experimentation. I eventually achieved an acceptable result by writing and reading .txt files. These files contained a number of lines (e.g. 0-1000) corresponding to the X axis of the canvas window. As the user moved the mouse in the window to draw a line, a pair of values (the Y value and the geo size, which were mapped to MIDI pitches and velocity values) was written to the text file at the line corresponding to the position on the X axis (Figure 5.11). Overlapping simply appended the new pair to the line, generating the possibility for polyphonic playback. The text file could then be 'read' through line by line at variable speed, outputting the pitch and velocity pairs to an oscillator. Different text files could be written as the RGB values changed, generating the possibility for playback of multiple voices. I recognised that this was a very different mode of interaction from earlier patches, and indeed from conventional music software.

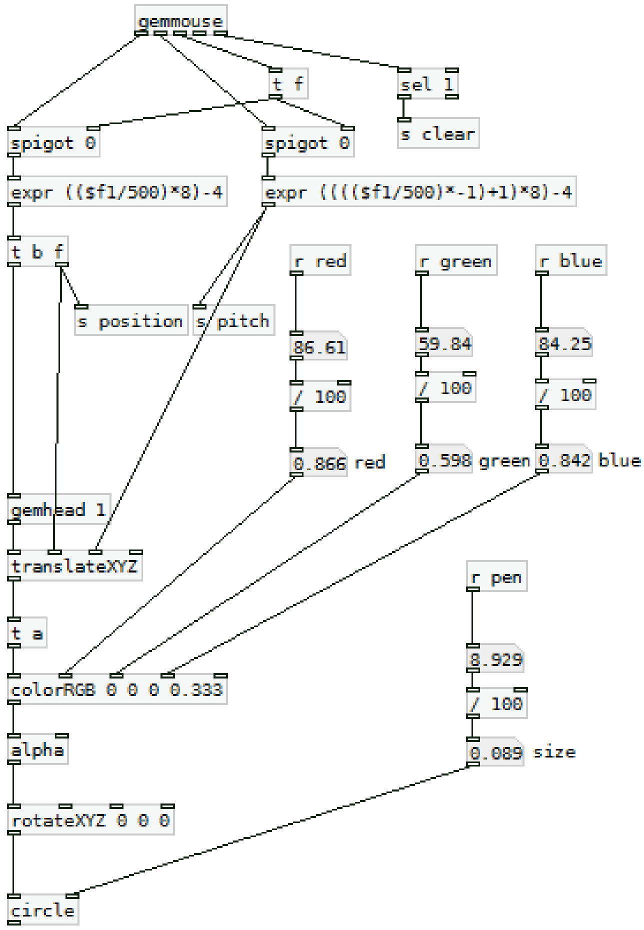
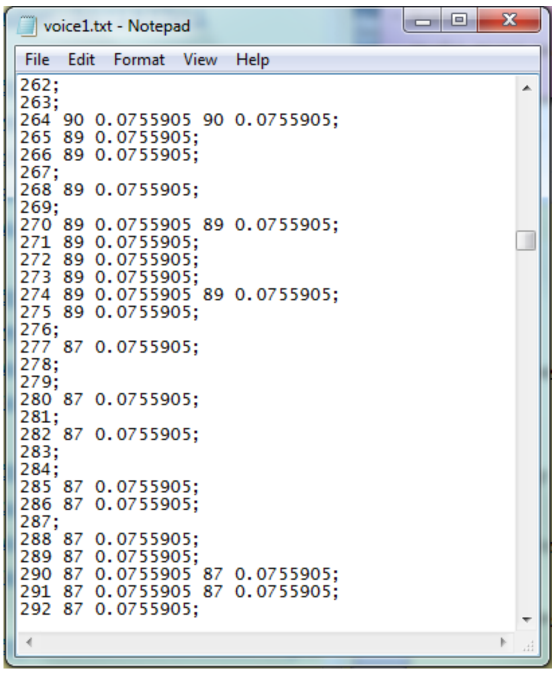


Figure 5.10 – Using the mouse to create geos



voice1.txt - Notepad

File Edit Format View Help

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Figure 5.11 – Text file showing X axis position, MIDI pitch and amplitude

5.2.5 Scale and Register

Initially, the Y axis of the canvas window controlled pitch by changing the frequency of an oscillator. Later, MIDI note numbers were used instead, limiting the range of notes to the chromatic scale. At this stage, I experimented with different divisions of the Y axis to produce different musical scales; this meant that gestures painted into the canvas window played back with a more musically-coherent result. The scale could also be altered to compare how gestures sounded in different scales. As the most common scales in Western music contain seven notes, later versions used the order of seven colours from the familiar children's song *I Can Sing a Rainbow*: red, yellow, pink, green, purple, orange and blue (Figure 5.12).

Colour	Scale Degree
Blue	Leading Tone
Orange	Submediant
Purple	Dominant
Green	Subdominant
Pink	Mediant
Yellow	Supertonic
Red	Tonic

Table 5.1 – Scale degrees

At first, the major and minor scales for all chromatic keys were used, with a separate control for changing the register. I later experimented with less conventional tunings, such as the quarter-tone scale, and non-Western tuning systems such as Indonesian slendro. Having previously taught modules on the music of other cultures at key stage 3, including Indonesian gamelan and Indian raga, I recognised that this interface might offer a means of composing with scales that would otherwise be difficult to access.

5.2.6 Dynamic Patching

A significant progression point during this stage was the implementation of dynamic patching. Until this point, all objects and patches were generated manually. Dynamic patching is an advanced form of object-oriented programming which allows abstractions to be generated from a set of variables. This means that the patch can be extended by user operation, or by automatic processes, generating possibilities afforded by high-level languages, such as *C#* or *JavaScript*, that are often used in commercial software development.

Dynamic patching in *Graphick Score* occurs when the user interacts with the canvas window; when a geo is created, a list of variables is used to generate an abstraction, which defines the geo and also the musical properties. This was at first limited to its X and Y co-ordinates and size, but later expanded to include various other inter-related properties. These abstractions are then stored in a sub-patch, each with a unique identification. Playback of a scene triggers a locator bar to move across the canvas window. As this bar reaches the X co-ordinate of any abstraction stored in the subpatch, it triggers the abstraction to send its variables to the sound source (triggering the corresponding timbre, pitch, dynamics etc.) as well as momentarily ‘lighting up’. Each abstraction also stores the number of the scene for which it was created, allowing it to be deactivated or reactivated as required. In later developments, these geos can be selected (using the right mouse button) and dragged to a different position, resized, and edited in other ways. Doing so changes the associated variables in the abstraction. Consequently, text files were no longer required to store values, as all variables were encoded directly into abstractions (Figure 5.13).

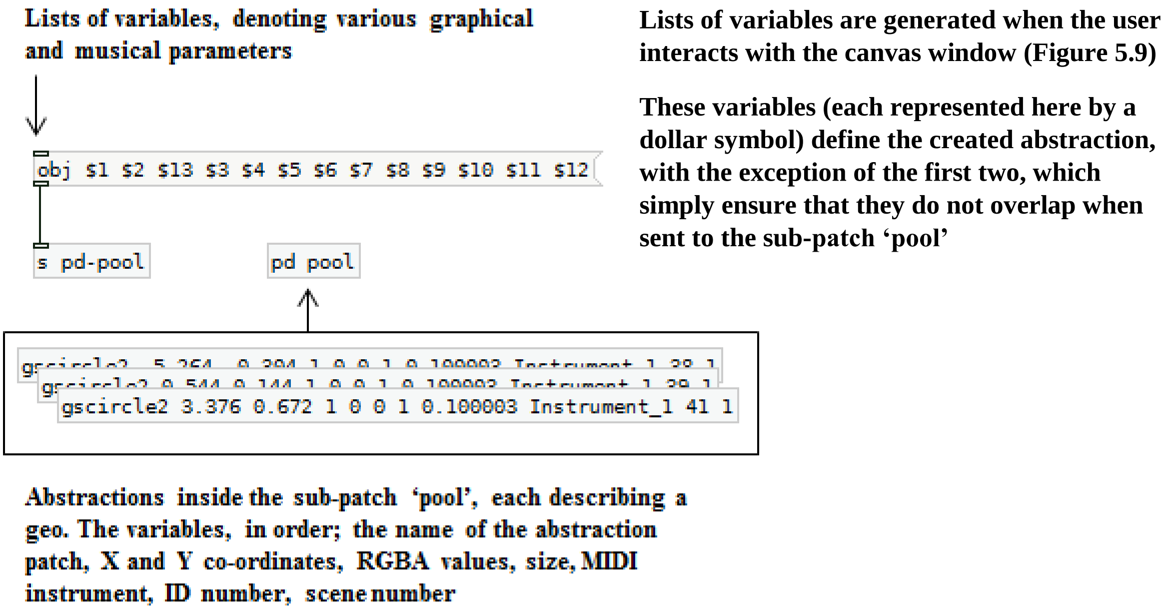


Figure 5.13 – Dynamic creation of abstractions

5.2.7 Remote Communication

With dynamic patching meaning that every geo could be edited individually, the possibilities for the programme increased substantially, but so did the amount of graphical processing. Lines and curves could be drawn, consisting of multiple geo abstractions, so alpha blending was no longer required. However, this quantity of graphical processing began to interfere with audio processing when complex scenes were created, leading to audio crackling and dropouts. I resolved this issue by dividing the patch into two separate menus (the graphics

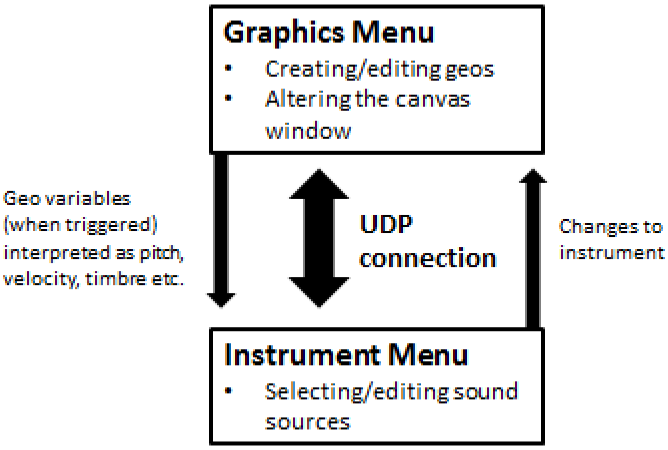


Figure 5.14 – UDP messaging between patches

menu and the instrument menu) which were loaded by separate instances of *Pd*. I then set up a remote link between the two patches using UDP (user datagram protocol) messaging, which allows communication channels to be established without prior communication protocols (Figure 5.14). This channel is established automatically whenever the two patches are loaded on the same computer. The addition of remote communication allowed complex graphics or audio processes to be undertaken without interfering with one another. The graphics and instrument menus therefore developed independently, leading to further variations.

5.2.8 Designing Voices

Synthesizer and sound design patches (which may be termed VST instruments) are commonly produced in *Pd*. I intended that these could be downloaded and used as voices, by loading them as abstractions. I also designed several voice patches myself, such as a drum machine and an FM (frequency modulation) synthesizer (Figure 5.15). These were intended to allow a much greater degree of control over timbre.

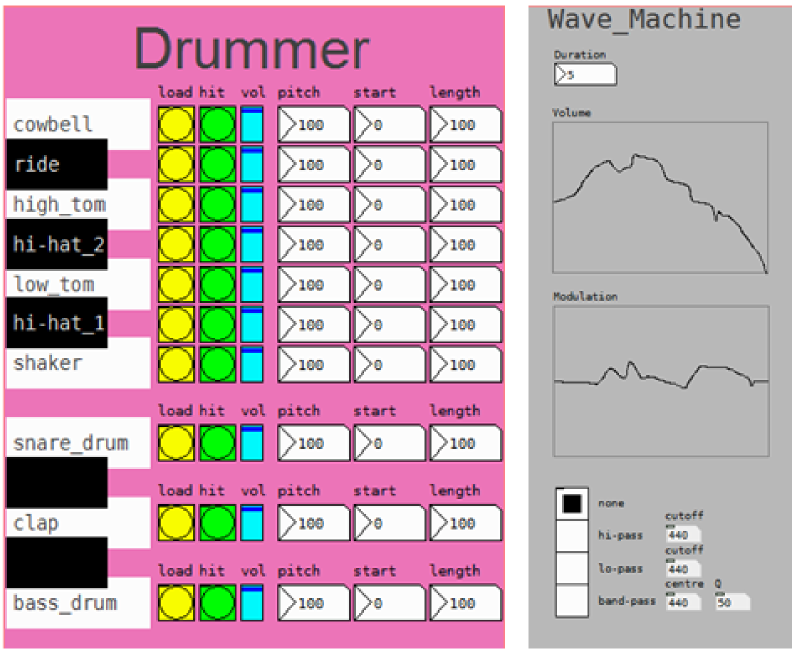


Figure 5.15 – VST patches made for *Graphick Score*

5.2.9 Expanding the User Interface

Developments during this time were aimed at producing a prototype interface for a pilot study (Figure 5.16). The graphics menu allowed the user to define the scale on the Y axis, as well as dividing the X axis into any number of steps. A list of basic shapes and RGB settings could also be selected. A cursor was designed for the canvas window, with the note name corresponding to the current Y co-ordinate printed onscreen. The instrument menu consisted of 16 slots for loading VST instruments, as well as 16 MIDI outputs, allowing the interface to be used as a control surface for external software or hardware synthesizer.

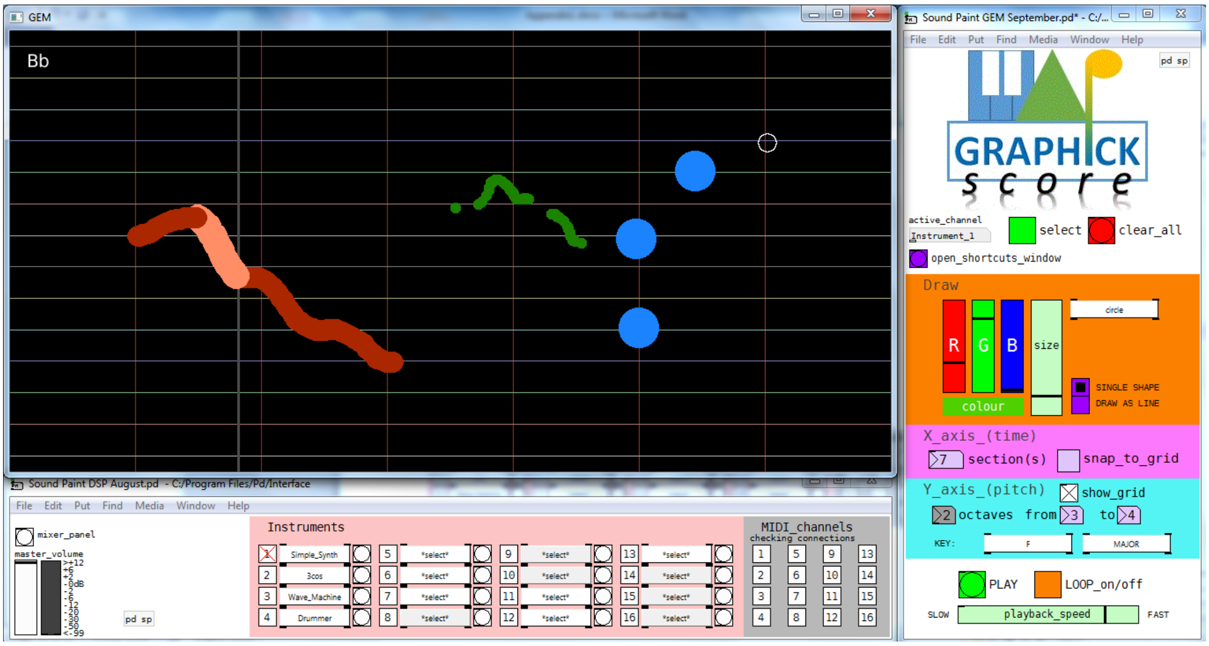


Figure 5.16 – The user interface of *Graphick Score* in August/September 2015

A number of additional windows and menus were temporarily added. This included a mixer panel, which could be opened from the instrument menu (Figure 5.17). The intention for this panel was to allow channels to be routed through effects through send and return channels, much like a conventional mixing desk.

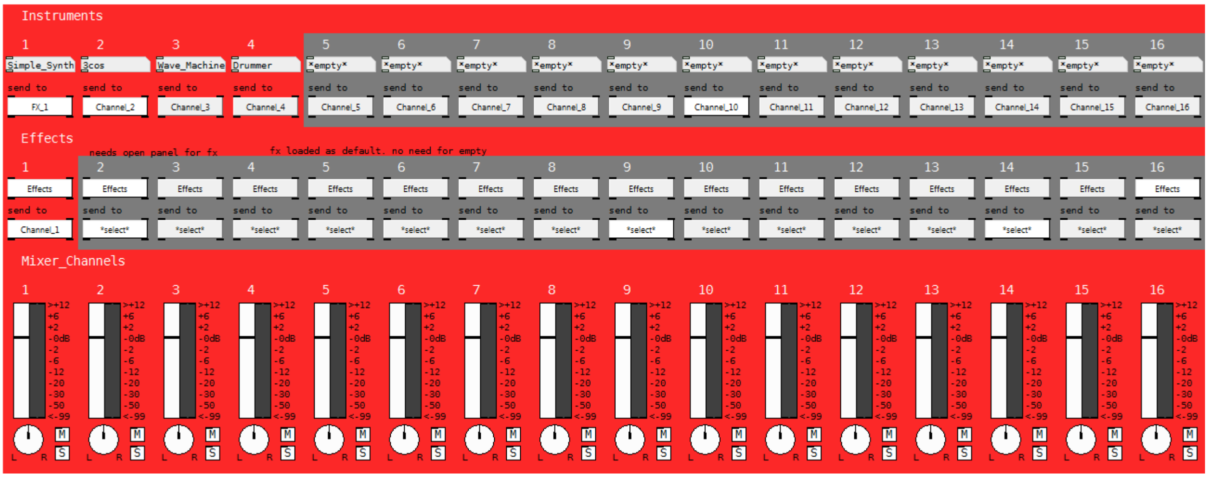


Figure 5.17 – The mixer panel

5.2.10 Alternative Models

One of the alternative graphics menus which reached the testing stage, titled *MetroNotes*, avoided a linear timeline altogether (Figure 5.18). Interaction with the canvas window was much the same as with *Graphick Score*, with the Y axis determining pitch. However, instead of triggering geos using a locator bar, each one 'pulsed' at a metronomic rate, determined by its position on the X axis, which sent the pitch, velocity and other values to the instrument menu for playback. Moving a geo from left to right caused this pulsing rate to increase. This design meant that complex generative patterns could be created from a small number of geos. A *rhythm composer* was later added, allowing the user to programme each geo with a rhythm rather than a steady pulse.

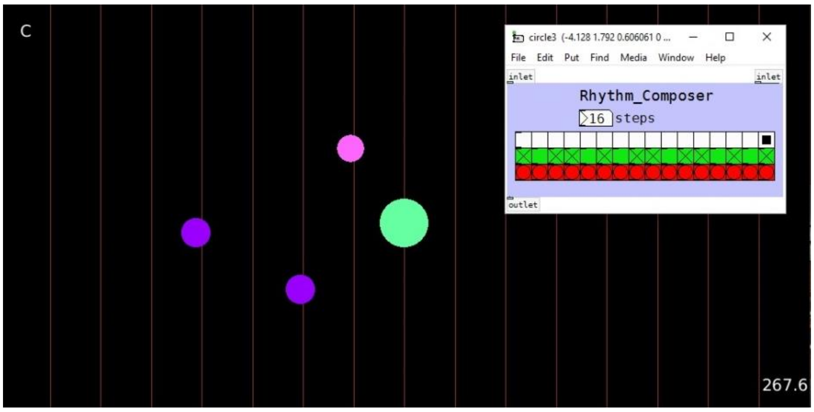


Figure 5.18 – *MetroNotes*

5.3 Summary

The design and development taking place in phase 1 resulted in a graphic score based sequencing environment, presenting a novel mode of digital music composition. Simple relationships between musical and graphical dimensions were explored from the earliest versions of this interface, based on ideas that young children may intuitively understand, or be able to refer to verbally. For example, I felt that different colours and shapes would clearly indicate sounds (or timbres) of different character, while those which looked similar would indicate that the sound is similar. Velocity was represented by the size of the shape, as I reasoned that children would recognise the relationship between a big shape and a loud noise, or a small shape and a quiet noise. Other relationships were based on more traditional musical ideas. For example, pitch was determined by the position on the Y axis, relating to the common metaphor of *high* and *low* pitches. Table 5.1 shows the various musical dimensions and corresponding representations in the earliest versions of the graphic score programme, as well as the intended verbal descriptions (i.e. how I expected a novice learner may refer to them).

Musical Dimension	**Graphical Representation**	**Verbal Description**
Pitch	Y axis, or relative height	*High and low*
Structure	X axis, or time line	*Left to right*
Timbre	Shape and colour	*Different sounds*
Texture	Quantity of visible shapes	*More and fewer*
Dynamics	Size	*Big and small*
Duration	Length of shape (lines could be drawn for longer durations)	*Long and short*
Tempo	Initially operated by a slider, but changed in later versions	*Fast and slow*

Table 5.2 – Basic musical dimensions represented in *Graphick Score*

This system presented some intuitive modes of representation, which I hoped children could easily understand. However, some obvious limitations were also present. I was concerned that the idea of big and small sounds (dynamics) would be confused with longer and shorter sounds (duration). Also, though the idea of fast and slow tempo seemed intuitive, I wanted to find a way of representing this onscreen that could be immediately understood. I decided that these issues would be addressed in a pilot study, and that decisions relating to representation and interaction would be continuously readdressed as findings emerged.

6. Phase 2: Development

September 2015 – May 2016

Figure 6.1

This chapter is an account of phase 2, where the software artefact produced during the previous phase was continuously developed and tested in response to four studies:

1. *Exhibition at University A, September 2015*
2. *Exhibition at University B, November 2015*
3. *Focus Group at School A, January 2016*
4. *Focus Group at School A, May 2016*

Research focused on the development of the user interface, and its suitability in facilitating experiential music composition. Note that all examples of pupil compositions referenced here can be found in the digital appendix (see 1.1.5 for guidance on locating specific examples).

6.1 Exhibition at University A, September 2015

6.1.1 Context

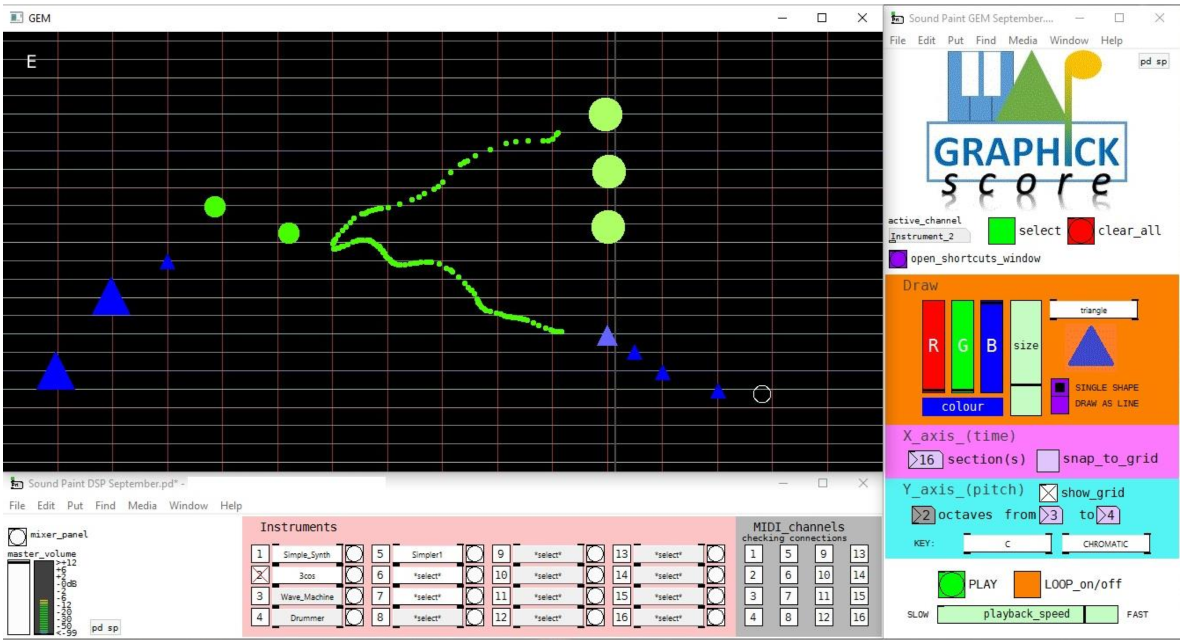


Figure 6.2 – ***Graphick Score*** **in September 2015**

Following the initial development of *Graphick Score* during the first year of research the programme was exhibited at University A as a pilot study. At this stage, the programme had reached a reasonably stable version of the 'sound painting' interface (Figure 6.2). The purpose of this study was to gather anecdotal feedback on the user interface, with the intention of improving layout and navigation. The registration of new students at the music department presented an opportune audience, as the programme could be set up for use by the students as they waited for their appointment. Participants were all 18+ years of age, with a background in music, and many had a sound knowledge of sequencing software such as *Ableton* and *Logic*, as well as scoring software such as *Sibelius*. The benefits of this demographic were the perspectives gathered from different musical backgrounds, and the possibility of specific expectations prior to using the programme, and clear suggestions following. This pilot study allowed for general feedback to be gathered in a less structured setting than the later school-based research. However, it was also clear that there were respects in which the data obtained might be deficient within the context of the study. Firstly, the setting would only allow for a very brief period of use by each participant, so information obtained with regard to functionality would necessarily be limited. Secondly, the participants were much older than the target age group for the programme, so their reactions and interactions would have to be weighed up against the pertinent pedagogical considerations. To mitigate these concerns, the pilot study focused more on the layout and navigational menus of the programme rather than its functionality, and participants were informed of the target age range for the programme. Ultimately, it was decided that the study would gather a useful set of reactions from the perspective of adult music students, as well as indicating the extent to which a musical background might suggest certain expectations with regard to layout and navigation.

6.1.2 Method

A basic workstation of computer, keyboard, mouse and speakers was set up in a teaching room at the music department. As students waited to be registered, they could approach and use the programme if they wished to do so. Others observed and passed comment, but did not use the programme themselves. I explained the purpose of the study and the target demographic to new arrivals, but did not go into any instructions about the operation of the programme as I wished to observe the extent to which the interface could be used intuitively, without prior directions. No instructions were given to the participants, and the study did not follow a consistent structure. Being an initial study, it seemed appropriate to conduct in an open-ended manner, allowing for the emergence of possibilities which I might not have considered. Written memos were made, and, as with all later studies, a Zoom H2n portable recording device was set to record the discussions for later reference and coding.

6.1.3 Results

Participants generally responded well to the canvas window, being able to compose musical ideas with little difficulty. Upon interacting with it, the relationships between pitch and position, as well as size and volume, became apparent. Some were asked to construct a specific musical feature, such as a chord or simple melody, and all were able to comprehend and complete this task within the context of the programme. However, few participants used the graphics or instrument menus at all. When asked about this, many stated that they were confused by the layout of these sections, and felt that they should be simplified. One participant said that, being dyslexic, the canvas window interface might have helped them to engage with music-making as a young child, which they found difficult. They were less engaged by the graphics and instrument panels, however:

> ‘The controls are overwhelming. There are too many of them and they all look too similar.’

Many participants were confused by the instrument menu. The fact that each channel consisted of three unlabelled controls proved a barrier. In this version, the numbered box was used to select the channel, the menu to the right of this was used to select a VST instrument to load into this channel, and the rightmost button opened the front panel of the VST instrument so that controls could be edited. The general response was that the opening of separate hidden windows should be avoided. For example, the shortcuts window, consisting of a list of keyboard commands, was seen as inefficient. Several participants suggested an onscreen key to illustrate this, or a set of keyboard ‘skins’, as can be obtained for DAW sequencers such as Logic or Ableton. Also, the mixer panel was seen as an unnecessary addition of this version (see Figure 5.17). Some participants liked the idea of this feature, but noted that it was inconsistent with the aesthetic and functionality of the programme, being typical of conventional DAW sequencers.

A significant number of the participants expressed confusion at the use of separate controls to select geos or switch between drawing single geos and lines. That this was something that needed to be toggled on and off was generally seen as a barrier to creative progress. However, the option to change the number of steps in the X axis, to quantise to these steps, and to switch between major, minor and chromatic scales in the Y axis, were all seen as useful features. Some participants suggested a wider range of scales, and a margin to inform the user of the scale degrees, the note indicator in the upper-left corner being not immediately noticeable according to some. A number of participants felt that the programme was not presented in a way that invited the user to interact with it, and that certain defaults should be in place to guide the user upon first use. Suggestions included onscreen demonstrations and a default setup of VST instruments and samples. It was also generally agreed that a wider range of graphics would make the programme more visually appealing. Some suggested alternatives to the relationships between audio and image. For example, two participants felt that colour would be a better indicator of velocity. One felt that it would make more sense for the structure to be read up the Y axis, with pitch along the X axis.

A working prototype of the *MetroNotes* variation of the programme (see 5.2.10) was also shown to some participants. In this version, geos repeatedly send pitch and velocity information to the audio engine at a metronomic rate. This means that there is no linear timeline or playback function; melodies are instead generated by creating different pitches at different rates. The quantise function still works within this version, as the vertical lines represent rates which synchronise after a certain number of cycles, the equivalent of different beat durations within a given tempo. Participants were intrigued by this novel mode of composition, but felt that the use of a rhythm composer for each geo complicated the interface. The general consensus was that the simplicity and directness of this approach, without any playback controls, was the source of appeal.

This study was a source of useful anecdotal feedback. In general, responses to the canvas window as a mode of composition were positive, but reliance on external controls within the outer menus and hidden panels was suggested to be a barrier to experimentation; this applied to both *Graphick Score* and the *MetroNotes* variation. The use of keyboard 'skins', or stickers to identify keyboard shortcuts, might be a promising resolution to this issue. In addition, many of the controls were suggested to be of questionable usefulness and efficiency going forward. This relates particularly to the mixer panel of *Graphick Score*, which was perhaps inconsistent with the overall aesthetic of the programme. The response suggested that developments should focus on varied interaction with the canvas window to replace some toggles and other controls from the graphics menu.

From this study, I concluded certain changes which could be made prior to the next exhibition: A wider range of graphics and scales could make the programme more visually and musically appealing. General response to the relationships between sound and image was broadly positive at this stage, though a few participants had alternative assumptions, such as the use of colour to indicate velocity. I felt that this latter suggestion may be informed by familiarity with DAW sequencers, the participant having referenced these in their suggestion. In such interfaces, the note events of only one channel are displayed at a time. In an interface where multiple voices need to be clearly shown, I suspect that changing colour may confuse in terms of identifying separate voices. The suggestion that the timeline should occur on the Y axis, effectively flipping the axes, would be unusual for a composing environment. This layout may be more appropriate and intuitive for performance-based software, where the user benefits from a sense of the musical material scrolling towards them, such as the keyboard performance software *Synthesia* or the app *Piano Tiles* (see 3.2.3).

Finally, response to *MetroNotes* as an alternative mode of interaction was generally positive, but it was clear that the versatility of the programme should be increased while maintaining the simplicity of interaction. In other words, further external controls should be minimised. An analogue to this design is the app *Bloom* (see 3.2.1), which generates looping patterns of notes and corresponding visual circles in response to minimal interaction by the user, i.e. touching a single portion of the screen. This requires no understanding or preparation by the user, and is consequently suitable for any age. It is by interacting with the application that the user explores the relationships between the visual and musical material and their kinaesthetic role in generating this material. It can be seen that, throughout the responses, transparency between action and musical result, and the minimisation of settings (menu options, etc.) was a key factor in whether participants responded positively during their brief interaction with either of the programmes.

6.2 Exhibition at University B, November 2015

6.2.1 Context

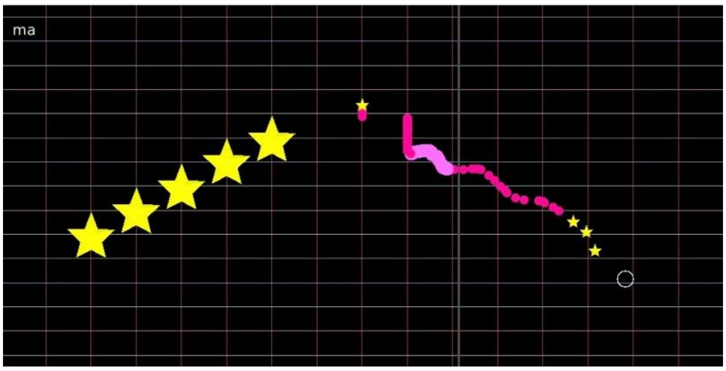


Figure 6.3 – The canvas window in *slendro* tuning

Exhibition of *Graphick Score* at University B followed much the same format as the pilot study, though the setup was more expansive and took place over a longer period. At this point, the programme was being prepared for use in schools, so initial technical and aesthetic issues were still being resolved. This public exhibition of developing technologies provided an ideal opportunity to gather more general feedback, and to observe how the average adult fared in using the programme. This also provided an opportunity to examine some of the suggestions that emerged from the pilot study, and to gather opinion on other variations, such as the *MetroNotes* interface.

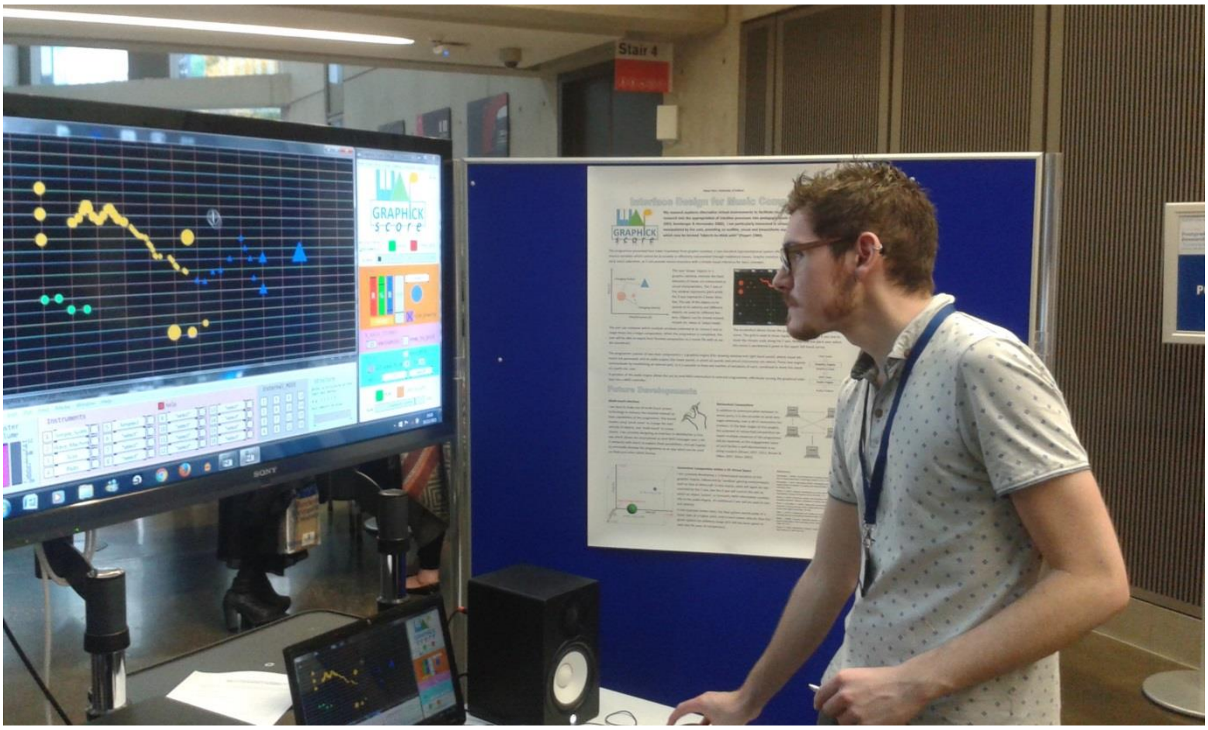


Figure 6.4 – Exhibiting *Graphick Score* at University B.

Following the pilot study, a wider range of graphics and scales were added to the programme. This involved simple constructed geos such as stars and hearts; 2-dimensional shapes consisting only of a basic outline and inner colour. Added scales now included the whole tone scale, and a 5-tone equal tempered scale as an approximation of the Indonesian *slendro* (Figure 6.3). This latter was included due to the inclusion of gamelan music in the key stage 3 music curriculum, and in consideration of the inaccessibility of any approximation of this tuning using a subset of the chromatic scale. In place of conventional note names, the traditional Indonesian names for the degrees of the scale were displayed in the canvas window; *ji – ro – lu – ma – nam.*

6.2.2 Method

Graphick Score was set up as a workstation in the exhibition space continuously from 9am to 6pm (Figure 6.4). During this time, visitors were invited to use the programme, or to ask questions about its development. Notes were made of any feedback or observations for later consultation, and an audio recording was also made.

Figure 6.5 – Keyboard commands printed onto a mouse-mat

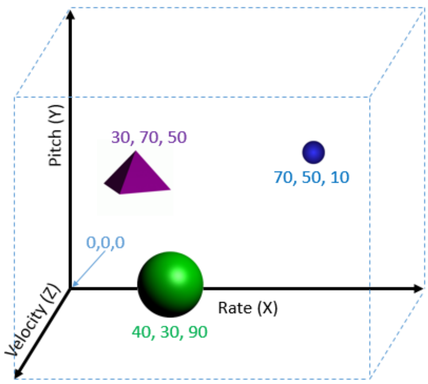


Figure 6.6 – The proposed design for *SoundWorlds*

Several changes were made to the setup following the response generated from the pilot study. A set of keyboard and mouse commands were presented on a laminated mouse-mat display, which I hoped would minimise the need for interaction with the graphics menu (Figure 6.5). A second poster displayed the various proposed developments for the programme, including a brief plan for a proposed 3-dimensional equivalent of *MetroNotes*. This version, called *SoundWorlds*, used the Z axis to control velocity, meaning that interaction with external menus would be reduced by the greater level of control afforded by positioning objects in a 3-dimensional space (Figure 6.6). Responses to these ideas were gathered during the exhibition. Finally, the MIDI output channels were routed to instrument channels in *Ableton Live*, meaning that the interface could be used to access the VST instruments in this DAW.

6.2.3 Results

The improved appearance and functionality of the interface led to responses of a generally more favourable nature than at the pilot study. Participants were more eager to use the programme without instruction. This can be attributed in part to context, the participants having attended an exhibition specifically to use such technologies, unlike the pilot study, which was populated by passing participants. However, the keyboard and mouse controls were clearly a factor, as participants consulted these during their interactions with the programme. All participants agreed that it would be more efficient to use a set of keyboard stickers to indicate controls. Also, the inclusion of separate modes for creating and selecting geos was seen as a barrier to interaction. The suggestion that the right mouse button could fulfil this function without the need for a separate mode was met with a positive response.

Participants were impressed by the capacity for interacting with external software through the MIDI outputs. One participant suggested that this would be a better way of accessing sound sources than the built-in VST functions, as it would improve the versatility of the programme. Additionally, this generated discussion about possible other MIDI capabilities. The participant in question – a former music student – wanted to know if it would be possible to write MIDI files using the programme. I agreed that this possibility would be worth pursuing in future.

SoundWorlds was met with intrigue, with many participants asking for more details after reading the poster. I was keen to discuss this, as I had not yet devised a means of interface. The mouse only allows movement on a 2-dimensional plane, whereas *SoundWorlds* would require movement within a third axis. A number of solutions were discussed with several participants, including a mouse with a jogwheel, and a joystick. Following the study, a working prototype was developed using the Leap Motion controller (Figure 6.7; 6.8). However, other than performances and conference presentations, this option was not explored in further study for this project due to the complexity of the interface and lack of readily available control surfaces[16].

[16] At this time, *Graphick Score* was being developed as a desktop-only application. Touchscreen interfaces may offer a more accessible and readily-available control surface for the 3-dimensional layout of *SoundWorlds*, so I intend to revise this option during later research.

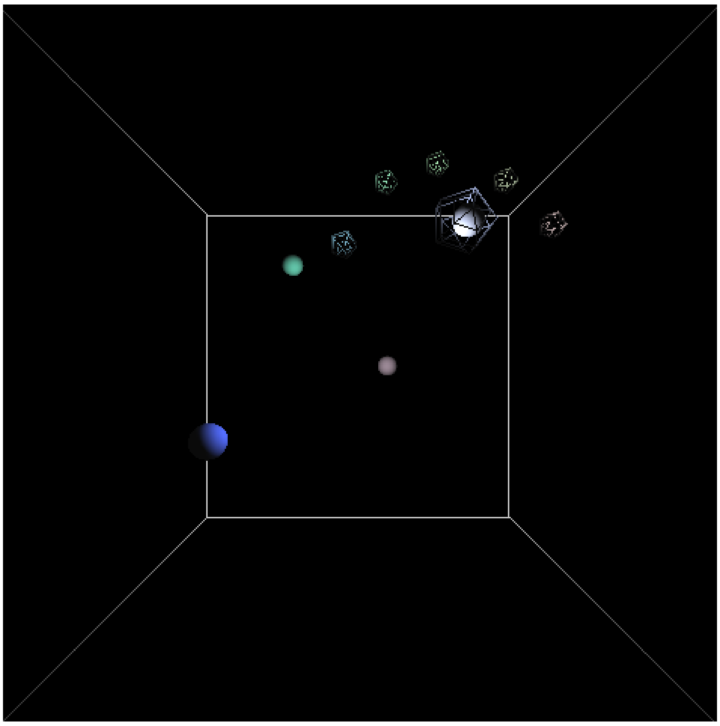


Figure 6.7 – *SoundWorlds* uses the Leap Motion to allow the user to 'grab' and 'move' 3-dimensional geos, altering their musical parameters. The palm of the hand (large mesh sphere) and five fingers (surrounding smaller mesh spheres) can be seen grabbing a geo here.

The exhibition at University B generated a more positive response to the programme, and also several ideas for further development. The use of keyboard stickers to indicate shortcuts, and removal of the selection mode, were clear improvements for the next study. I also decided to further expand the MIDI capabilities of the programme, and investigate the possibility of a write-to-MIDI function. The benefit of this would be that musically untrained users could create MIDI files using *Graphick Score*, and load these into DAW sequencers or score editors, acting as a form of scaffolding for generating musical scores and MIDI projects as well as interacting with staff notation.

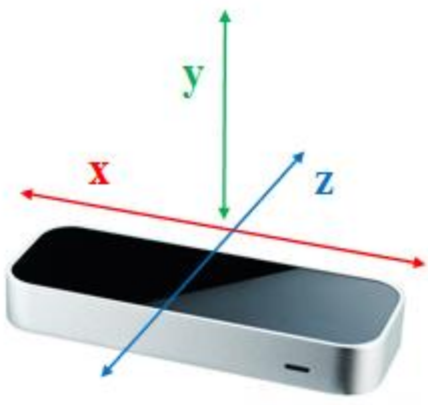


Figure 6.8 – The Leap Motion uses infra-red to map hand motions to a XYZ axis

6.3 Focus Group at School A, January 2016

6.3.1 Context

The first study to take place in a school was at School A, a state comprehensive secondary school. The purpose of the study was to evaluate use of *Graphick Score* by Year 7 students, i.e. those who had only recently begun secondary school education, and in many cases formal music education. Consent was granted from the school, and sought in advance from the pupils and their legal guardians through a letter distributed by the school a week previously. This also contained information about the study, contact details, possible frequently asked questions, and assurance that data would be stored anonymously. This format was used for all subsequent studies, and all names used are not the real names of the participants.

Following the exhibition at University B, the select mode was removed, with all select functions accessible using the right button of the mouse. The separate mode for drawing lines was also removed; lines could be created by holding the left mouse button and dragging. A default set of VST instruments was also loaded into the instrument menu. In the interest of moving towards a possible 3-dimensional interface, the menu of available geos was now expanded to include a library of *.mod* files (Figure 6.9). These files, often used in 3D printing and game design, are 3-dimensional virtual models of various items. A pack of model files available for public domain use were downloaded and incorporated as geos. A possible future development was that these models could be turned and rotated to affect some parameter of the sound source, though this was not yet achieved at this stage.

6.3.2 Method

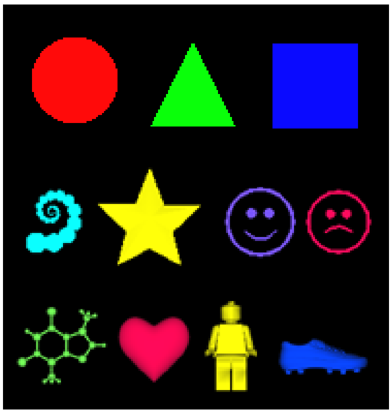


Figure 6.9 – Different geos; simple geometric shapes, complex shapes, 3-dimensional *.mod* files

Five workstations were set up in an otherwise empty classroom of School A. These consisted of laptops running *Graphick Score*, with a mouse and set of headphones. Two sessions of 30 minutes each were planned, with five Year 7 students in each session (though the second session had only four participants due to absence). These participants were chosen by the Head of Music at School A, and were a mix of boys and girls with mixed levels of musical ability. As a focus group, I wanted a sample representative of the range of students in the class.

When participants entered the room, the purpose of the session – to develop a programme for music composition – was explained. A short survey was completed by each participant, which asked whether they had any instrumental training or other musical experience. The purpose of this survey was to gather information about the musical background of each participant for comparison of results. The participants had 20 minutes to use the programme, after which followed a brief discussion. This was done as an informal group discussion, as I felt that pupils would be less reticent about presenting their opinions in this setting. Finally, participants were asked to rate how easy the programme was to use, on a scale of 1 to 10, with 1 being very difficult and 10 being very easy.[17]

6.3.3 Results

All participants used the canvas window with no visible difficulty, and the menu of graphical geos was also used extensively. This also included the use of the right mouse button to select and drag geos, which appeared to pose no great difficulty. Few other controls were used beyond the selection of different geos. Some participants tried to change the voice in the instrument menu, but this was done by changing the VST rather than switching channels. Similarly, the geo and colour was mostly changed within a single channel rather than selecting a new one. Consequently, most of the results show different geos, some of which have a different colour, but which are almost universally built through channel 1 on the instrument menu.

The mode of interaction observed was very similar for many of the participants; this typically involved 'filling' the screen with a variety of geos, clearing it, and then moving on to carefully drawing a line or some other pattern. In the first session, the two girls began this process with their headphones on, while the three boys did not, only putting these on after having drawn on the canvas window to listen to their result. In the second session, more instructions were given as to how the programme worked, with a few functions being demonstrated to the group. This led to different results in the second session; all participants used the headphones, and moved to new scenes rather than clearing the screen. Also, this led to a different line of questioning. In the first session, with no direction or demonstration, one participant asked *'What should we do?'* Participants were also often looking at the screen of their neighbour, as if looking for confirmation of process. In the second session, with a demonstration of the programme, participants instead asked *how* to do specific functions. This suggested that some demonstration of the working environment encouraged experimentation and engagement.

[17] Scanned copies of these surveys can be found in the digital appendix, within the folder for this study.

Results for each session were similar. Participants generally used the programme to draw pictures and create patterns, not paying attention to the 'sound' of their results. Alice and Jessica (Figure 6.10; 6.11) both had formal musical training, for clarinet and piano respectively, but were in separate sessions. Both have filled the screen with various geos, and recognisable patterns, such as smiling faces, can be seen. However, as Jessica attended the second session with its more detailed demonstration, she has made more use of different functions, such as geo type and colour.

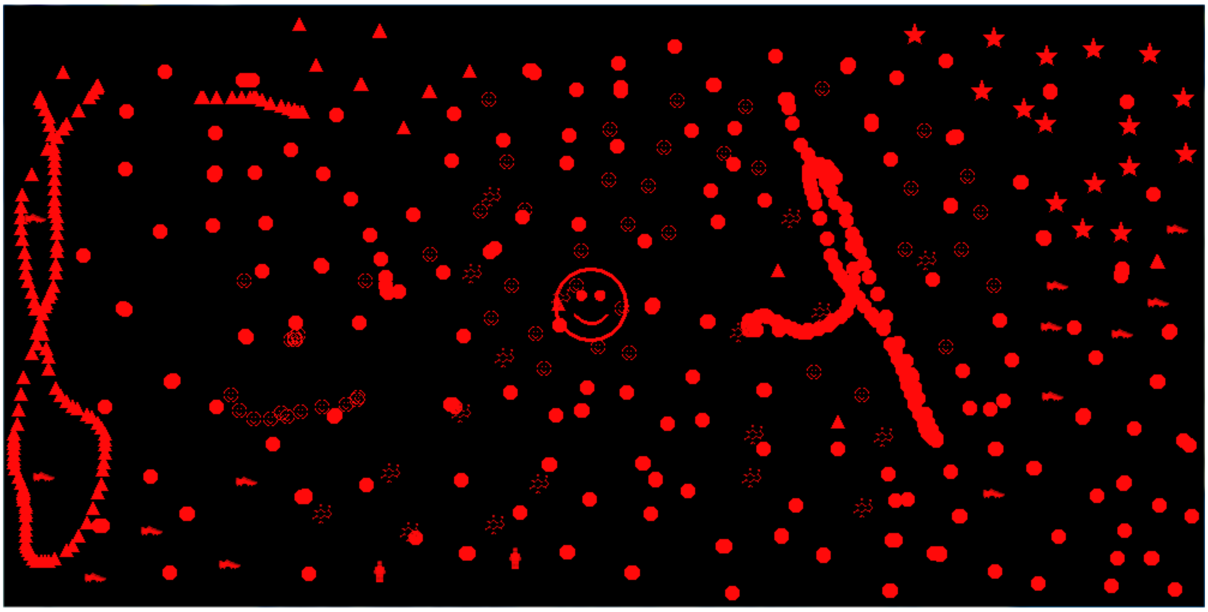


Figure 6.10 – Alice

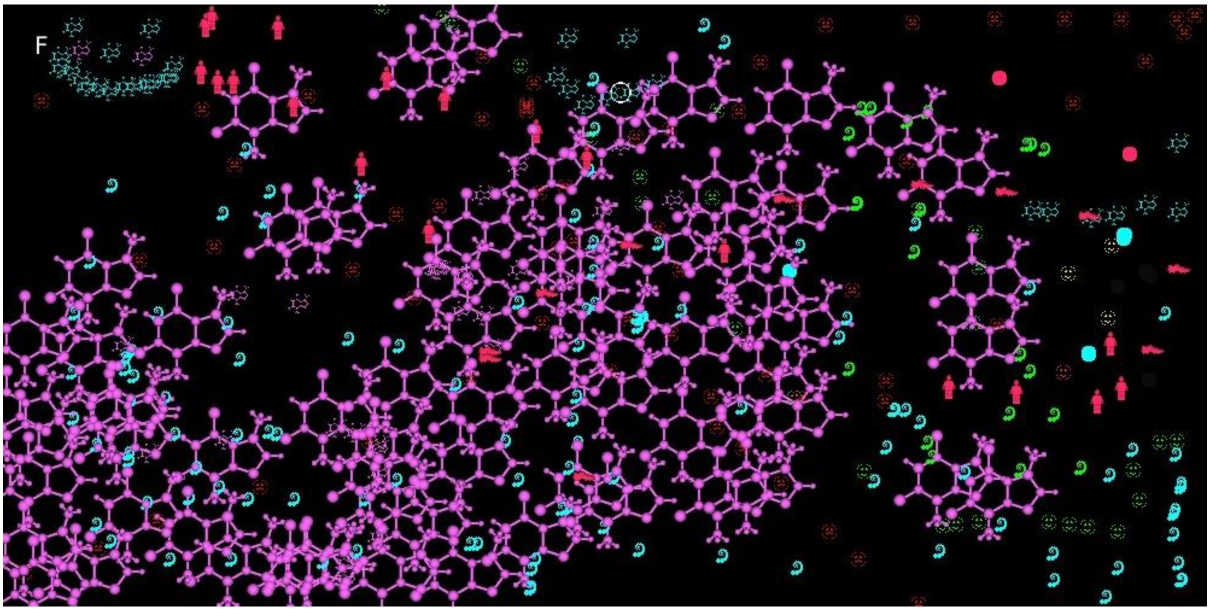


Figure 6.11 – Jessica

Other participants produced tidier results, tending to draw a contour and listen back to it. Examples of this are Bill from the first session (Figure 6.12), and Hattie from the second session (Figure 6.13). Neither of these participants had any instrumental training.

Discussion was very much focused on the graphical elements of the programme. Participants wanted to see more geo types, and were particularly eager about the prospect of an emoji-like menu, typical of social media communications. This was suggested by one of the participants:

> 'I think it should have more like the smiley face. Like you get on… like Facebook…'

No mention was made of the sound sources used, though the suggestion of a specific sound for each geo type received a positive response. In response to the question: *'On a scale of 1 to 10, how easy was the programme to use?'* results were mixed but tended toward the higher end of the scale, indicating that the participants found it fairly easy to interact with the programme.

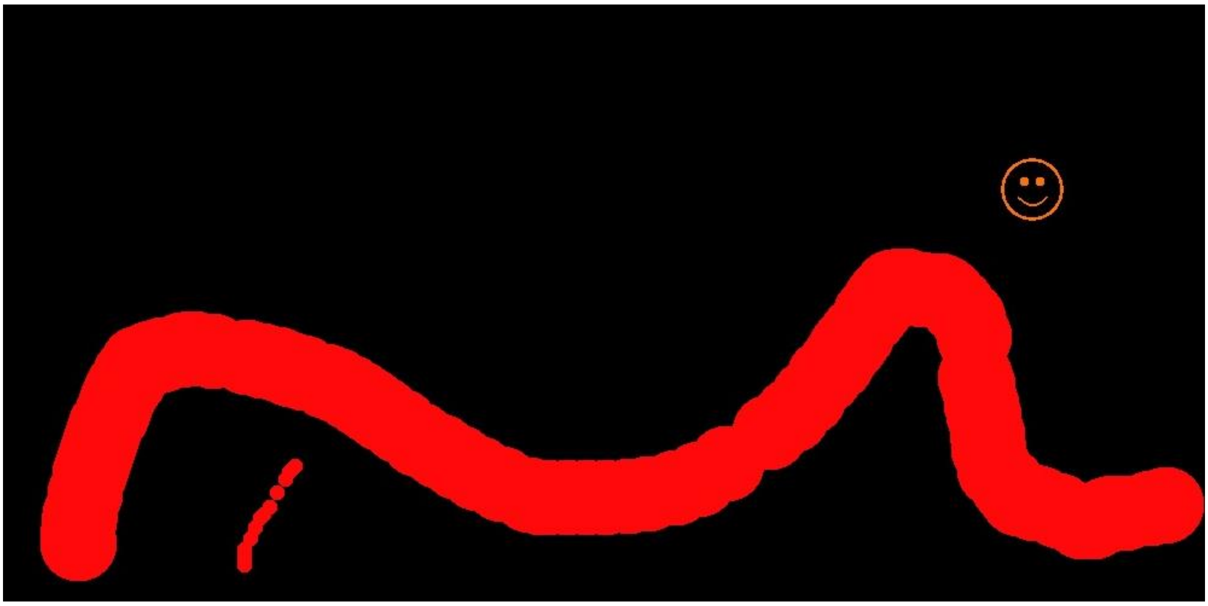


Figure 6.12 – Bill


Figure 6.13 – Hattie

The results of this study indicate that participants found the interface visually easy to use, and even engaging, but that this did not prompt a mode of use that focused on musical output. This can be seen from the screenshots and observations on mode of use, which mostly involved visual engagement, and the discussion, which focused on the graphical elements. None of the participants used the XY grid within the canvas window, even when shown how to make it visible.

In summary, evidence of engagement with the interface was improved following a demonstration of its functions, but this was mostly focused on the graphical elements. The priorities for development in advance of the next study concerned improving the possibilities for creative musical exploration; the sound sources, and the relationship that exists between interactions with the canvas window and resulting compositional material. I concluded that, where possible, this should utilise the already observed engagement with visual and graphical explorations (painting, drawing, making patterns out of shapes).

6.4 Scaffolding with Simple Structures

6.4.1 Tune-blocks

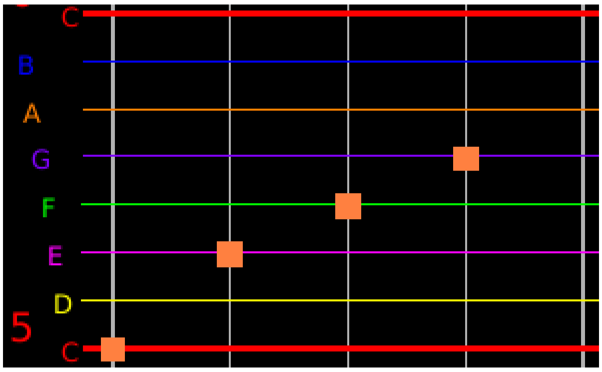


Figure 6.14 – A tune-block for the song *Oh When the Saints*

The most significant change to *Graphick Score* during this phase was influenced by Bamberger's concept of *tune-blocks*, which are used in the pedagogic composing software *Impromptu* (see 3.2.3). In this programme, which is aimed at pre-school age children, the user arranges tune-blocks into a recognisable melody. The idea of arranging recognisable structures is a common feature in sandbox games, such as *Minecraft* and *Lego* (see 3.3), and I also recognised the relevance to Papert's *objects-to-think-with* (see 2.1.4). Therefore, I decided to incorporate tune-blocks into *Graphick Score*, to see if pupils of my target age group could arrange these scaffolding structures on the canvas window, and what influence this might have on creative exploration compared to the previous study.

Tune-blocks were formed by dynamically generating a pattern of multiple geos at positions relative to the cursor, so that the user could create a block of geos starting anywhere on the canvas window (Figure 6.14). A list of melodic fragments was accessible via the graphics menu, which the user could 'stamp' onto the canvas window. Upon selection of a tune-block, the suggested line was highlighted; i.e. if the first note of the fragment began on the tonic, this line became bolder than the others. The user could then choose to place the fragment on this line, or on another line, allowing more complex structures to be formed from these fragments (Figure 6.15). Various nursery rhymes, popular songs, folk songs, and melodies from children's films were included in the list at different stages. Block and broken chords were also later added (Figure 6.16).

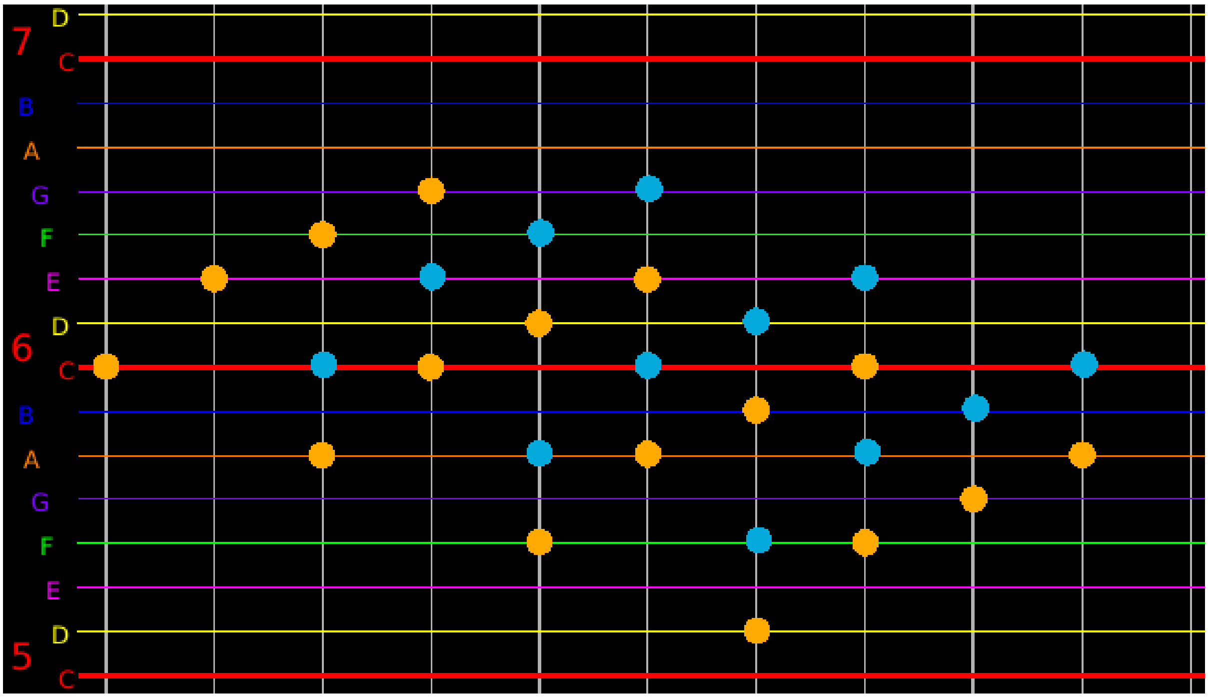


Figure 6.15 – A sequence generated using the tune-block shown in Figure 6.14

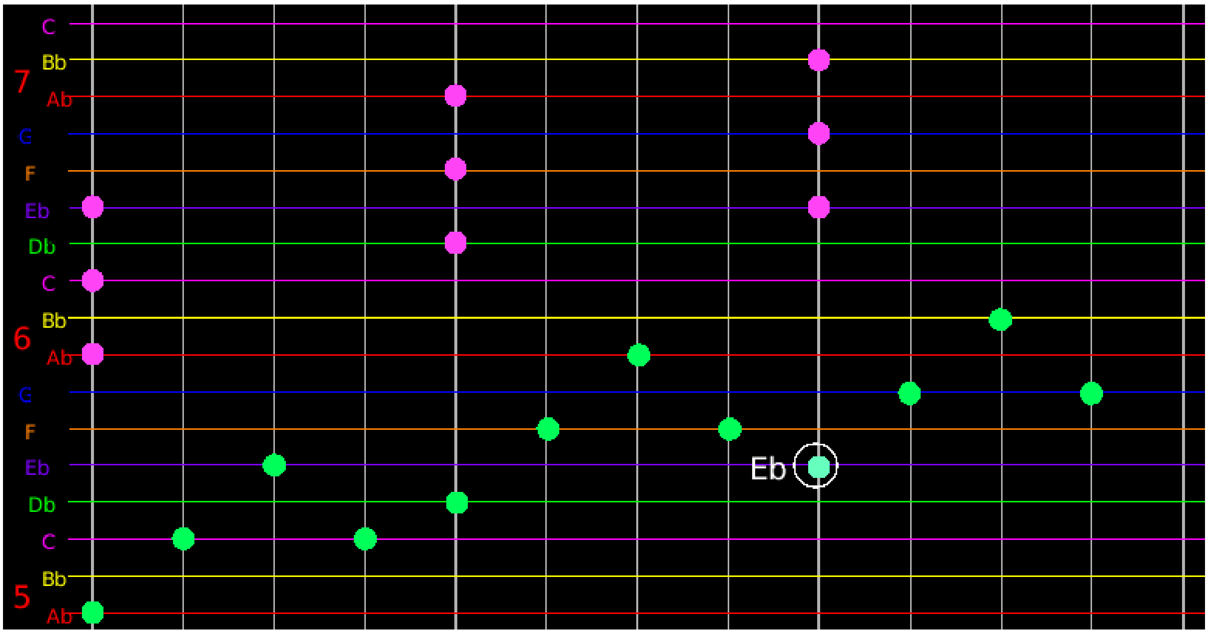


Figure 6.16 – Block chords and broken chords

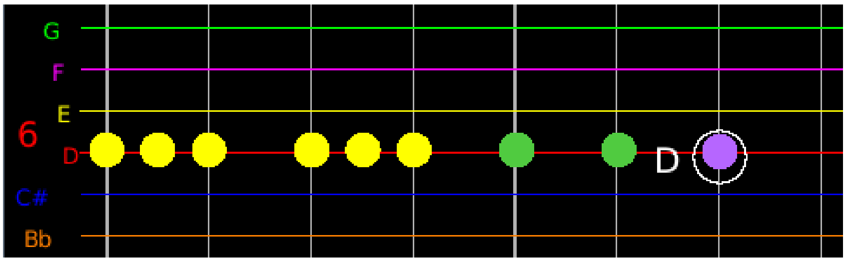


Figure 6.17 – Fruit rhythms making the rhythmic sequence for 'pat-a-cake pat-a-cake baker's man'; *coconut coconut apple pear*

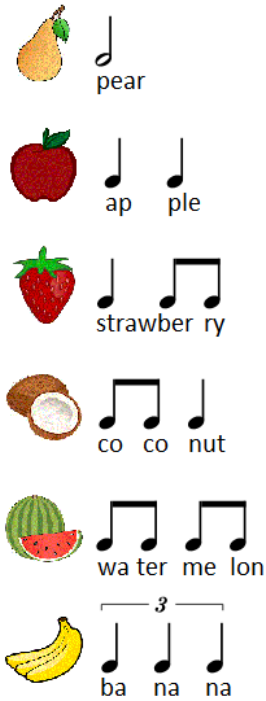


Figure 6.18 – Fruit rhythms

Tune-blocks (see 3.2.4) were also added as a way of making rhythmic patterns. Fruits with names corresponding to the rhythmic pattern were used for the menu (Figure 6.17; 6.18). Initially, these menus were text-based, but later became populated by cycling images (see 7.1).

6.4.2 Editing Tune-blocks

Following these changes to the interface, any block of geos (including drawn lines) could be selected by dragging across a region using the right mouse button. A white rectangle is displayed around the selected geos, forming a new tune-block. This block can be edited in a number of ways: moved, copied, deleted, resized (altering the dynamics), sent to a new MIDI channel (changing the instrument), and flipped or rotated. The latter function is perhaps the most musically interesting of these possibilities; when a region of geos is selected, all the relative positions are calculated within a sub-patch, allowing them to be repositioned along the Y or X axis, generating horizontal and vertical mirror images. By combining this with the copying and moving functions, a single tune-block can produce several variations (Figure 6.19). These changes generate the possibility for motivic development; a segment of 'drawn' music can be isolated and manipulated, producing retrograde, inversion and sequence among other gestural compositional devices; this is a feature lacking in other compositional environments (see 3.2.4).

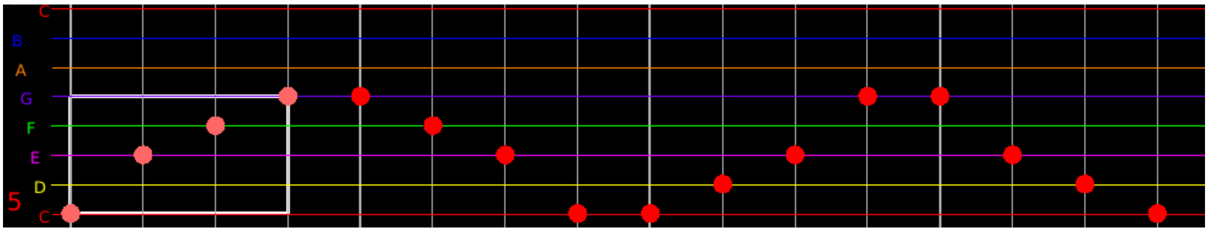


Figure 6.19 – Rotations of the tune-block shown in Figure 6.14

6.4.3 Other Developments

Later versions of the instrument menu further simplified the layout. The VST instruments were removed to focus on the 16 MIDI output channels. These could be assigned to any MIDI output device, though the general MIDI instrument set was given as a default (Figure 6.20). A basic structural sequencer was added at this stage, allowing a sequence of 16 scenes to be programmed.

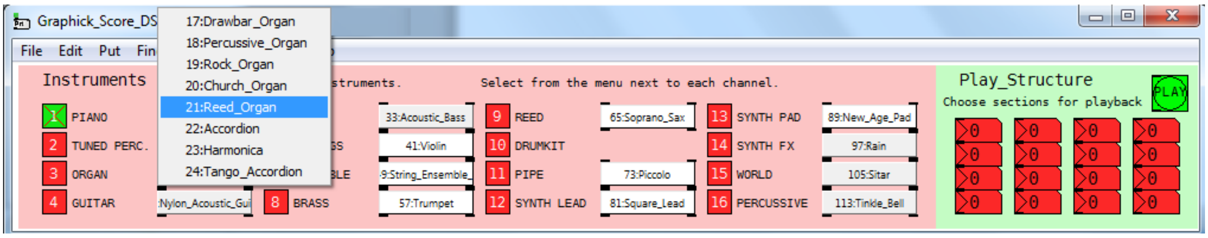


Figure 6.20 – The instrument menu

Various changes made at this stage were aimed at making the interface more user-friendly, following commonly-observed mistakes when using the programme. For example, when the user tries to draw in the canvas window without an instrument selected, a message box directs them to the instrument menu instead (Figure 6.21). One other significant change in this version was the

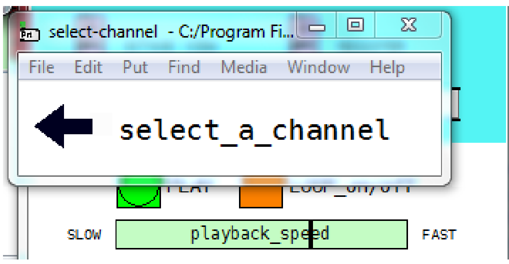


Figure 6.21 – A message directs the user to select a channel

removal of a geo selector, as this had become too much of a focal point in the previous study, and I hoped that a selector based upon musical content would provide different results. Instead, a simple geo was assigned to each MIDI channel, along with a default colour, though this could still be changed. The 3-dimensional model files were not included in this version, as I found that rendering large quantities of these objects placed great demand on the CPU, and often led to playback issues and errors. I therefore decided to return to more advanced graphics at a later date, when some more efficient application could be found. At this time, it was clear that to use these complex graphics for single note events was an inefficient use of memory and processing power, but that their appeal demanded that they be reintroduced for some other purpose at a later date.

6.5 Focus Group at School A, May 2016

6.5.1 Method

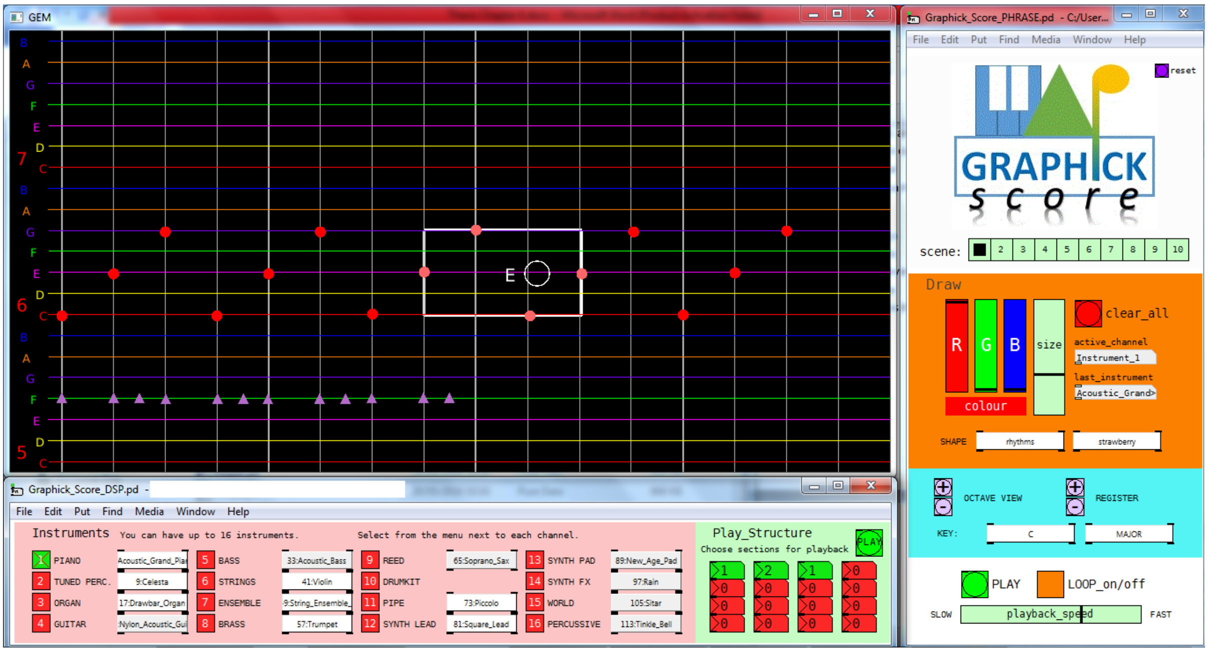


Figure 6.22 – *Graphick Score* in May 2016

This study involved a return visit to School A, and an almost identical setup and arrangement to the previous study. Of the nine participants, eight attended again, with two new participants being added to fill the ten possible spaces. The same survey was again used, and the same structure. A brief demonstration was again given, but this focused on the construction of melodic patterns. Again, the participants understood that the purpose of the study was to develop the programme, and that their role was to evaluate it in terms of ease of use.

6.5.2 Results

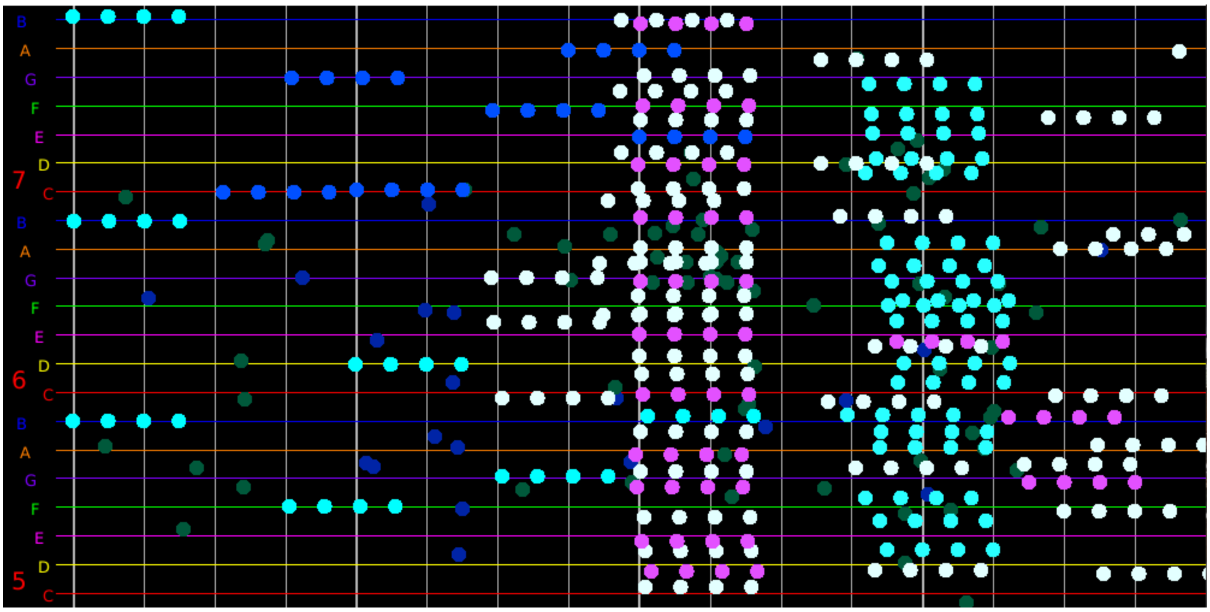


Figure 6.23 – Lara

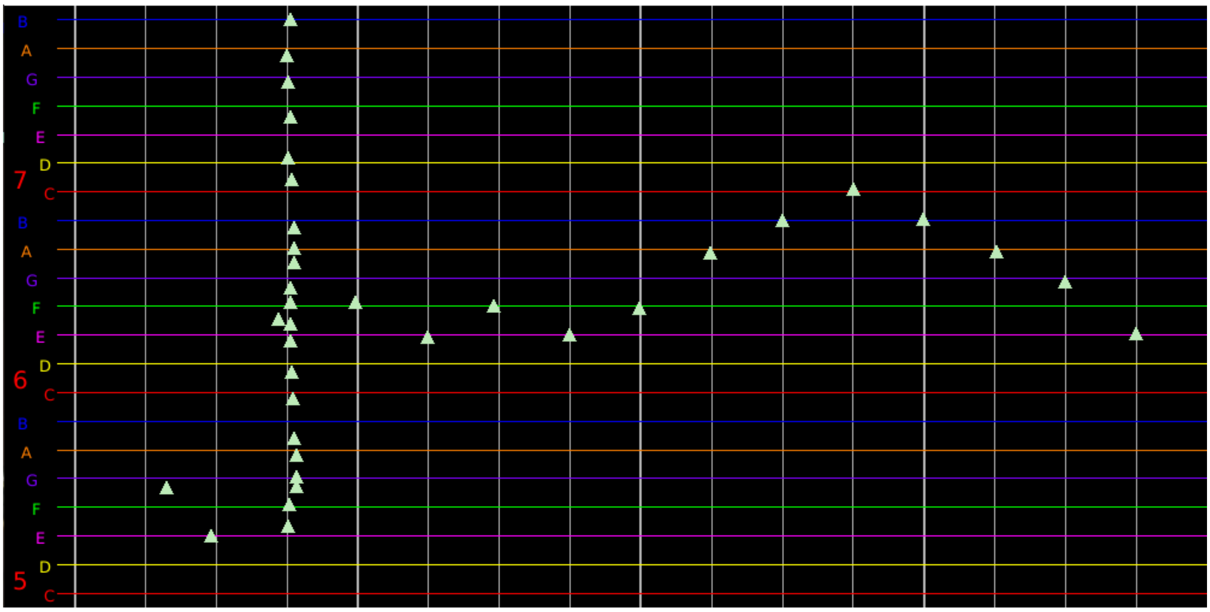


Figure 6.24 – Lee

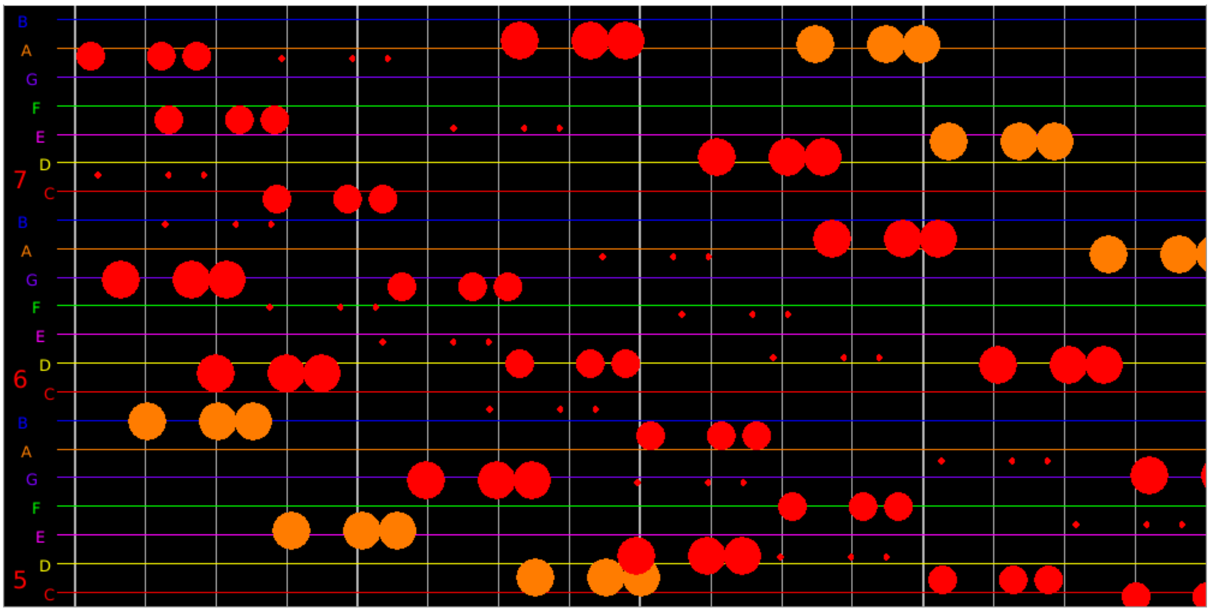


Figure 6.25 – Hattie

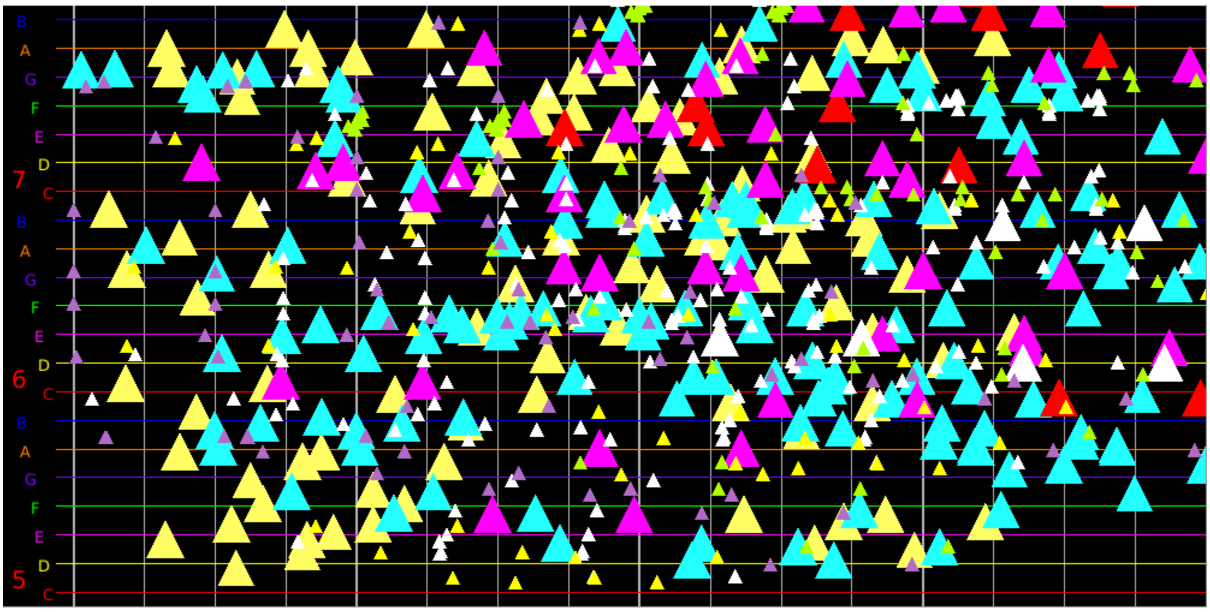


Figure 6.26 – Jessica

It was clear from observation that the participants were using the programme in what might be described as a more linear fashion, with material conforming to the grid. For example, Lara, who is musically trained and able to read standard notation, arranged rhythms in a vertical and horizontal sequence (Figure 6.23). A similar pattern is seen in the work of Lee, also musically trained, who followed a vertical line with a melodic contour by placing geos on the grid (Figure 6.24). A sequence was also observed in the work of musically untrained participants, but this tended to conform less rigidly to the grid. For example, Hattie follows a repeating diagonal pattern across the canvas window (Figure 6.25). These participants were observed listening to the results of their sketches as they made them. However, other participants showed fewer signs of listening to the musical results. Jessica, who is musically trained, filled the canvas window with geos in much the same manner as in the previous study (Figure 6.26). However, Jessica also made use of the copying function to build her patterns, which is more evident in the less busy scenes (Figure 6.27). As with the previous study, few participants changed the instrument. No participants made use of the function to select and rotate groups of geos.

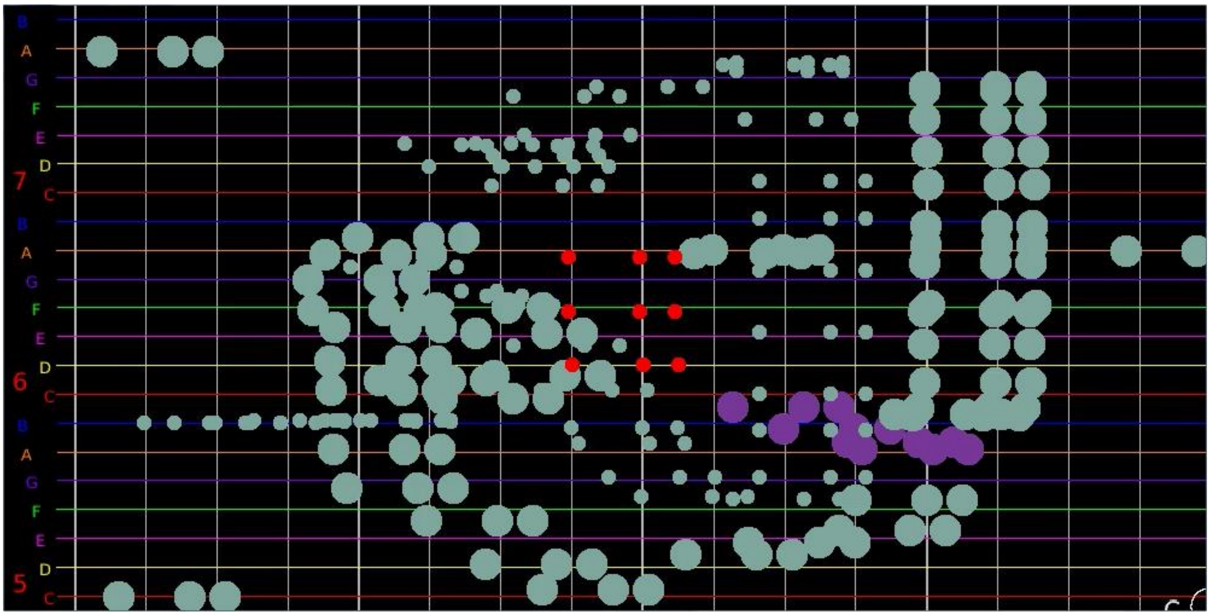


Figure 6.27 - Jessica

Discussion focused more on the construction of musical material and less on graphical material. As one participant who attended both studies stated:

> 'It was easier to make something in time… to make it sound in time.'

This was a function of the grid, which had been ignored in the previous study. However, it is notable that this was used more readily by trained musicians than those who had no instrumental experience. When it was pointed out that few participants changed the menu of phrases or instruments, it was generally agreed that these components did not look inviting. Many of the untrained participants did not know what to expect from the language used, especially with regard to instrument type, and menu options such as 'chords':

> Me: ‘When picking [a shape] did you know what it would be?’
>
> Participant: ‘No, I just chose it.’ [With agreement from others]

In response to the question: *‘On a scale of 1 to 10, how easy was the programme to use?’* results were more consistent than in the previous study, being mostly scored at 7 or 8.

A much clearer impression of how the programme could be used for composition was arguably gained from this study in comparison to the previous one. This is shown by the more sequential nature of the content, the more musical focus of the discussion, and the consistency of the response. There was a general consensus that the use of tune-block structures and the canvas window grid made the programme easier to use, though some participants felt that it was less aesthetically inviting than the previous version, due to the temporary abandonment of complex graphics such as *.mod* files. This accounts for the narrowing of results in response to the survey question. It is notable that, again, mode of interaction was mostly confined to the canvas window. To further examine the usefulness of the other functions, and therefore make the programme more versatile, I decided that I would have to redesign the graphics and instrument menu, and to re-evaluate some of the language used.

6.6 Summary

Phase 2 principally focused on the development of the user interface. The development of a sandbox interface, with intuitive and improvised composition leading to meaningful musical patterns, was the goal of this phase of research. Comparison of the concepts raised in the discussion of each study led to the emergence of certain principal categories.

The first category is visual-oriented exploration, observed in the ‘sound-painting’ seen in the earliest studies. It can be seen from the first two studies that a concise interface, with minimal reliance on the selection of options, was preferred. The two later studies revealed a mode of exploration which tended toward the visual; participants seemed to focus more on how the score looked than how it sounded, and the graphical options were related to the emoji images used in social media platforms. Exploration of the programme was mostly confined to the canvas window, i.e. the component which produces an instant visual result, rather than exploring different menu options. However, the examples demonstrate a range of different explorations, including patterns which form coherent musical gestures.

In producing a sandbox composing environment for experiential exploration of the dimensions of music, one of the considerations for this project was to minimise the need for verbal explanation prior to creative tasks (see 4.1.1). In the third study (see 6.3), more engagement with *Graphick Score* was observed in the second group, who were given a brief demonstration of the programme. This is likely due to the still relatively unclear layout of the interface at this point. It is notable that the new participants in the fourth study (see 6.5) were not confused about the mode of operation itself, though here a musical learning outcome of sorts had been indicated in the demonstration of constructing a melody. This study showed more evidence of listening by the participants, but was still predominantly based on the formation of visual patterns.

Secondly, scaffolding with simple structures emerged as a further mode of interaction. Bamberger (1996) argues that, from a pedagogical perspective, a fragment of melody, or tune-block, is simpler than a single note in isolation, as it is a more identifiable structure, with a greater potential for understanding. Similarly, Papert (1980, p.11) describes *objects-to-think-with* as having the 'capacity for personal identification'. In the third study (see 6.3), such identification is apparent in the participants who recognise emoji-like geos, noting their absence in the following study. I later incorporated Bamberger's tune-blocks into *Graphick Score* as a way of pursuing musical identification. The results from the subsequent study indicate more musically-coherent patterns and sequences, arranged on the now-present metric grid, as well as greater evidence of listening to these results. However, it is also observed that the desired capacity for identification was not yet present here, as participants were still making many choices at random, and did not know what to expect from the tune-block options. This suggests that, while these structures can offer potential for scaffolding musical behaviours, we need to further embed meaning-making structures which can support creative choices.

While these form two distinct conceptual categories emerging from this early stage of research, they are also clearly interconnected: If users of *Graphick Score* tend toward a more direct and visual-oriented mode of interaction and exploration, scaffolding structures can support this by allowing for more meaningful patterns and structures to arise from simple and limited actions. However, by situating the stage of development outside of the classroom – perhaps for too long – many features were explored which were admittedly unsuited to the design objective, such as the mixer panel, and the use of VST instruments and effects. Also, the lack of a clear learning objective acted as a barrier to exploration in the classroom-based studies, as participants required a demonstration in order to embark upon a task. This was not the case when used by adults during the exhibitions.

These outcomes suggest that the mode of use should be explored alongside refinement of the current features in phase 3. The objective of experiential composition with the dimensions of music appears to be reinforced by the canvas window to a point, in that participants have been engaged by interacting with it. In chapter 3, I discussed how interactive digital technology may clarify learning materials by making them visible and tangible to the learner (see 3.3.1; 3.3.2). In the earliest versions of *Graphick Score*, the interface offered basic interaction with pitch, dynamics and structure, but other dimensions, such as timbre and tonality, were inaccessible to the novice user. The addition of tune-blocks, and the means of altering them through repositioning and rotating, has enhanced these possibilities by presenting a more complex interplay of, and interaction with, musical dimensions than a single note can provide; as Bamberger (1996, p.34) notes, this increased complexity generates a scaffold with which is simpler for the novice learner to engage:

> We are asking students to begin with what we believe are the simplest kinds of elements, but which for them may be the most difficult. In doing so, I think we are confusing smallest elements – in music, isolated, de-contextualized pitch and duration values – with what we assume are also the simplest elements.

Being aimed at the very young, *Impromptu* focused on sequential arrangement of tune-blocks (see 3.2.3). *Graphick Score* attempts to harness this innovation for a school-age demographic by offering further arrangement possibilities, facilitating more complex compositions. However, this approach requires a clear layout and clear objective, something which should be further refined.

Development up to this point raised some unexpected but interesting educational possibilities. *MetroNotes* offers a format for generative music composition, which would present an alternative to the timeline-based interfaces usually found in composition software. Composition with non-Western scales has also been explored using *Graphick Score*, which presents an opportunity to investigate the tunings of other cultures in the classroom. As stated, the addition of tune-block structures presents an opportunity for enhanced engagement with musical dimensions.

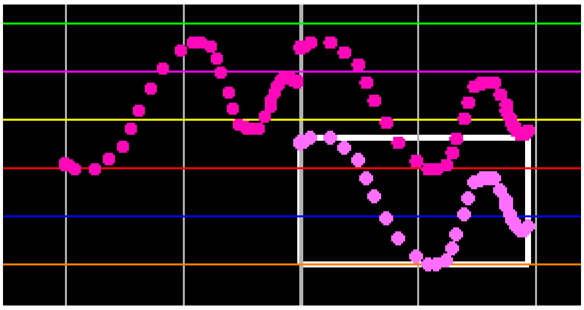


Figure 6.28 – Arranging a block of 'sound painting'

Glaser (1992, p.76) argues that grounded theory involves the cultivation of a core category, which involves favourable selection of the emergences which appear most significant. As my research is practice-led, these significant emergences should be the focus of my practice going forward. The addition of tune-blocks, and mode of interacting with them, enhances the possibilities for the 'sound painting' interactions observed in earlier studies. For example, improvised gestures may be arranged and edited into more complex formations (Figure 6.28). Such possibilities, as well as other expected outcomes, have the potential to emerge in the next research phase, as the classroom application of *Graphick Score* comes under closer examination. However, some of the features earlier described do not fit in with this design strategy: These modes of interaction are timeline-based, and unsuited to the non-linear interfaces of *MetroNotes* and *SoundWorlds*. Furthermore, implementation of tune-blocks meant the temporary removal of alternative scales, as the melodic options are all based on recognisable popular tunes from Western culture:

> 'Through listening to music of our own culture, we have become most responsive to structural functions such as stability and instability – whether a phrase sounds ended or is still going on…'
>
> (Bamberger 1996, p.42)

Consequently, an expansion of educational and creative possibilities led to a limitation, or at least a restriction, as certain promising yet incompatible features of the software are not investigated in the next phase of research.

Phase 3 is characterised by classroom research with objectives typical of music lessons, with *Graphick Score* being applied and examined in the intended situational contexts. As the focus is on learning objective, sensitivity to emergent possibilities which may extend beyond that which can currently be addressed by *Graphick Score* is required. In particular, this concerns the application of touchscreen tablets, which may present unique implications as digital technologies in music classrooms (see 3.2.1). Though it is my intention to develop *Graphick Score* as an app in future, this may not be addressed within the duration of this project. Therefore, I resolved to remain open to opportunities to apply these technologies to address the core activity of experiential composition in sandbox environments where possible. My intentions for the following phase can be summarised as follows:

- Use and refine *Graphick Score* in the context of music lessons.
- Ensure the presence of clear learning objectives and outcomes.
- Enhance the possibilities for scaffolding structures in facilitating creative composition.
- Work toward the construction of an intuitive, concise and accessible layout.
- Be continually sensitive to emergent possibilities which may support the existing research aims, conducting studies with alternative bespoke and existing resources where necessary.

7. Phase 3: Application, Refinement, Expansion

June 2016 – July 2017

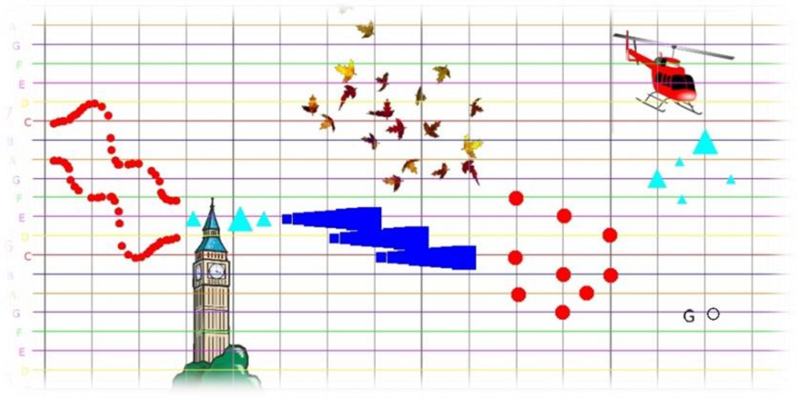


Figure 7.1

This chapter is an account of phase 3, where the software artefact is tested and refined in music lesson contexts. Additionally, new emerging ideas are examined through the application of other technologies, such as bespoke and commercial touchscreen tablet apps. This phase involved seven studies with contrasting situational contexts:

1. *School B, June 2016*
2. *School C, July 2016*
3. *School B, December 2016*
4. *School B, December 2016*
5. *School D, March 2017*
6. *School C, June 2017*
7. *School C, July 2017 (2 days)*

The same methods of data collection and analysis were applied for all studies, and a theoretical summary of the creative learning opportunities and barriers observed concludes this chapter. Note that all examples of pupil compositions referenced here can be found in the digital appendix (see 1.1.5 for guidance on locating specific examples).

7.1 Refinement of the Interface

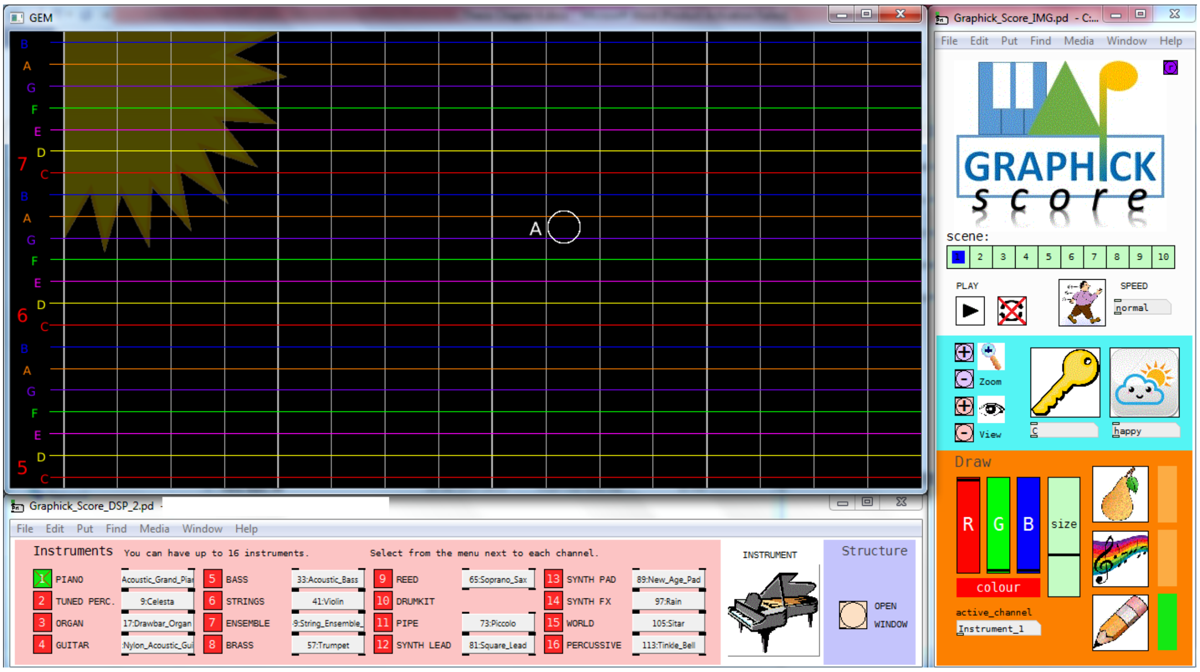


Figure 7.2 – *Graphick Score* in June 2016

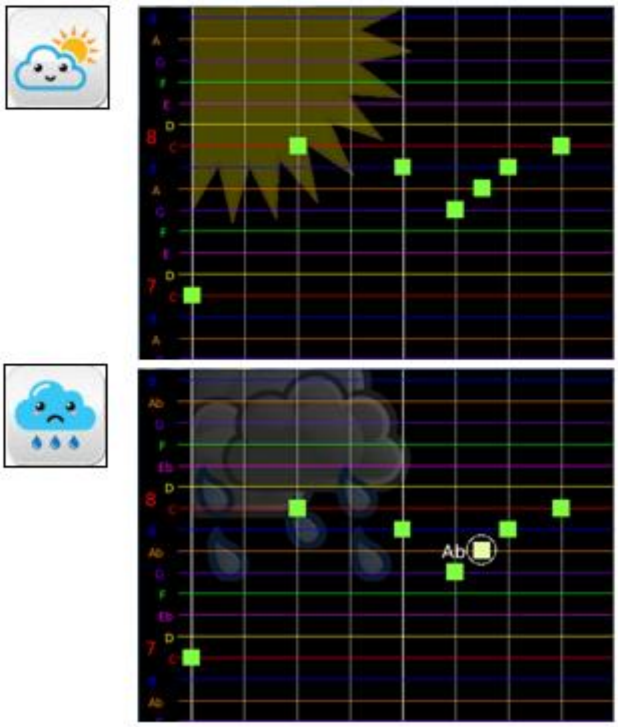


Figure 7.3 – The tune-block for *Somewhere over the Rainbow* is changed from a major to a minor key. The resulting flattened note is circled.

The start of phase 3 saw the programme develop to a more user-friendly and classroom appropriate state (Figure 7.2). These changes were informed by the research conducted in phase 2, and aimed at developing an interface which promoted exploration and experimentation through concise and, where possible, self-explanatory controls. Most of the menu options are replaced by image buttons which, when clicked, cycled through a sequence of contrasting images relating to a musical dimension. For example, major and minor tonality is represented by sunshine and raincloud icons, displayed on the graphics menu and canvas window (Figure 7.3). Similarly, the previously used tempo slider was replaced by a sequence of animal images representing different playback speeds (Figure 7.5). In this way, simple cultural analogues were used in place of musical descriptors. Buttons displaying graphics were used for other functions: The fruit-rhythms button, when pressed, cycled through images of fruit, the list of tune-blocks was shown when the user clicked the rainbow button, and the draw function could be activated by clicking the pencil. All of these functions could be accessed from the keyboard, on which corresponding stickers were displayed (Figure 7.4).

Figure 7.4 – Keyboard stickers for operating the programme

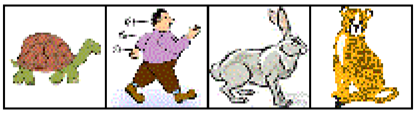


Figure 7.5 – Animal tempos, moving from slow to fast; tortoise, man, hare, cheetah

The instrument menu also was also updated for a more user-friendly layout. An image of the selected instrument was displayed, and a brief flourish on the chosen instrument and key was heard, providing a visual and audible acknowledgment of the selection. Default colours and shapes are also applied to each instrument channel, with the corresponding colour shown behind the instrument name for quick reference; this colour changes if altered by the user (Figure 7.6). An image of the selected instrument was displayed in the instrument menu, though to make room for this, the structure panel had to be moved to a hidden window. This temporary solution was undesirable, as previous research had indicated that such options went unexplored, but I reasoned that this part of the interface was not as well developed as other components, and not necessary for immediate use, as structure could be directly altered by changing scene during playback.

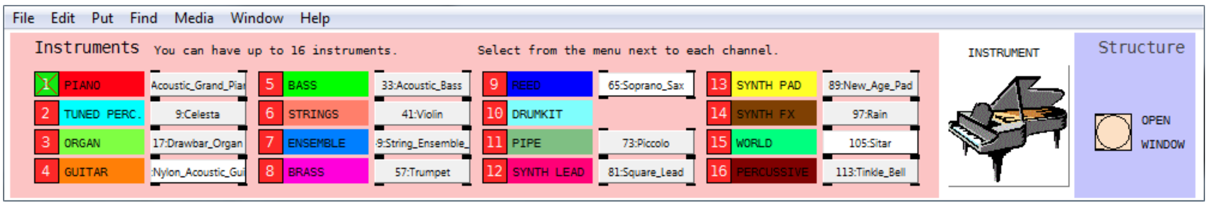


Figure 7.6 – The instrument menu

7.2 Storyboard Composition at School B, June 2016

7.2.1 Context

Up to this point, studies had focused on the design of the programme, rather than the outputs of the participants using the programme. Therefore, I decided to structure subsequent studies more like a music lesson, and to focus on a more specific age demographic. I opted for key stage 2, as the National Curriculum states two aims at this level which I felt *Graphick Score* could practically address:

- ‘improvise and compose music for a range of purposes using the inter-related dimensions of music’
- ‘use and understand staff and other musical notations’

(DfE 2013, p.2)

I held a meeting with the head of Year 6 at School B, a primary school. We agreed that I could visit the school for a full day, from 9am to 3pm, holding sessions with five pupils at a time, and hopefully working through the entire Year 6 class. With the assistance of my contact at the school, I devised a lesson plan to fit in with their current scheme of work. The class had been writing storyboards for a forthcoming school play, so we agreed that it would be appropriate to ask the participants to create a storyboard using *Graphick Score*. This would be the first time that the programme would be used for a functional purpose rather than being objectively evaluated, and the proposed activity seemed promising in that there would be much possibility of creative expression. I hoped that this storyboard format would encourage the participants to imagine representations for the musical and graphical material, and that this would reinforce links between these two components, perhaps lessening the focus on graphical content alone observed earlier studies.

7.2.2 Method

Learning Objective: *To compose a short story using sound*

I was allocated a small classroom within which to set up five workstations as with prior studies, with headphones and computer mice. This room, it was explained to me, was

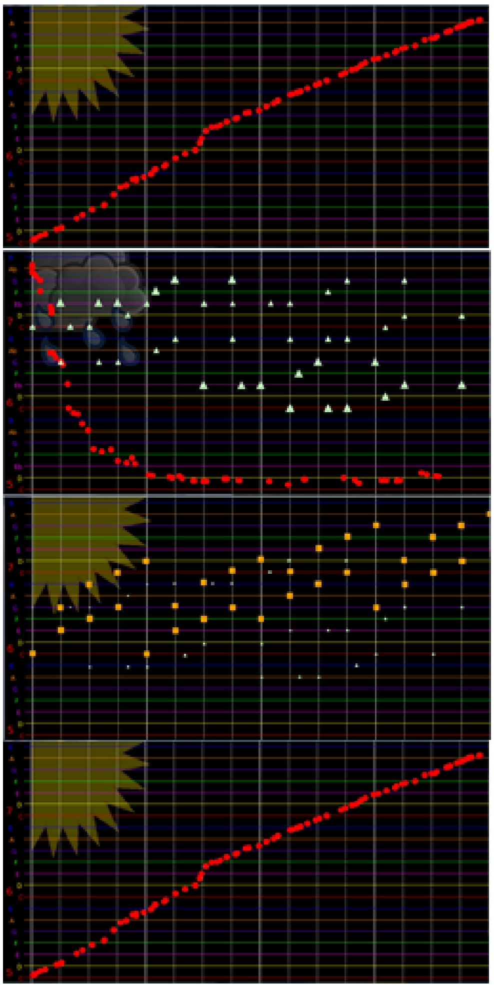


Figure 7.7 – The example story, *Incy Wincy Spider*, told with 'sound painting'

frequently used for alternative activities, so pupils were used to being taken there in groups during class time. Also, due to the artistic nature of the main activity from which the pupils were being drawn – rehearsing a play – I was confident that the pupils would not feel a sense of disruption to the educational setting. This would further support the planned lesson structure. In total, 26 pupils used the programme over the course of the day. One participant, whose computer had unfortunately frozen prior to showing their work, asked if they could attend again for the final session, and was allowed to do so. The work was later recovered.

When each group entered the room, I engaged them in a discussion about what they had done during the half-term break. This was to put them at ease within the setting, and to quickly establish a dynamic. It also served the purpose of providing a frame of reference for the forthcoming storyboard activity, as their anecdotes could be used as examples within the activity. I then posed a question to the group:

> 'Words can be used to tell a story, and so can pictures. But can sounds be used to tell a story?'

I then asked for examples, making sure that the difference between 'sounds like' and 'represents' were clarified. To illustrate this, I used *Graphick Score* to show how a xylophone might sound like rain, and a sad melody might represent rain. As a demonstration, I then built a storyboard using different scenes in *Graphick Score*, asking the group if they could guess the story (Figure 7.7). In every session, this was eventually identified as *Incy Wincy Spider*, though some prompting was occasionally required. I then asked the group to build their own story with sounds.

I delivered these sessions alone, providing support to the students where requested. Each session lasted for approximately 50 minutes in total. At the mid-point of the session, the group were asked to play an excerpt of what they had composed, and discuss how this related to their story. At the end of the session, this was repeated with the entire story. Data was collected by observation and written memos, and an audio recording was made, which was later transcribed. The pieces made by the participants were saved and later sent to the class teacher as screen recordings.

7.2.3 Results

The sessions resulted in a very high level of engagement throughout the day. All participants completed the task, and none expressed any boredom, confusion or dissatisfaction. A much wider range of functions were used; Participants tried the different tune-blocks and rhythms, altered the speed and tonality of their scenes, and listened to the various MIDI instruments. Selecting, moving and rotating groups of geos were also commonly used functions. A range of exploratory questions were asked, such as:

> ‘Can you have that bit fast and that bit slow?’ [Referring to sections within a single scene]

This indicated that participants were imagining functions that they wished to apply to their music, and that some creative impulse was being engaged.

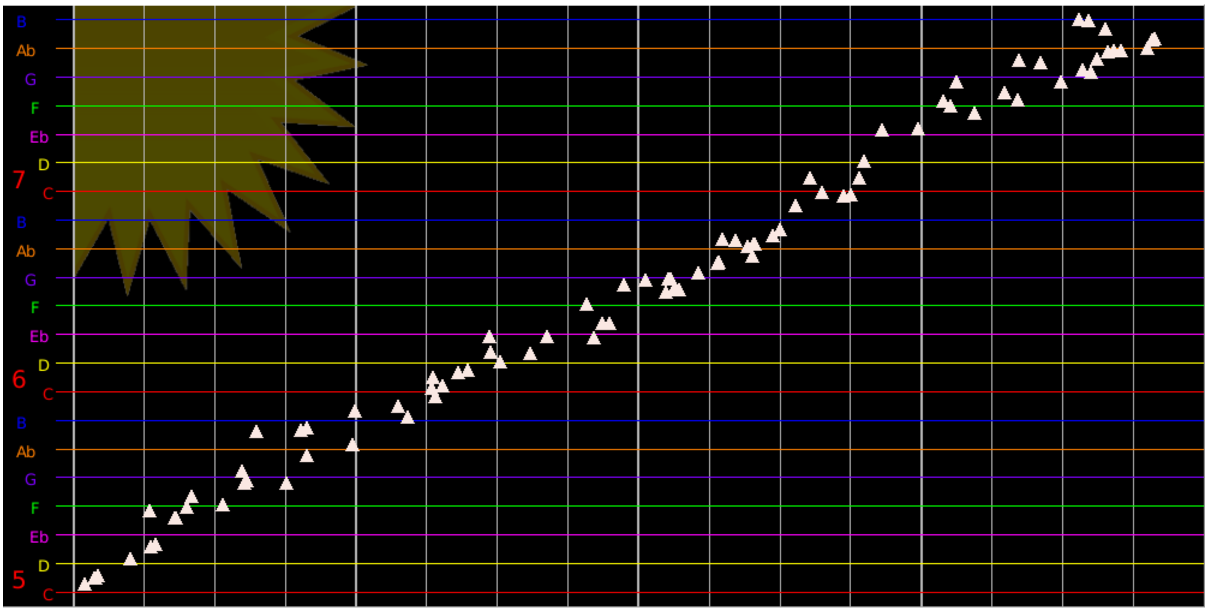


Figure 7.8 – Carly

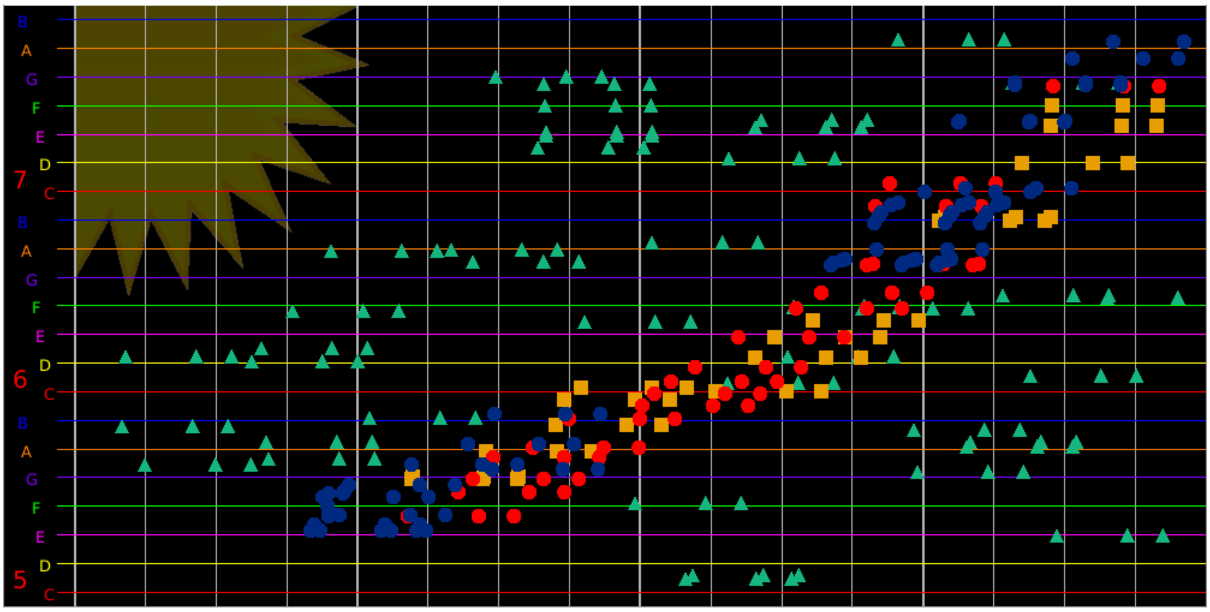


Figure 7.9 – Imogen

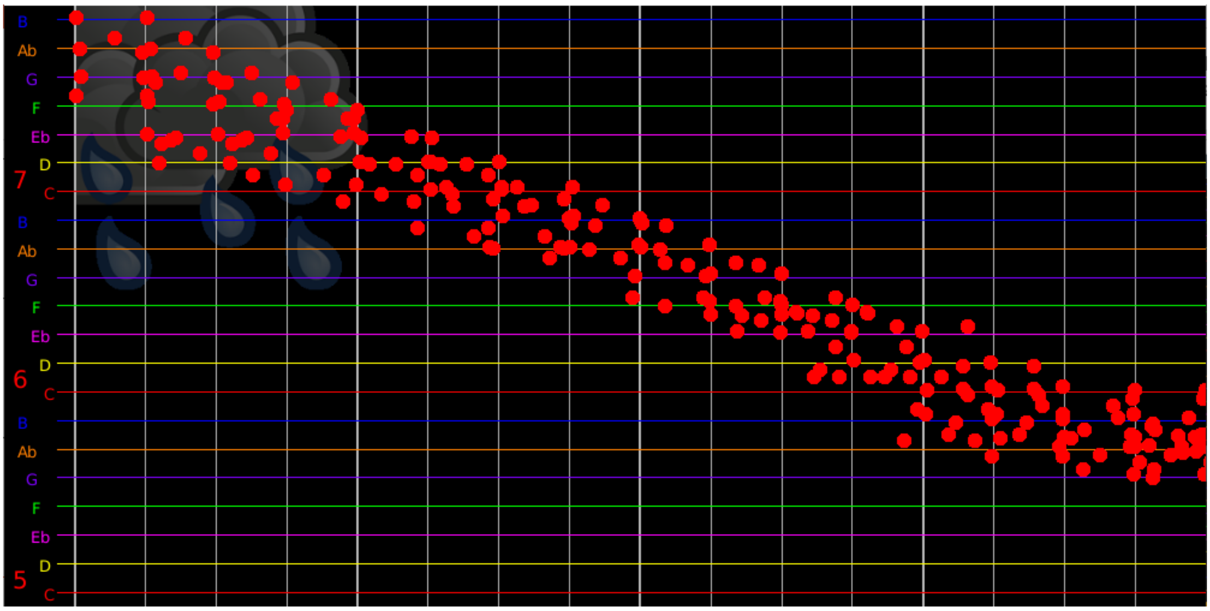


Figure 7.10 – Hayley

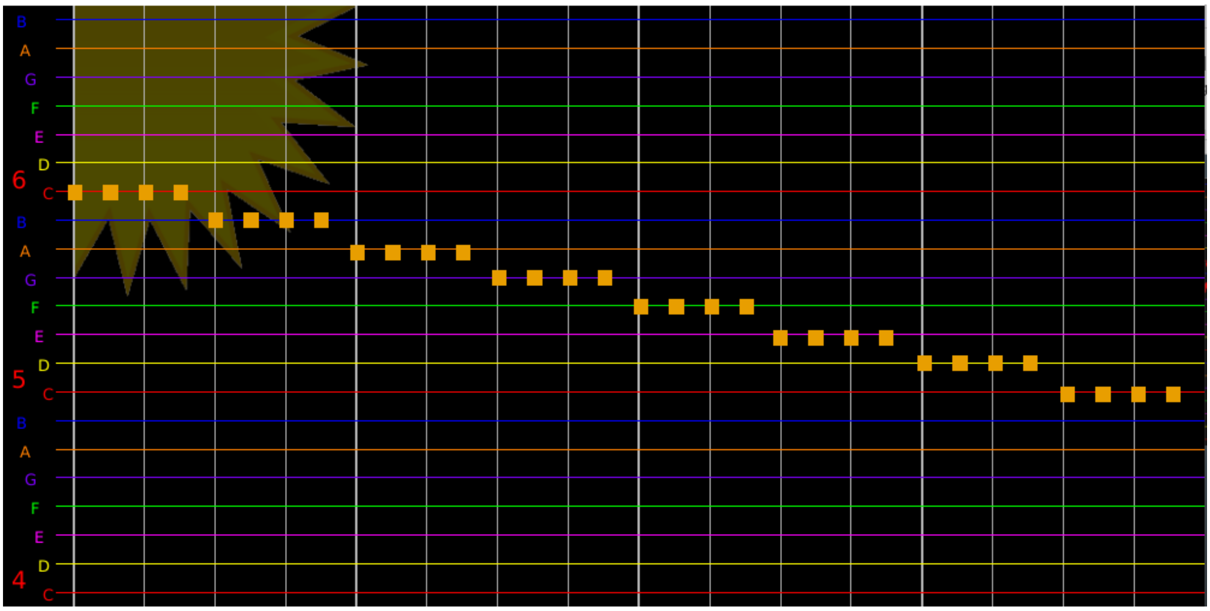


Figure 7.11 – Kody

Some participants mimicked the up-and-down gesture used in the demonstration of *Incy Wincy Spider*, but reworked it to tell another story. In some instances, this was done by drawing using the pencil tool (Figure 7.8; 7.9; 7.10) while others used metric rhythm blocks to create a sequence (Figure 7.11). Both of these modes of interaction were seen in prior studies (see 6.5.3). Pupils described their ideas of what this represented during the discussion:

> Imogen: '… a rabbit being chased by something…'
> Other Pupil: 'You could have the piano for running fast, going down, then like, one drum.' [Makes action of something going down a hole with arm]

Here, the other pupil provides some instrumental suggestions to build upon this gestural idea, a rapid piano ostinato and the single bang of a drum as the rabbit jumps down its hole. In the later discussion as Imogen built upon this idea, it became apparent that the tempo animal images were being used as a creative stimulus:

> Imogen: 'I did a rabbit trying to run up a hill… It was a rabbit trying to get up a hill, so he got up but then it rained. So he had to go back down but then there was a cheetah at the bottom because I saw that. [Points to tempo icon.] Then he had to run back up, and he got away from the cheetah. Then he finds his family so he's happy.'

Karla takes the nursery rhyme used in the demonstration as a starting point, before moving on to variations on a fairy tale. Here, the discussion on musical features during the midpoint of the session appears again to have led to a broader experimentation of musical gestures and connected narrative, which appears loosely based on the indicated story:

> Karla: 'So I did *Incy Wincy*, but then for the last four scenes I did *Little Red Riding Hood*.'
> 'That's where she's walking along' [linear drawing across screen]
> 'She thinks someone's following her' [suspenseful, quiet tones]
> 'This is where he's chasing her' [busy, loud noises]
> 'This is where he's falling' [crashing noises, drums]
> 'This is where he's upset' [sad sounding music]
> 'And then he tries to get up again' [tinkling sounds, glockenspiel]
> 'And then he's celebrating' [synthesizer, fanfare-like]

Another recurring feature was the way in which participants engaged with each other, showing their ideas and asking questions:

> Kathy: 'So, what happens is… Have you ever watched *Peppa Pig*?'
> Me: 'I have. My niece really likes it'
> Kathy: 'Right, so basically, Peppa and George… it's dead sunny outside so they want to go and see what's happening, and see if they can go and play outside. But then it starts raining. Then it goes sunny, and they get to jump in muddy puddles so they're happy.'
> 'so this is the happy bit where they think it's sunny'
> 'then it starts raining'
> Other pupils: 'what instrument is that?' 'that sounds good! play it again'
> Kathy: 'Then this is supposed to be the bit where they go outside.'

Here, as with other examples, the images of sunshine and rain, with the text 'happy' and 'sad' in the graphics menu, provide a wider narrative framework within which the pupils sketch out details. Drawn gestures are again used for actions (jumping in puddles), with melodic ideas made from tune-blocks, resulting with a major or minor tonality as required. Other examples made more prominent use of tune-blocks to indicate motion or action:

> Anna: ‘Mine’s about like… this is waiting in a queue’
> ‘it went… *(doo doo doo doo)*’ [imitates it with up and down finger movement, like a rollercoaster]
> ‘mine was… it was in Gulliver’s World. and we’re waiting on a queue, then going on a ride, then waiting in a queue…’
> Me: ‘so how did you represent the queue and the ride?’
> Anna: ‘I went like… I put like four notes, like, 1 2 3 4, with’
> Other pupil: ‘… with like strawberry?’
> Anna: ‘yeah… and then with like pear… I did 1234, 1234’
> Me: ‘right, okay’
> Anna: ‘and then I did the same… and I did, erm, apple, and I did the upside down ride, the hoop thing, where you go up then you spin’

This use of the language of the programme – fruits, animals etc. – to refer to musical features present in the compositions was interesting, as it suggested that a frame of reference had been established which enabled the participants to describe their ideas. Participants very quickly built confidence in this setting, wanting to show their compositions, and being keen to show others how they had utilised some function. This was especially prominent with the returning participant, Anna, who was eager to show her existing knowledge of the programme. At one point, when one participant asked for help as I was busy with another, Anna took off her headphones and said ‘I’ll show you how.’ Another participant reconstructed melodies from the tune fragments and, when invited to play their work back, had devised a game:

> ‘You have to guess the songs.’

The idea that participants might use the programme to build games and other activities was unexpected, but has parallels with the problem-creation applications of sandbox games such as *Minecraft* (see 3.3.2).

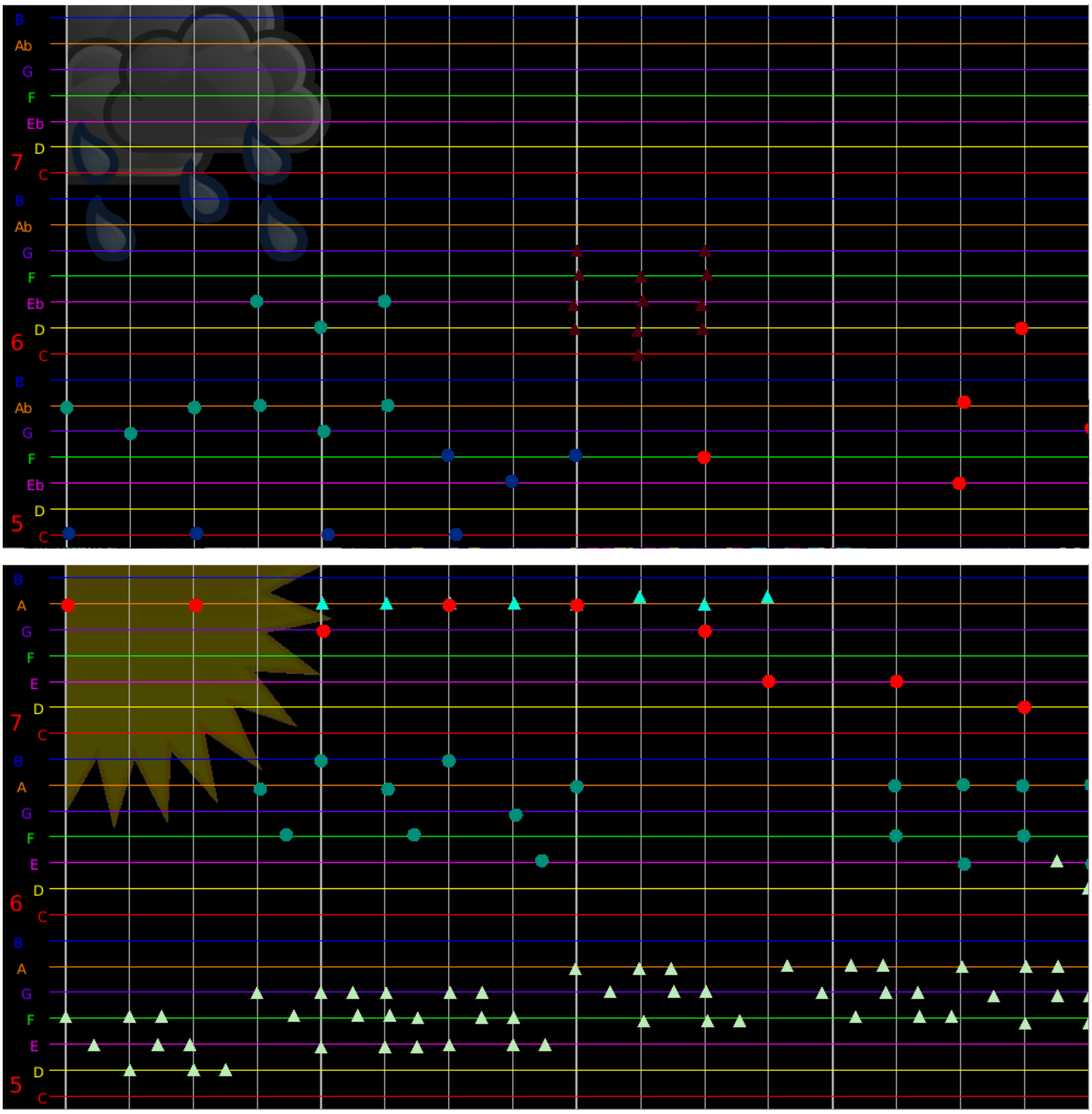


Figure 7.12 – Rob

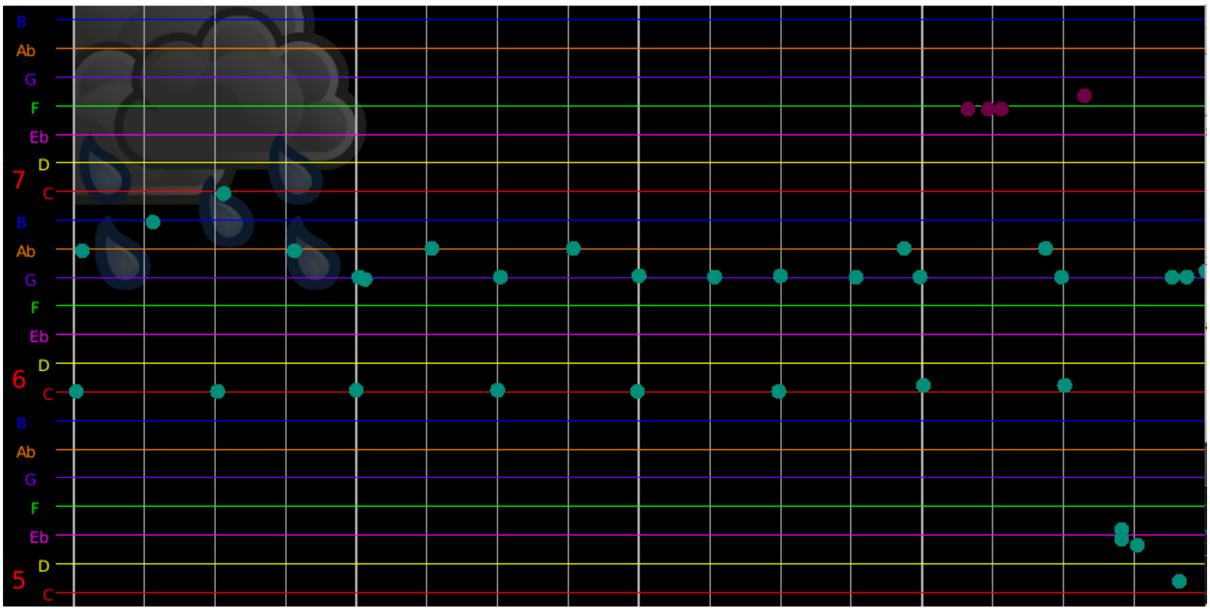


Figure 7.13 – Renee

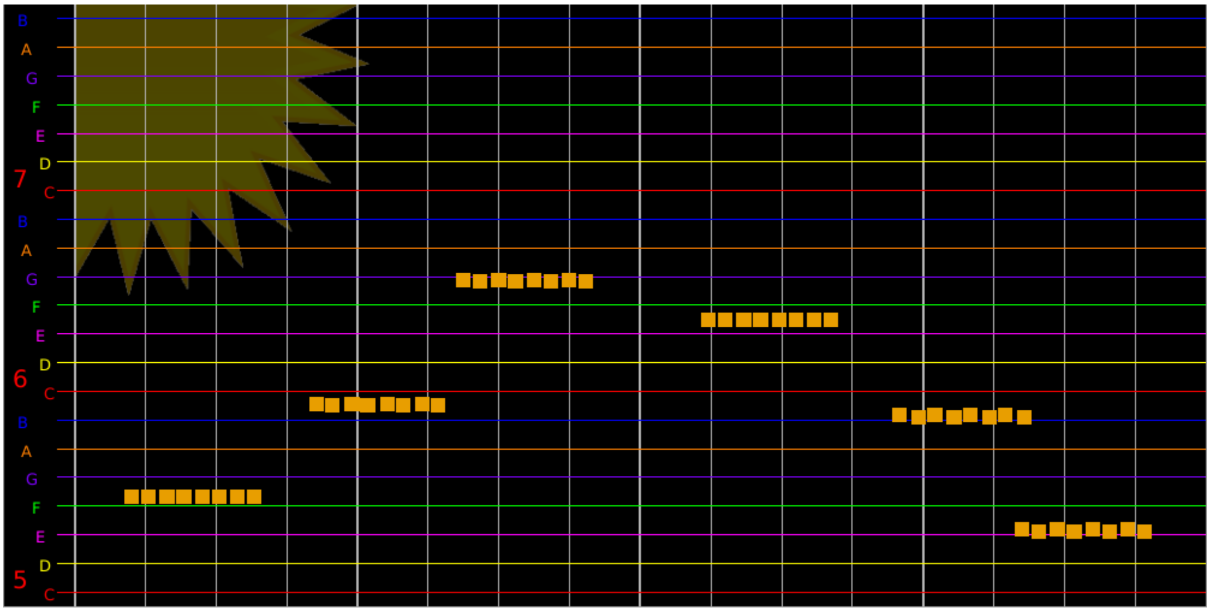


Figure 7.14 – Barry

Another interesting feature was the use of melodic contour and metronomic, repeating sequences, which occurred much more frequently than in the previous studies. For example, Rob (Figure 7.12) makes use of copied rising and falling patterns to achieve a polyphonic and polyrhythmic complexity. Sometimes, these gestures emerged from simple representations of the sun and rain images on the canvas window. Renee (Figure 7.13) uses the grid lines to produce a metric series of blue ‘rain drops’, while Barry (Figure 7.14) represents the sun through wavering orange trills. That these gestures appeared to emerge by discovery, abstracted from the simple graphics, was an unexpected occurence**.** This often led to learning opportunities which could be categorised as discovery learning. For example, when one participant (Leighton) stated:

> ‘Mine sounds like Japan.’

It transpired that the participant had used a sequence of slow rhythms in a pentatonic scale, and that this was a good imitation of Japanese music, the pentatonic scale being often used to teach the music of Japan at key stage 3. The sound used, a guitar, was reminiscent of a koto when heard in this manner. For other pupils, experimentation with basic musical dimensions within the grid of the canvas window produced results of surprising regularity when played back. An example of this is Emma (Figure 7.15) who uses the grid to produce blocks of sound; intitially stacked thirds followed by three single note crotchets, gradually increasing in texture and dynamics, until the notes ‘scatter’ about. This is an example of where the drawing of visual patterns – what I have come to term ‘sound-painting’ – allows pupils to engage with changing musical dimensions, and produce results with a clear musical coherence despite the rudimentary mode of interaction.

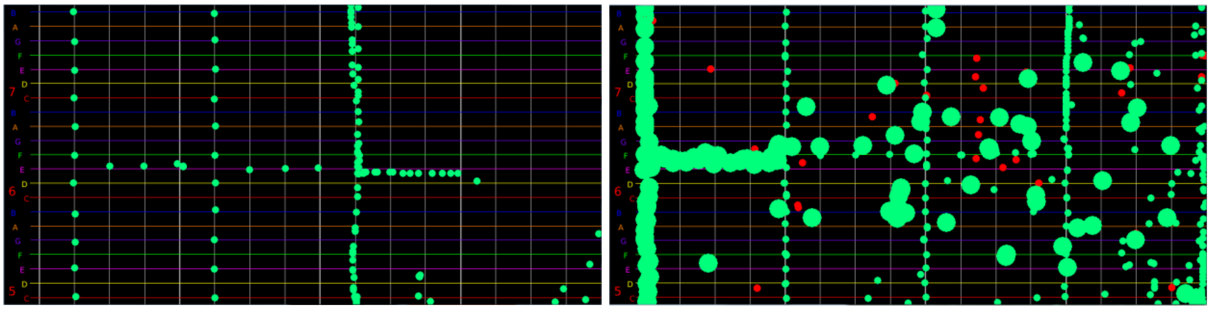


Figure 7.15 – Emma

In other examples, sound-painting was used to characterise actions and events from a simple story. Take, for example, Aisha’s *Owl* composition (Figure 7.16):

> Aisha: ‘I’ve done… this is like an owl… then it flies over, and it drops, then that’s it in its nest’

Though straightforward, the images tell a clear story in which there is a present musical element. The owl, flying through the air, lands with a drop in pitch. Its sedentary position in the next scene is represented by the circular 'nest' at one end of the window, as it waits out the rain. Structure and timbre has been used in a simple but effective manner to tell the story. A similar approach to 'drawing' movement is seen in Millie's *Bird* (Figure 7.17), and Ronan's *Humpty Dumpty*, which depicts the motion of the egg falling off the wall with a dropping pitch, and the visual and audible mess as it hits the ground (Figure 7.18). These motions have been noticeably copied and pasted, effectively generating motivic gesture. A clearer example of this is found in Harvey's *Ghost* (Figure 7.19). Here, the visual and audible characteristics were pointed out by other pupils; the single synthesizer timbre described as sounding 'sort of spooky', and the vaguely ghostly-looking geo which by default accompanied it. Harvey took these ideas to build several scenes of changing texture, from tense sparse notes to 'shock' bursts of sound, such as the copied glissando (shown in the figure) which is repeated at different intervals. Again here, these painted ideas become compositional gestures which the pupils use to tell their stories.

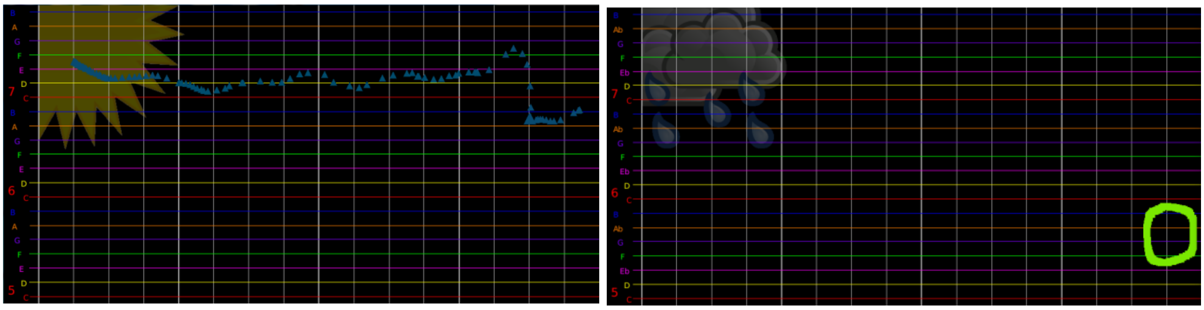


Figure 7.16 – Aisha, *Owl*

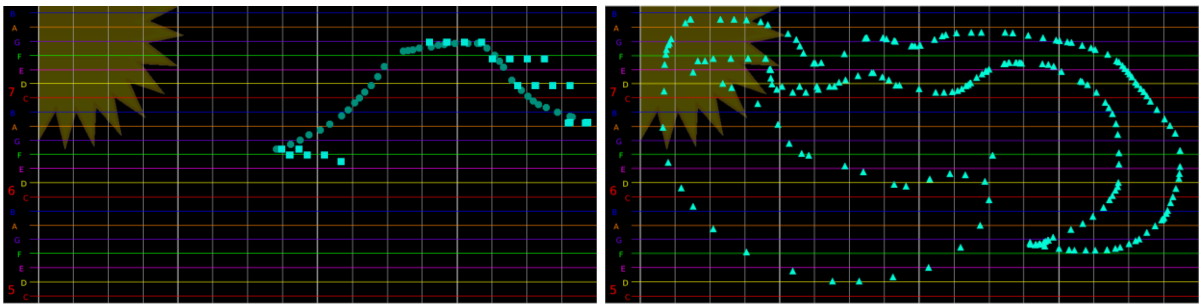


Figure 7.17 – Millie, *Bird*

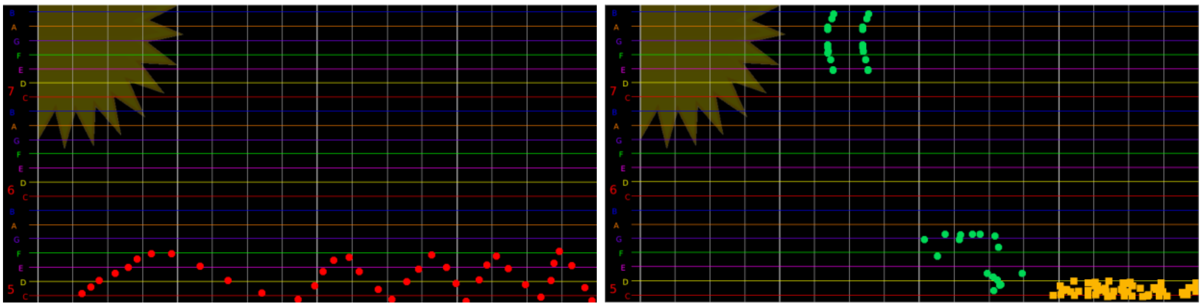


Figure 7.18 – Ronan, ***Humpty Dumpty***

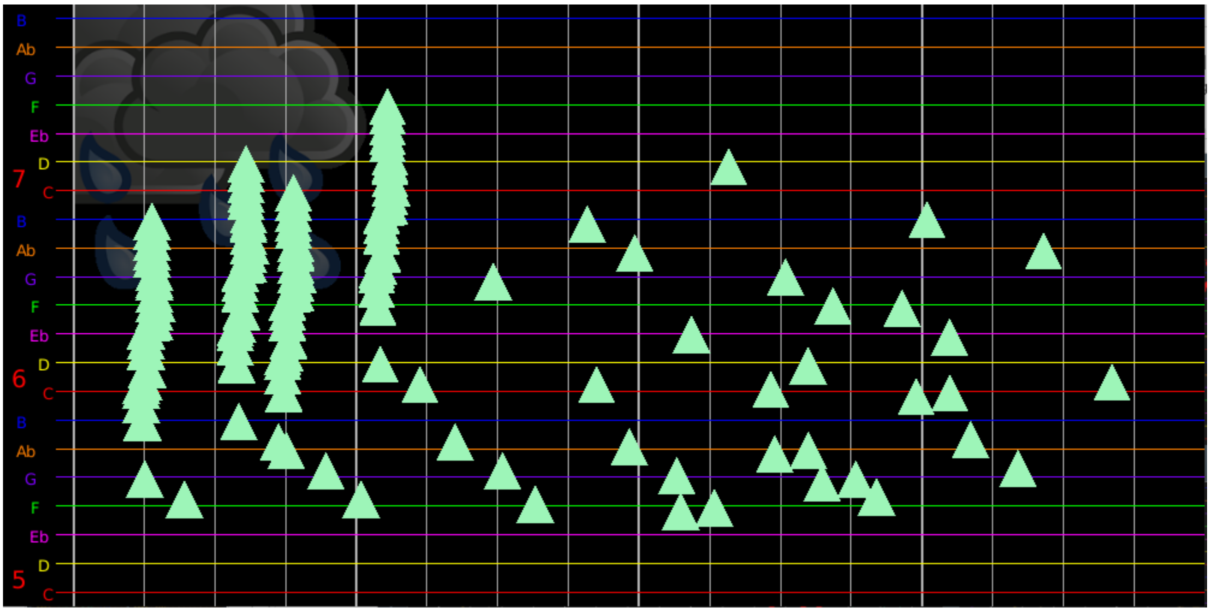


Figure 7.19 – Harvey, *Ghost*

This study proved to be much more successful than any previous attempts. The high levels of engagement and improved mode of interaction point to the effectiveness of the new user interface, as evidence by the participant's willingness to assist one another in working out functions, and in their referral to the onscreen icons when discussing their work. Also, I believe that the educational setting was a powerful factor in influencing a creative output. Pupils felt that there was a challenge and purpose for the activity, as well as an underlying social influence to tell a story. This demonstrates the importance of considering not just what technology is used, but how it is used to support a wider learning environment (see Fullan & Langworthy 2014, p.30).

Evidence of creativity can be seen in the use of melodic and sequential material, and in the impressionistic depictions of actions, characters and events. The pupils were quick to attribute meaning to their creative explorations, drawing from the initial discussions on holiday activities, the demonstrated example, and other ideas emerging from their 'sound painting' in *Graphick Score.* This sometimes emerged from the presence of images linked to musical dimensions, such as the use of sun or rain to accompany happy or sad scenes, or the use of the animal tempo images. It is interesting that certain contexts are so quickly adopted and altered. The demonstration of *Incy Wincy Spider* was chosen as a simple four-stage story that anyone could identify, to model a possible outcome of using the programme. The up-and-down motion and sunshine/rain polarity was then appropriated by some pupils for their own purposes. Others took the idea of a nursery rhyme as a starting point, leading to representations of *Red Riding Hood* and *Humpty Dumpty*; it was unexpected that the demonstrated story would lead to this kind of influence, being aimed at a much younger demographic. In some cases, it is perhaps unclear how the story, as told by the student, relates to the musical gestures employed. Interestingly, those with perhaps the most clarity are 'drawn' gestures without the melodic coherence of the tune-blocks, but still presenting a collation of musical dimensions to represent an action or event. Within the scaffolding format of *Graphick Score*, this 'painting' or 'drawing' can lead to results of surprising musical coherence, which is apparently then shaped to give some meaning (e.g. *this is about a bird/an owl/a ghost* etc.) This is evidence of compositional thinking at a very fundamental level; indeed, *inspiration* appears to be present here (see 2.2.1) as the pupils 'shape the tools' of the environment (see 5.1.2) to generate meaning.

Many examples suggestive of the target activity of experiential composition have been afforded by this digital resource. Given an open-ended objective to tell a story through sound, pupils used the tools offered by *Graphick Score* for creative explorations, in many cases leading to opportunities of discovery learning, and the development of expressive actions which were not demonstrated; this includes the copying and arrangement of motivic gestures, and the use of tune-blocks to develop harmonic and rhythmic sequences. In accordance with the recommendations of Bassey (1998) I now decided to apply the same resource to a different situational context in a new school environment.

7.3 Melodic Composition at School C, July 2016

7.3.1 Context

Following the storyboard format of the previous study, I wanted to further explore the capacity for more traditional compositional approaches of melodic and harmonic writing presented by *Graphick Score*. The study at School C focused on a more conventional composing activity with a group of pupils who had prior musical experience. I arranged with my contact at the school to conduct an afternoon session with pupils from a Year 5 class. These were all instrumentalists, mostly consisting of members of the school brass band, and were therefore used to reading and performing music, but had less experience with composition. School C has a good reputation for musical practice, but my contact wanted to implement more interactive technology, especially for composing activities, and was eager to see how the pupils responded to new interfaces like *Graphick Score.* Therefore, seeing how these ten young instrumentalists approached composition with a digital scaffolding tool was very much a suggestion of the class teacher, which I agreed would make a valuable situational contrast to the previous study. In some respects the two studies were similar, in that the same resource was used, the pupils were roughly the same age (within one year), and the same time frame and activity for the session. However, the pupils had more musical experience than the previous group, and objective was different, focusing on harmonic and melodic writing.

7.3.2 Method

Learning Objective: *To compose a piece with varying rhythmic and melodic patterns*

The study involved two successive groups of five pupils taken from years 5 and 6. As with previous studies, five workstations were set up in a classroom. After engaging with each group in an informal discussion about their musicality, a demonstration of the programme was given. This involved comparison of a messy scene and a tidy scene, with the group being asked *'which sounds better, and why?'* (Figure 7.20). The group then had 15 minutes to build some ideas and explore the programme, following which they would share with their neighbours, and then another 20 minutes to complete their pieces. After this, we listened to and discussed the pieces as a group.

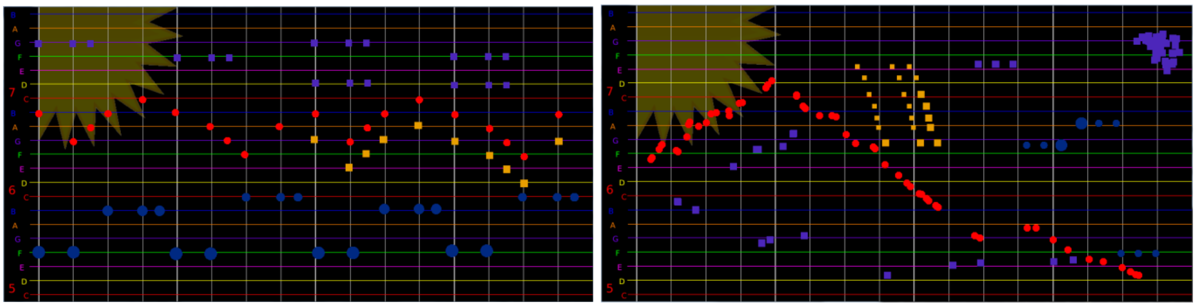


Figure 7.20 – The demonstration from the session

7.3.3 Results

The pupils all decided that the first example from the demonstration sounded the better of the two, being more 'in time' due to the notes conforming to the grid. After some prompting, the idea of repeating sequences being 'catchy' was also established, and also the spacing of notes to construct harmonies or chords. This latter concept was less readily understood. Although a brief discussion, this was useful in that it gave me a sense of the skill level of the group, perhaps more efficiently than the surveys used in phase 2.

This study yielded some interesting results in terms of music composed, but I felt that engagement and depth of discussion did not match that of the previous study. I attribute this to the learning materials not capturing the pupils' imaginations, as they were composing without the stimulus to tell a story. I did ask the groups to think of a title for their pieces, and to discuss a possible title with their neighbour after the first 15 minutes, as I hoped that this would provide an insight into compositional intentions. However, no participants had a title in mind when presenting their work.

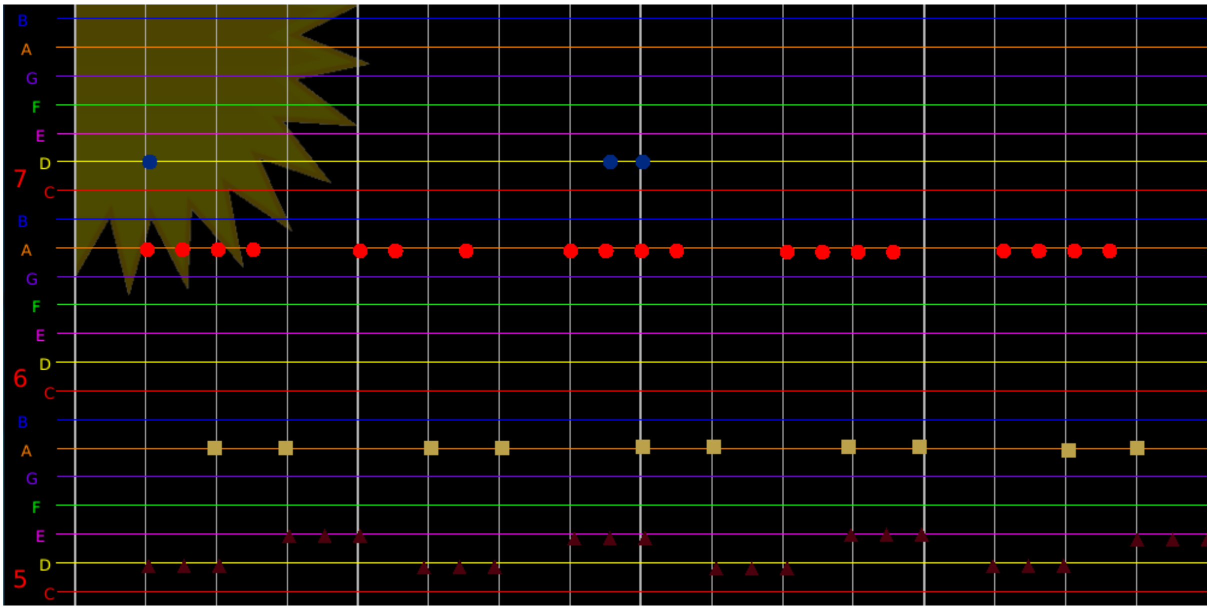


Figure 7.21 – Natasha

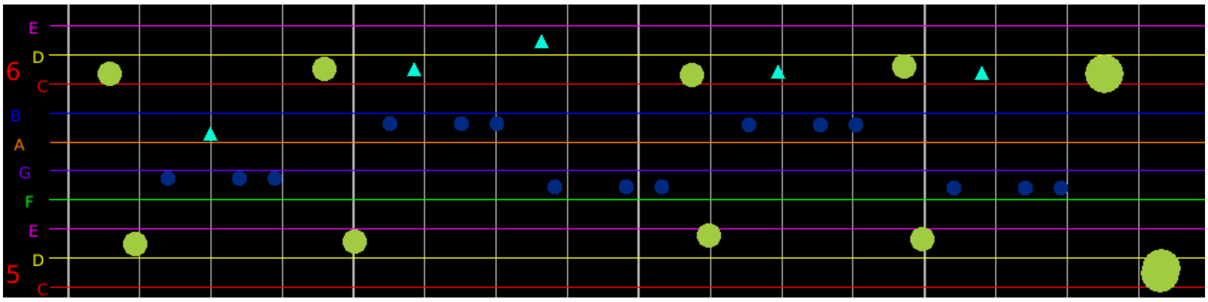


Figure 7.22 – Ethan

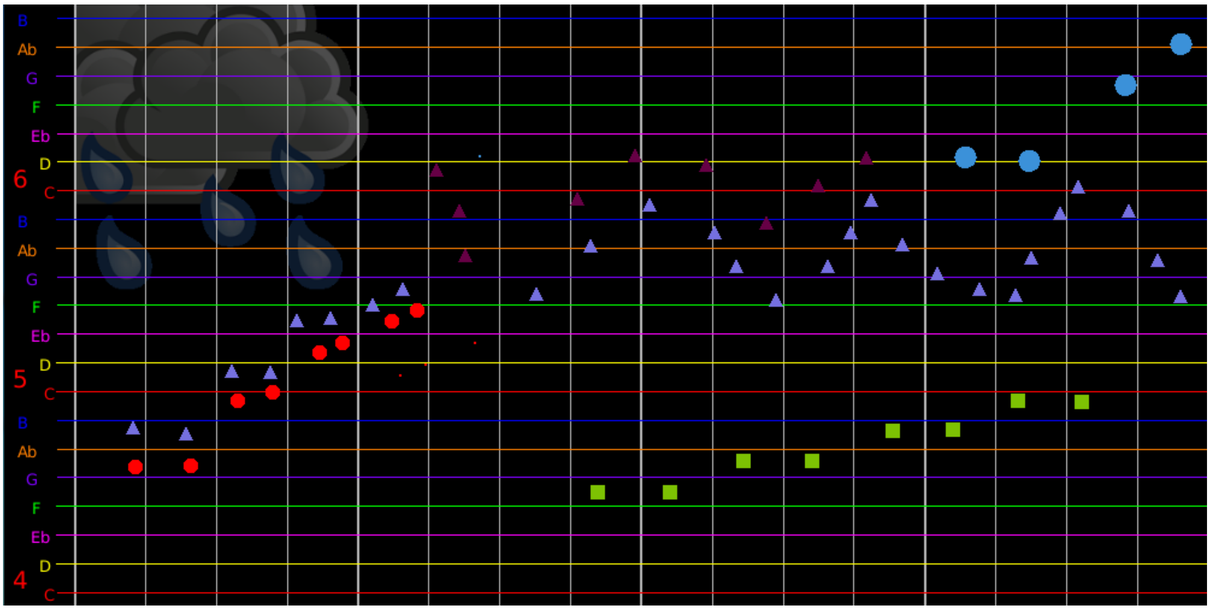


Figure 7.23 – Rickie

Many of the pieces showed use of different phrases, rhythms, and voices, arranged in a metronomic sequence. Several scenes composed by Natasha contain a bass ostinato and repeating cross-rhythms (Figure 7.21). Similarly, Ethan (Figure 7.22) makes use of a repeating motif composed of several voices. This use of tune-blocks for regular formation upon the grid appears to have been very quickly ascertained from the demonstration by these pupils. The example by Rickie (Figure 7.23) contains several conjunct melodic patterns which are partially harmonised and imitated by other voices. Notice how the contour of the blue triangle melody is harmonised a third above by another voice; this appears to quite closely mimic the harmonic pattern used in the demonstration (Figure 7.20). The first harmonic sequence in Rickie's scene here appears to mimic the harmonic pattern of the demonstration, but places the second voice a tone above, before build a harmony of thirds in the second half of the scene, suggesting that the demonstration acted as something of a visual scaffold which allowed her to attempt this kind of harmonic writing. This resonates with the visual-oriented explorations seen in earlier studies (see 6.6) as well as the mimicking of the visual up-and-down gesture demonstrated in the previous study (see 7.2.3).

The harmonic and melodic constructions from tune-blocks seen here are similar to those which emerged from the previous study. Again here, the pupils appear to have quickly established musical gestures, and developed them into complex textures. Sammy's piece has particularly interesting examples of polyphonic texture and musical gesture (Figure 7.24). It contains a number of repeating rhythms and melodies spaced apart to form a consonant harmony, and decorated by harp glissandos and flourishes as well as trills; as such, several distinct voices combine to produce a musically and visually coherent piece. The work of Lewis (Figure 7.25) is, by contrast, mainly constructed of percussion instruments and rhythm-blocks, as well as blocks of sound less characteristic of diatonic harmony-oriented writing. It transpired that Lewis was the drummer of the group, and it appears that he drew from his existing experience and knowledge in approaching this piece; this is, of course, an idea very much present in constructivist-oriented instruction (see 2.1).

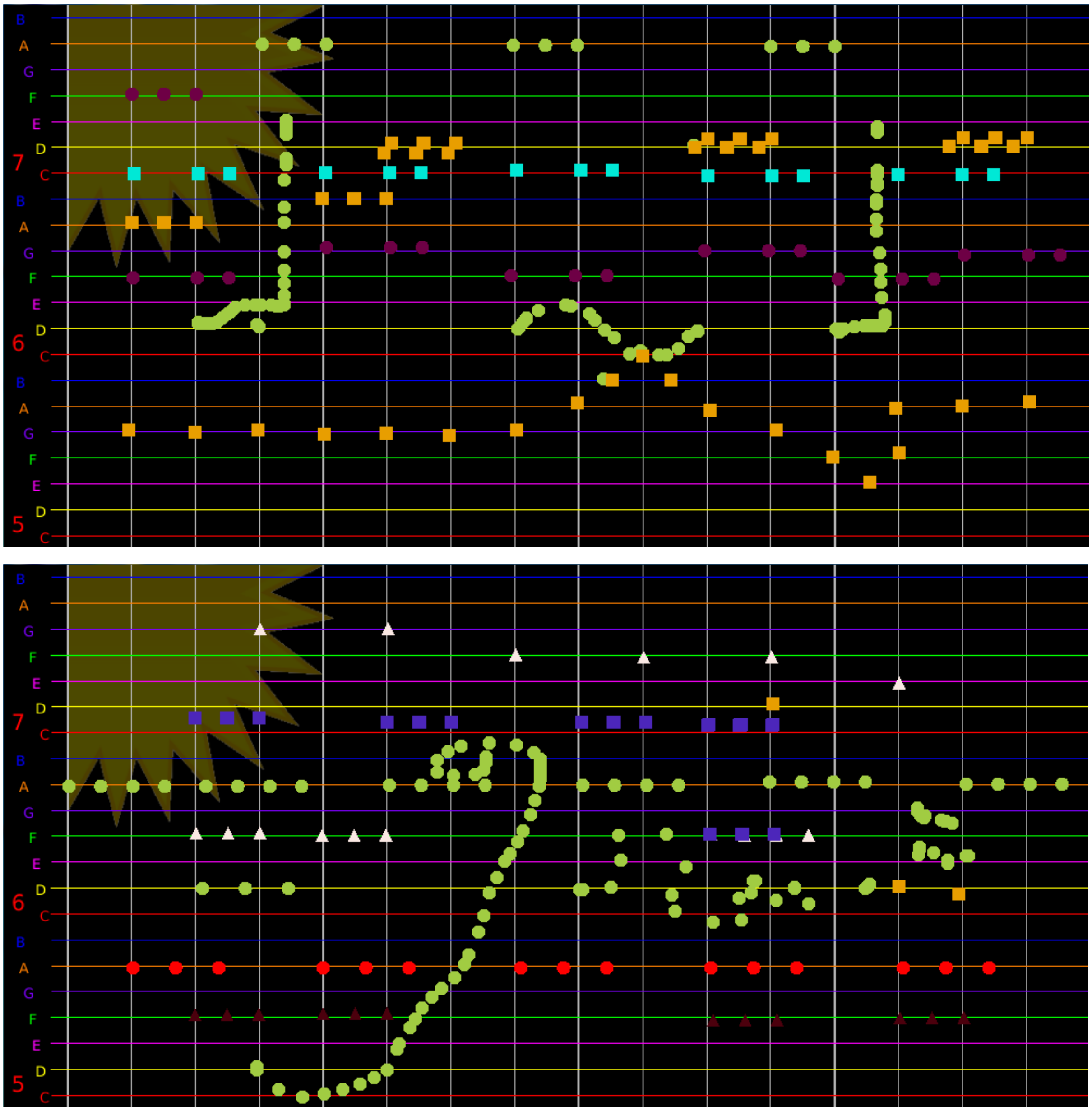


Figure 7.24 – Sammy

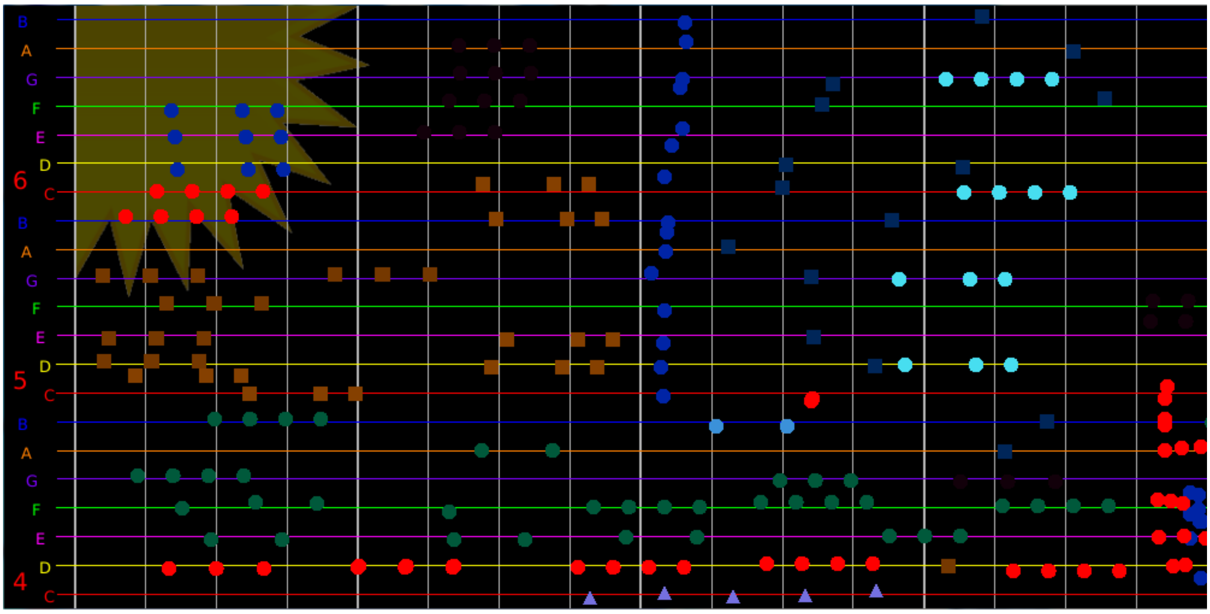


Figure 7.25 – Lewis

In this study, the pupils' use of *Graphick Score* appears to have again drawn heavily from the demonstration. This resulted in instances of harmonic and rhythmic sequences, as the objective required. The pupils were mostly able to compose with ease using the programme, with some evidence of gesture and ornamentation, suggesting that *Graphick Score* offered an accessible means of applying existing musical skills, and perhaps a scaffold for more complex compositional writing. However, relatively little attention was given to musical dimensions such as dynamics, with most geos at a uniform velocity. The earliest studies (see chapter 6) suggested that menu options were rarely used for functions such as tempo and velocity, as well as other variable settings. Options such as change of instrument were more readily utilised. The suggestions from pupils of different instrument timbres in the previous study (see 7.2.3) indicates that this is something they were actively considering when composing; part of their creative intention. One of the musical dimensions that become more frequently utilised was tempo. This was previously operated via a slider on the graphics menu; when it changed to a series of animal images, it was not only more frequently utilised, but also influenced discussion and narrative. Perhaps the mode of operation for dynamics should be made more inviting to the user through some sort of conceptual representation, or altered somehow via direct interaction with the canvas window.

There is, perhaps, less evidence of experimentation in this study, compared to the previous study. Less evidence is seen of pupils 'shaping' the tools of the environment to achieve creative outcomes. In part, this may be explained by the relative 'disinclination to experiment' which has been observed in more experienced students in other research (see 2.2.2). However, I also feel that the task did not establish the forum for discussion observed in the previous study, where the activity focused on telling a story rather than upon abstract musical features. This provided a framework for discussion and reflection, with the pupils able to give clear reasons and suggestions for creative choices, relating these to anecdotal ideas in place of musical terminology. By focusing on musical ideas with no narrative framework in this study, we were effectively dealing with these concepts in the abstract, and the reflective component of the experiential learning cycle was consequently less noticeably propelled; it is worth noting that these students had no titles for their pieces, though this was given as an objective at the start. We also saw very little of the drawing or painting actions which provided many imaginary narrative ideas to the previous study. The pupils were following a more paint-by-numbers approach, and had no incentive to attribute meaning to what they were doing[18]. Therefore, the sense of creative ownership, exploration and reflection observed in the previous study was largely absent. This suggests that, in sandbox environments such as *Graphick Score*, the facility for creation of meaning is as important as the scaffolding tools which support creation of sounds; when dealing with abstract musical concepts, we have seen more promising results, in terms of experiential learning, when pupils shape these ideas within a narrative framework.

7.4 Performance and Composition with iPads at School B, December 2016

7.4.1 Context 1

Following the previous study, I felt that the way tune-blocks were used within *Graphick Score* should be addressed; results at the conclusions of the previous phase indicated that pupils did not know what to expect from melodic tune fragments (see 6.5.2). Indeed, the idea of arbitrary song choices for these materials seemed a limitation, and finding melodies recognisable to the demographic from a single phrase was a challenge. I wanted these structures to be something which could be harnessed and shaped for a creative intention, and which perhaps presented more interplay of musical dimensions than the fragments of popular

[18] In hindsight, this was initiated by the opening activity, which suggested that the grid-conforming scene was a 'correct' way of writing, compared to the freehand scene.

music hitherto used. For these reasons, I decided to focus on manipulating tune-blocks for a single song in the next study, and to address how the narrative might change to results in musical diversions. I also wanted to examine the possibility for a different social dynamic, being aware that previous studies had mostly consisted of pupils working individually with headphones, cut off from their peers for much of the session. This presented the opportunity for a new situational context; developing bespoke resources for touchscreen tablet, but continuing to focus on the core objective of experiential composition with digital technology.

The next two studies were conducted with the Year 5 class of a primary school in December 2016. I decided to apply some of the software features used in *Graphick Score*, such as tune-blocks and story-based mechanisms for engaging with musical elements, but to focus specifically on the use of tablets. I therefore drew up a set of questions for these particular studies, which relate to my existing questions and use much of the language of the National Curriculum:

- *How might the tablet function within the dynamic of the classroom, in terms of facilitating 'performance in solo and ensemble contexts'?*
- *How might the tablet be used to encourage 'increasing accuracy, fluency, control and expression'?*
- *How might the tablet allow pupils to engage with the 'inter-related dimensions of music' in their performance and composition?*
- *How might the tablet utilise alternative modes of representation to lead pupils toward a greater understanding of staff notation?*

The studies took place in a primary school over two Friday afternoon sessions of 90 minutes, taking place a week apart. The Year 5 class consisted of 27 students. No pupils were identified as requiring special assistance, and none of the pupils took extracurricular music lessons to learn an instrument or sing. While I led teaching of the lessons, the class teacher was on hand to provide assistance. 15 iPads were available for use, meaning that most of the students had one between two. One concern before the study was that the iPads would not be sufficiently audible through the built-in speakers, while separate amplification for each iPad was an unreasonable solution due to cost. Different methods were tried to resolve this issue during the course of the study.

Prior to the session, I contacted the teacher by email to request a description of the usual activities of a music lesson in Year 5:

> The school accesses the 'Charanga Musical School' website which provides a breakdown of objectives for each year group along with a range of practical resources for the children to take part in. The activities that the children take part in include singing and using percussion instruments to help them perform a composition.

In music lessons at this time of the year, the class would usually use *Charanga* to learn and sing Christmas songs, perhaps accompanied by percussion instruments. Being a Catholic school, nativity plays were an annual feature, and the performance of Christmas carols a popular music activity in December. The Year 5 teacher felt that this would present a good opportunity to try some new approaches to performance of songs with which the class were already familiar. Drawing from the National Curriculum, the main outcomes for this lesson series were to facilitate solo and ensemble performance of Christmas songs using the tablets alongside percussion instruments and voices, and to demonstrate an attention to expressive functions, as well as the 'inter-related dimensions of music'. In the second lesson, a similar approach was used to facilitate performance and composition.

The purpose of the first lesson was to create variations in performance of the song, changing the 'mood' with attention to musical dimensions, and providing opportunities for discussion and reflection on how they function individually and in combination. Certain dimensions could be expected to be addressed more readily on an individual basis, being fairly instinctive to comprehend and manipulate. In particular, dynamics and timbre might fit into this category. Other dimensions, by contrast, might require a degree of co-ordination and communication between players to properly execute, such as tempo and texture. The remaining dimensions of tonality and structure – and perhaps to some extent, pitch – are in the context of this task more related to composition and arrangement, and could be expected to require a greater degree of planning and creative exploration to address.

7.4.2 Method 1

Learning Objective: *To perform a Christmas song in groups, and to change the mood using the 'inter-related dimensions of music'*

The song chosen for this lesson was *Little Donkey*, a Christmas carol which the class knew from its usual inclusion in their school nativity plays. This was a particularly suitable piece to display in tune-blocks due to its regular phrasing pattern, which includes a recurring phrase with an easily recognisable rhythmic and melodic pattern (Figure 7.26). I felt that the chorus of the song would provide an opportunity to explore some contrasting dimensions, changing from major to minor chords and having melodic contour and lyrics of a more rousing nature. Also, the mid-bar chord changes might present more of a challenge than the steady changes of the verse. I saw these as potential scaffolding activities between the performance of the verse and a more creative arrangement-based exercise.

Figure 7.26 – The verse of *Little Donkey*

An interface was made in *MobMuPlat* which divided each bar into colour-coded tune-blocks, with each colour corresponding to the accompanying chord. The notes were represented as rectangles arranged into place according to their rhythmic position within the bar and pitch relationship to the rest of the melody. When one of these buttons was touched, the corresponding note of the melody sounded. Therefore, the player simply had to move consecutively through these buttons following the rhythm of the song. A second window showed the tune-blocks for the chorus. By swiping left or right, the player could move to the previous or next screen (Figures 7.27-8). This presented a form of scaffolding for engaging with musical dimensions, as I hoped pupils would be able to immediately play the piece using the tune-block interface, and therefore engage with musical changes directed by a wider narrative framework of what the song is about, and how the meaning might be altered.

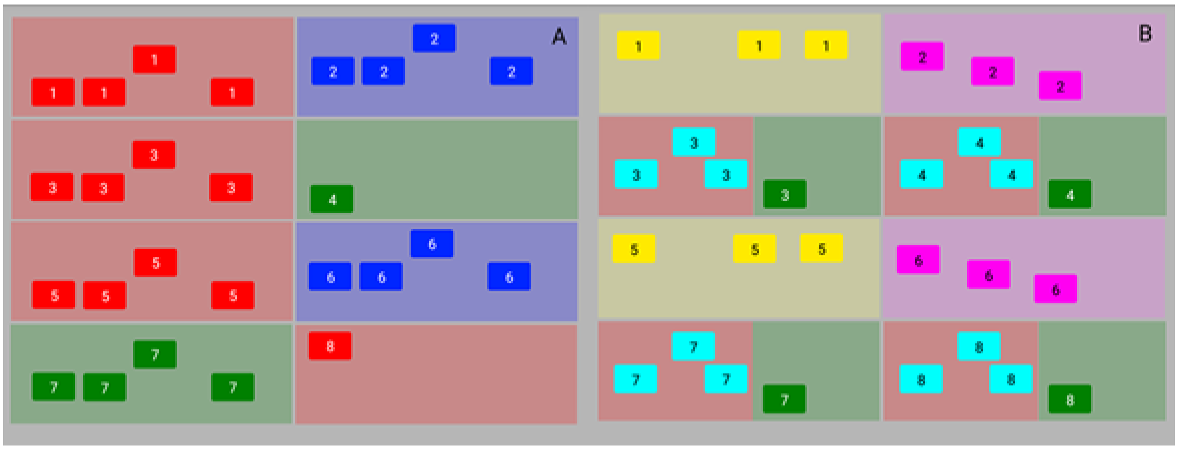


Figure 7.27 – The verse and chorus of *Little Donkey* in iPad tune-blocks

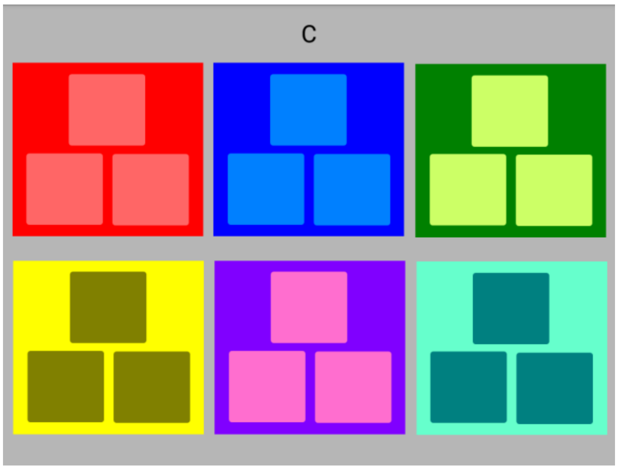


Figure 7.28 – The chord interface

A third screen showed six coloured boxes representing the chords of the song (Figure 7.28). These were colour-coded to match the corresponding tune-blocks, and each contained three buttons which played the root note, third and fifth of the triad chord in question. I decided to break the chord into separate notes rather than use a single button so that the pupils could play broken chords and come up with their own accompanying patterns. I considered arranging these in a vertical rather than horizontal line, to match the arrangement of pitch in the tune-blocks, but felt that this would require the hand to be angled at an awkward position. In my experience of teaching keyboards, novice learners often play chords using the three middle fingers rather than the more conventional thumb, middle finger, little finger position, so I decided to arrange the chords on the interface to match this triangular formation. This more naturally lends itself to touchscreen multi-finger performance, where the thumb is less likely to be used due to its different angle and shorter length compared to the other fingers. The final screen allowed the player to choose an instrumental voice for each of the three ‘performance screens’, as well as setting the volume. A general MIDI sound set was used for sound sources.

The plan for the lesson was to divide the class into five groups; three groups of 5 and two groups of 6. Each group had three iPads and an assortment of percussion instruments, and was allocated an area of the room in which to work. While planning the session, a number of obstacles were faced with regard to amplification. The iPads would need to be sufficiently audible over percussion instruments, and it was clear that the built-in speakers would not transmit a loud enough signal. Transmitting the three iPads of each group to a Bluetooth speaker was considered, though the models available could only accept one device at a time. Ultimately, the setup had to be reconsidered. A laptop was connected to each of the five speakers, containing the set of general MIDI sound sources. The iPad interfaces were then edited so that, as well as playing notes directly, they could transmit Open Sound Control (OSC) messages over a wireless connection to the laptop. This meant that, within each group, the sounds triggered by any of the three iPads were played through their paired laptop and out of the speaker. Though the school had a Wi-Fi connection, it was decided that a separate router be brought to minimise any possible issues with connectivity. In this way, the setup and equipment required to amplify the iPads in this particular way became quite complicated and extensive.

This lesson was less open-ended in structure than sessions incorporating *Graphick Score*, as the lack of a sandbox environment increased the dependence on a sequence of activities:

1. *Students are put into pairs, with an iPad each, and are given time to explore the interface and work out the song. Groups can then be chosen to identify and play part of the song.*
2. *Questions: ‘What is the song about?’ ‘How fast should it be?’ The class are likely to suggest a slow, plodding tempo to suit the pace of the tired donkey. This generates a discussion about how musical dimensions can be used to improve a performance.*
3. *Half of the class clap the suggested tempo, while others play the melody. Question: ‘In each block of melody, how many times do we clap?’ This introduces the idea of a bar of four beats.*
4. *Each group then plans and rehearses a performance of the song using iPads and percussion instruments. The teacher moves around the room asking further questions to each group to introduce other musical dimensions, e.g. ‘What kind of instrument would suit this part of the song?’ ‘How might percussion instruments be used to fit around the melody?’*

5. *Groups then add a new verse which takes the song in a new direction. They are asked to come up with a possible new lyric and to represent this with a change in musical features; e.g. 'little donkey, little donkey, time to go to sleep…'*
6. *Performances by each group take place at the end of the lesson, with other groups asked to comment on how musical features were used to create a mood for the song.*

This lesson was planned to allow as much time as possible for practical musical learning, such as performance and composition, followed by reflection and discussion focusing on the musical dimensions. Data was primarily collected by means of observation, and an audio recording was made of the lesson. The teacher, who was present for the sessions but did not participate, took some photographs.[19]

7.4.3 Results 1

It was clear from the start of the lesson that the students were enthusiastic about using the iPads, and that they were generally confident about operating them. This was a characteristic shared by both boys and girls. Both the teacher and I ensured that everyone had the opportunity to use an iPad, and the students worked well in groups. No instances of arguing over iPads or instruments were observed. The setup used for this lesson had, as discussed, reached a more complicated level than originally intended. Equipment was set up during the lunch break preceding the lesson, though it was agreed by both the teacher and I that these requirements would be to demanding for regular use, and that a more efficient solution should be found for the next lesson. The use of OSC communications proved highly stable, as each iPad instantly connected to the host laptop and speaker and the transmission of wireless communications remained unbroken. This allowed the students to rehearse and perform in groups using a combination of iPads and percussion instruments. However, further issues with this setup became apparent during the rehearsal session, as some students complained of being unable to hear what they were doing as the noise level increased. Students were tending toward turning the volume of their iPad as loud as possible to achieve clarity, and consequently other students had to follow suit to maintain a consistent level. With three iPads playing through each speaker, it also emerged that some students were struggling to identify which sounds were being created by them. I attempted to resolve this by emphasising the

[19] This was unexpected, but as the photographs show the activity taking place but not the faces of the pupils, I later requested permission to use these in the thesis, and obtained consent to do so.

importance of communication in group performance, and demonstrating how a performer should pay attention to the actions of their fellow performers in addition to their own. This went some way toward resolving the issue, though it was still apparent that the setup used was largely unsuitable for this kind of lesson.

The tune-blocks interface proved effective, as all students were able to play and identify the carol. This allowed us to begin discussing performance features immediately following the starter activity. Students were keen to answer the questions with practical demonstrations using the iPad:

> Me: So if the donkey is feeling tired in the song, how fast should we play it?
> Student: It would be like, slow, like… [plays the first two bars at a deliberate, plodding pace] … instead of… [plays at a franticly accelerated tempo]

This led to interesting developments during the group rehearsals, where students were engaged with capturing the mood of the song through interpretation of musical dimensions, or altering the composition in some way. I pointed out that percussion can be used to augment the mood of the song by finding interesting rhythms, perhaps filling in gaps in the melody, or taking a rhythm from a different song. This meant that the arrangements developed interesting textures as the lesson unfolded. Likewise, performance of the main melody was left to one iPad at a time in all groups, with others using the interface to provide some form of accompaniment, again supported by the use of colour-coding in the tune-blocks layout. In some cases, performance of the melody was divided between different players at different points, allowing students to switch between different roles. All the groups were engaged in discussion about these ideas, and were eager to perform when the opportunity arose.

Most performances were characterised by the use of clopping, steady rhythms on wooden percussion instruments during the verse, and tambourines or bell-like instruments during the chorus. The chorus was also generally louder than the verse. Both of these features were identified as being suitable due to the lyrics – the plodding, tired donkey described in the verse, and the contrasting chorus of *'ring out those bells…'*. One group added a new set of lyrics for an additional verse:

> *Little donkey, little donkey, sleep and dream tonight,*
> *Little donkey, close your eyes and go to sleep so tight,*

This was played using a low-pitched bass sound, with a quiet tinkling of bells and bell-sounds from the other iPads. The low pitch was characteristic of the slumping, drowsy donkey, contrasted by the high tinkling bells representing the stars above.
Three of the five groups used the whiteboards on their tables to make notes on the structure of the performance, regarding who would be doing what, or the notes they wished to play. This was undirected and emerged as they experimented with different ways of using the iPad other than playing the melody. Two of the groups changed the rhythm of the melody, wanting to achieve a more upbeat mood (Figure 7.29).

Figure 7.29 – Rhythmic variations

In the second group, this formed part of an intriguing structure. The verse had a tremolo-like effect, achieved by playing each note multiple times in rapid succession, using a guitar timbre. This was followed by the chorus, utilising bell sounds in the same manner as other groups. Finally, this was followed by an improvisation between two iPads, selecting notes at random within the colour-coded structure set out by the tune-blocks.

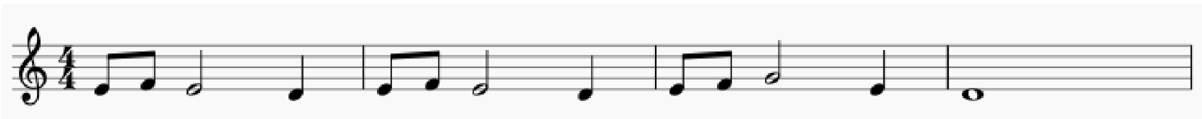


Figure 7.30 – Melodic variations with the same rhythmic structure

One group used notes from different tune-blocks to create a new melody to the same rhythm (Figure 7.30). This was followed by the normal melody of the chorus, while the rhythm of the verse continued to be played using the percussion instruments. This created an effective and interesting textural contrast. Another group followed the tune-block structure, but used this to create a new rhythmic and melodic pattern, while preserving harmonic structure (Figure 7.31).

Figure 7.31 – Melodic variations with the same harmonic structure

The final group had diverted the most from the original arrangement. A cello sound was used on all iPads, and only the screen showing the triad chords was used. Performance consisted of chords of long duration, alternating with broken chords moving in different directions, accompanied by a steady rhythm. The other students were particularly enthusiastic in commenting on this performance, and in finding comparisons or ways to describe it:

> ‘That’s definitely not *Little Donkey* no more!’
> ‘It’s like a drama… it sounded like the music to ‘Batman’ or something….’
> ‘It was like an organ weren’t it?’

This led to discussion on the qualities of dramatic music, and of the suitability of instruments like the cello and organ to creating this kind of mood, being capable of low pitches, and long sustained durations.

7.4.4 Context 2

The purpose of this lesson was to explore how a Christmas carol is constructed, and to compose a new one based upon these guidelines. It took place exactly a week after the previous study, with the same class of students. As such, it provided a valuable opportunity to build upon the learning outcomes of the previous session.

7.4.5 Method 2

Learning Objective: *To compose and perform a Christmas carol*

The interface used in the previous session had produced interesting variations on musical dimensions, but had perhaps proved restrictive, as it limited pupils to the notes of the song

Little Donkey. I wanted to continue to use tune-blocks and tablets, but within the context of a more open-ended task.

To avoid the increasingly complex setup that was eventually used for the previous lesson, the class was divided into pairs rather than groups, with each having one iPad. Headphone splitters were used to send the output to two pairs of headphones, while a single Bluetooth speaker was brought for the purposes of performance, as only one iPad would need to be used at a time. Two spare speakers were brought, however, in case the opportunity for multiple iPads to perform together arose. Use of iPads was simplified to a single interface, the *Rainbow Keyboard*, again made in *MobMuPlat*. This consisted of eight numbered and coloured keys, corresponding to an octave of the major diatonic scale (Figure 7.32). These keys illuminated when pressed, and played high-quality instrument samples. Clip-art images were used to show the selected instrument, and volume could again be altered using a dial. The screen was divided into two identical sections, allowing students to select different instruments or volume settings and easily switch between the two. On a second screen, the upper section was flipped upside-down, so that students had the option to play the iPad in pairs, by laying it flat on a table and sitting on either side of it.

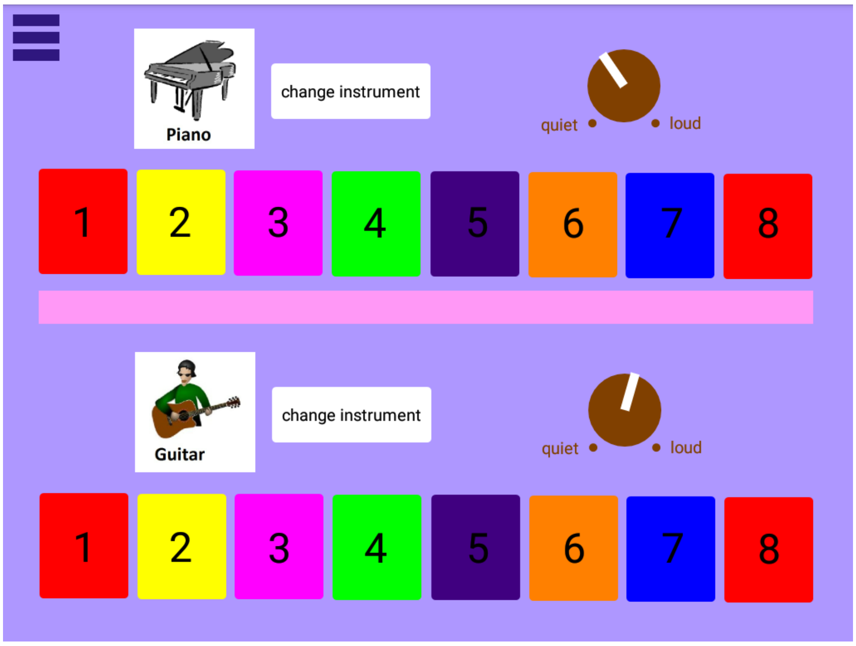


Figure 7.32 – The *Rainbow Keyboard*

Having found the tune-blocks approach to be effective in breaking down a melody into manageable sections, and also finding that the students could follow this with minimal direction, I decided to make a game out of the idea that could serve as a starter activity.

Christmas carols were again broken into bar-long tune-blocks, but would be mixed up. The class would then have to work out how to play them, identify the song, and arrange the tune-blocks into their correct structures. To use carols which would contrast in mood to *Little Donkey*, and which prove more challenging to work out and play, I decided on *Jingle Bells* and *Rudolph the Red Nosed Reindeer*. This would allow the students to use musical dimensions more characteristic of a sprightly mood, and the more complex rhythmic groupings and melodic contours would prove more of a challenge. The notes of the melody were numbered and colour-coded to match the iPad interface.

My original intention was to make a new tablet interface in which these tune-blocks could be arranged, but ultimately decided to print these off onto pieces of card, to be put back together like a jigsaw puzzle. The students could later turn the cards over, and compose their own tune-blocks on the blank side, arranging these into a larger composition.

The plan for this lesson was as follows:

1. *Students work in pairs, with a set of cards and an iPad, to put an entire tune together. Those who complete this task quickly are given percussion instruments and asked to plan a performance using the musical dimensions, in the same manner as in the previous lesson.*
2. *Selected pairs are then asked to perform the melody, followed by a discussion on what musical characteristics are commonly found in Christmas carols.*
3. *The class writes a short carol together. They are asked for a sentence that has something to do with Christmas, which is then chanted to fit a four-beat bar. A student is then asked to improvise a melody to this rhythm using the iPad. The class write another three tune-blocks in the same fashion to complete the song.*
4. *Each pair then writes their own carol. The teacher moves around the room to assist, and remind how musical dimensions might be used to create a mood.*
5. *The carols are performed at the end of the lesson, with the rest of the class commenting on how a Christmas mood was created using the musical dimensions.*

This was the last lesson before the Christmas holiday, so the ways in which musical dimensions might be used to create a seasonal mood were a prominent feature of the lesson. As with the previous lesson, the class start with a practical music-making activity, and the lesson follows a cycle of practical activities followed by reflective discussion.

7.4.6 Results 2

The use of headphones rather than the complex setup used for the previous lesson avoided the issues previously encountered, though it restricted performance and composition to groups of two. Again, the students responded well to the task, were observed to share use of the iPad, and were keen to perform. The starter activity of arranging the tune-blocks was met with great enthusiasm, and the students were able to work out the connection between the interface and the tune-blocks with no guidance (Figure 7.33). This may be a result of playing tune-blocks directly from the iPad in the previous lesson, or it may be due to the intuitive nature of this as a mode of representation. During the performance, students typically played at a slow pace, following the tune-block cards carefully, except for one pair, who tried to maintain a faster pace to keep up with the accompaniment of percussion bells they had decided upon. It was notable that one of the four pairs to perform following this activity had at least two tune-blocks in the wrong place, but performed the carol following this structure. This suggests that they were relying on the tune-blocks in the task and performance, rather than relying on their memory of the familiar tune.

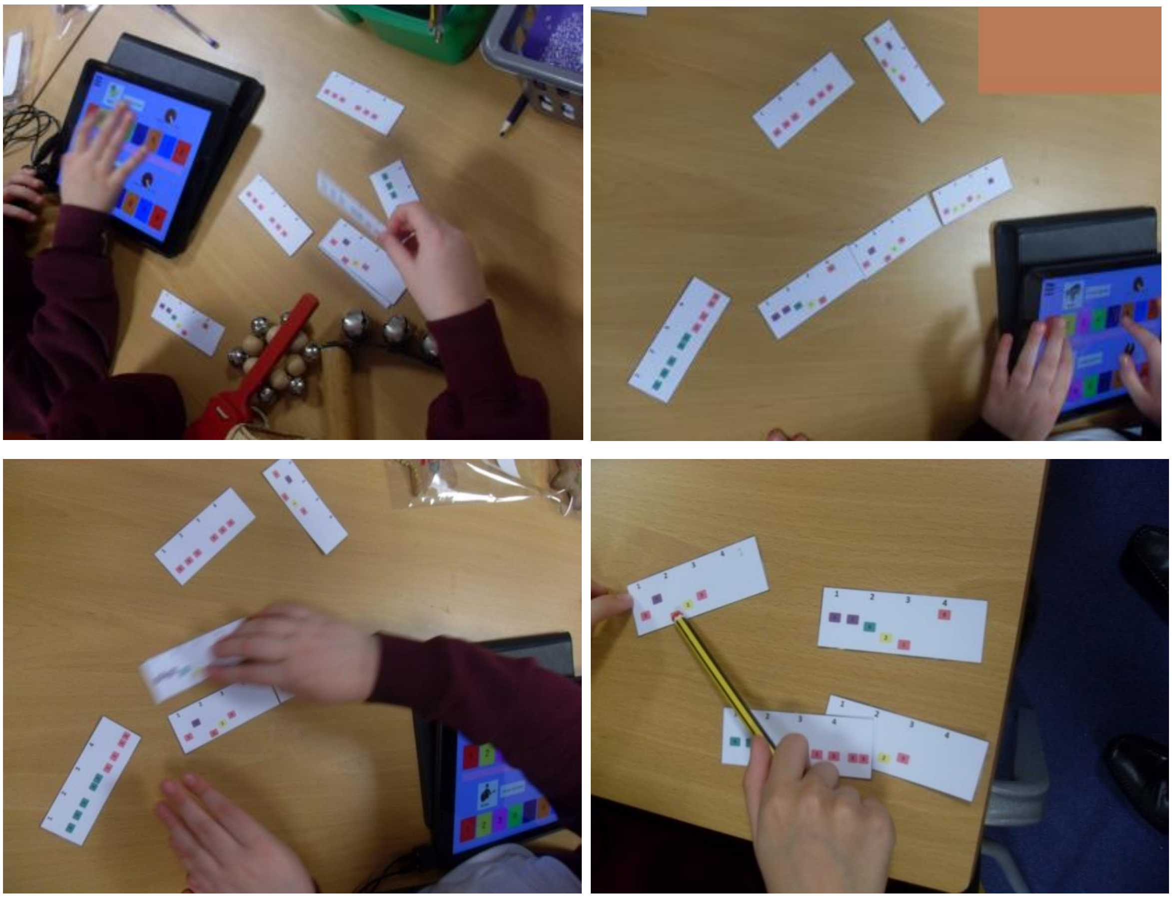


Figure 7.33 – Arranging tune-blocks into a complete structure

After a discussion about the lyrical themes of Christmas carols, a student suggested a first line for our carol: *'snow is falling all around'*. Students were then asked to chant this over a four-beat bar to suggest a rhythm, with an interesting pattern eventually being decided upon by varying the durations of syllables. Another student suggested *'snow is falling on the ground'* as a second line, following the same rhythmic pattern and ending with a rhyme. A number of improvised melodies were then suggested for the first line. The students soon realised, after reviewing the completed tune-block carols, that certain notes, particularly the red root notes at either end of the *Rainbow Keyboard,* would make the melody sound finished while others would make it sound unfinished. When a melody which generally rose in steps was selected for the first line, another student made an interesting observation:

> Student: 'Could you do like, for "the ground", could you go a bit lower on the bottom one though…'
> Me: 'Yeah, so go lower on the last note? Why would we go lower on the last note?
> Other student: 'Because it makes variation.'
> First student: 'Because the ground is below.'

The student had seen the opportunity to use the musical dimension of pitch to represent the lyrical theme, though the interrupting student's observation that this would give variation to the melody is also valid reasoning.

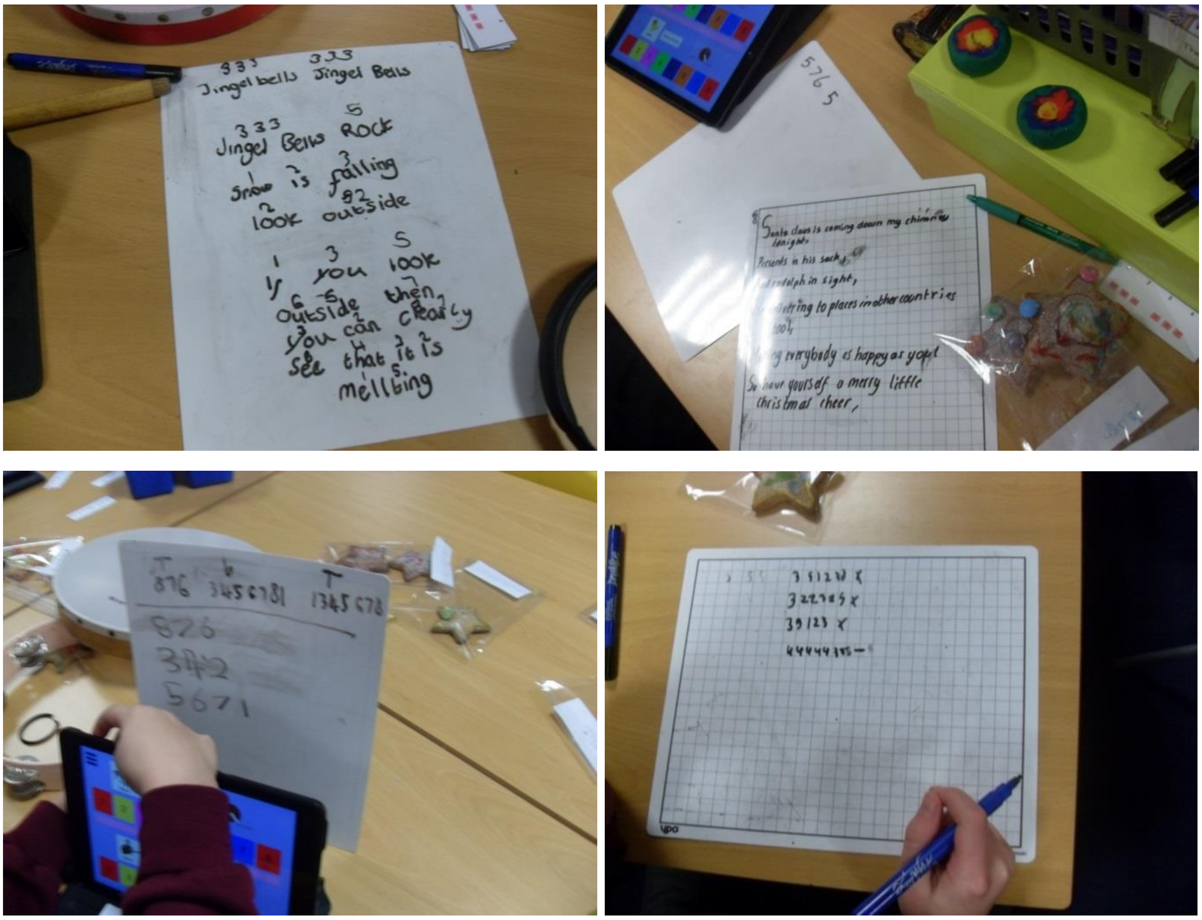


Figure 7.34 – Composing their own carols

The class were then able to compose their own carols following this method. Interestingly, pupils improvised their own notational systems from the numbers given on the *Rainbow Keyboard*; this was undirected and unexpected. Many of the lyrics were borrowed from existing carols, and altered to fit a new structure or theme. In a continuation of the pattern seen in previous studies, this also frequently involved a rhythmic structure borrowed from one of the carols used in the starter activity (Figures 7.34). Others had composed original melodies, often paying attention to melodic contour and the resolution of the tune by ending on an appropriate note (Figure 7.35). There was evidence of the iPad interface leading to more varied compositions, as students attempted to use all of the notes on screen by following ascending and descending patterns (Figure 7.36).

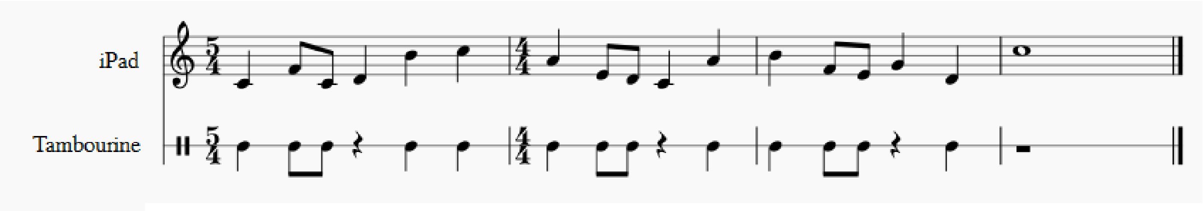


Figure 7.35 – Original composition by group

Figure 7.36 – Original composition by group

The composition of one student was characteristic of pealing bells, and followed a clear pattern, whereby the hands started at opposite ends of the keyboard and worked towards one another. In this way, the student had devised a memorable kinaesthetic pattern (Figure 7.37). When I attempted to repeat this performance to demonstrate the memorable nature of the pattern, the student was eager to again show how he had done it:

> Me: 'That was very memorable… I think I even remember how you played it…' [attempting to play the piece]
> Student: [correcting me] 'I'll show you. It went…'

Figure 7.37 – Original composition by pupil

After the lesson, one student was copying their melody from their whiteboard onto a piece of paper, saying they wanted to work out how to play it on a recorder. I opened another app with a standard piano keyboard layout, and showed the student how the numbered notes matched up with the white keys, so they were able to write down the note names for their melody. They then told me that their parents had a keyboard and they would play the tune on the instrument when they got home. The tablet can be seen acting here as a scaffolding tool, and leading to independent learning on the part of the student. In retrospect, this approach might have been used at the end of the lesson so that all students had a notated version of their composition.

Examples of deep learning are present in this study, defined by Fullan and Langworthy as instances of learning which '[develop] the learning, creating and "doing" dispositions that young people need to thrive now and in their futures' (2014, p.i), as well as what the authors term 'new pedagogies', 'models of teaching and learning that are both enabled and accelerated by digital technology and resources, and that take place in environments that support "deep learning"' (Clarke & Svaneas, 2015, p.7). The use of the tablet to facilitate performance through accessible modes of interaction and representation allowed the students to move further up the 'pyramid of processing' (see 2.2.1) and engage with higher order skills such as improvisation, and the manipulation of musical dimensions. We were able to conduct a highly practical lesson, where no students became stuck on lower order musical skills such as repetition or memorisation, and instead focus on highly social, creative and exploratory musical activities. As well as meeting the intended lesson outcomes, several advanced aims from the National Curriculum were also met.

How might the tablet function within the dynamic of the classroom, in terms of facilitating 'performance in solo and ensemble contexts'?

The students successfully and confidently performed in larger groups, pairs and solo contexts. Whether playing iPads or percussion, the students moved rhythmically to keep in time, and displayed other kinaesthetic responses to musical dimensions, such as hunching when playing quietly. Kerchner (2000) observes that many children of the same age group participating in this study are 'kinaesthetic listeners', responding to music with physical actions. That they respond in this way when playing a tablet is an indication of their readiness to employ it as a musical instrument, and also helped to co-ordinate the ensemble when students struggled to connect what they were playing with what they were hearing in the first lesson. Clearly, the setup used in the first lesson was not a sustainable solution, and other technical options should be explored in further research employing the tablet as an ensemble performance instrument.

How might the tablet be used to encourage 'increasing accuracy, fluency, control and expression'?

As discussed, the accessible modes of representation and interaction employed allowed the students gave the students a greater degree of control. The tune-blocks interface became a scaffold, or framework, from which the students could deviate whilst still maintaining sight of the original melody. This allowed them a further degree of control and accuracy in their invented patterns. We can also see evidence of this in the second lesson, where the simplicity of the interface led to fluent and confident performances. In this case, however, the tablet was relatively limited in terms of dynamic control, or the capacity for varied articulation. There are many functions of the touchscreen tablet which could be utilised to allow students a greater depth of control, such as touching the screen in different place for different dynamic levels, tilting to control certain parameters, or using a variety of gestures.

How might the tablet allow pupils to engage with the 'inter-related dimensions of music' in their performance and composition?

These lessons focused heavily on the use of musical dimensions to create mood or represent lyrical themes. Students were able to show their understanding of musical dimensions, but also how these relating to their performances and compositions, or those of others. This was, for the most part, something that the students were able to 'jump ahead to', as they were able to perform the pieces following the starter activities and able to focus their attention on the creative development of their performance. However, as above, I feel that there is far greater capacity to use a range of tablet functions to communicate musical dimensions, especially if we wish to explore the potential of the tablet as an expressive instrument in its own right and not merely a surrogate or scaffold for 'real' instruments.

How might the tablet utilise alternative modes of representation to lead pupils toward a greater understanding of staff notation?

The use of tune-blocks was a highly successful component of both lessons, as was the use of game activities, such as the jigsaw puzzle starter of the second lesson, in promoting understanding of pitch and rhythmic relationships. This led toward a greater understanding of staff notation in at least one instance, as the student at the end of the second lesson learned the corresponding note names so that they could play their composition on other instruments. Simplified layouts of this kind, especially when interactive, can help children to understand the basic functions of musical notation, and the touchscreen is an ideal interface for communicating this meaning, as it can effectively combine the functions of score and instrument. In the first lesson, the students literally played the score, by following the onscreen notations, later deviating from this score to produce original musical ideas. By contrast, in the second lesson, the students used the tune-block cards as scores, or wrote their own on whiteboards.

7.5 Sound Objects and Keynote Sounds

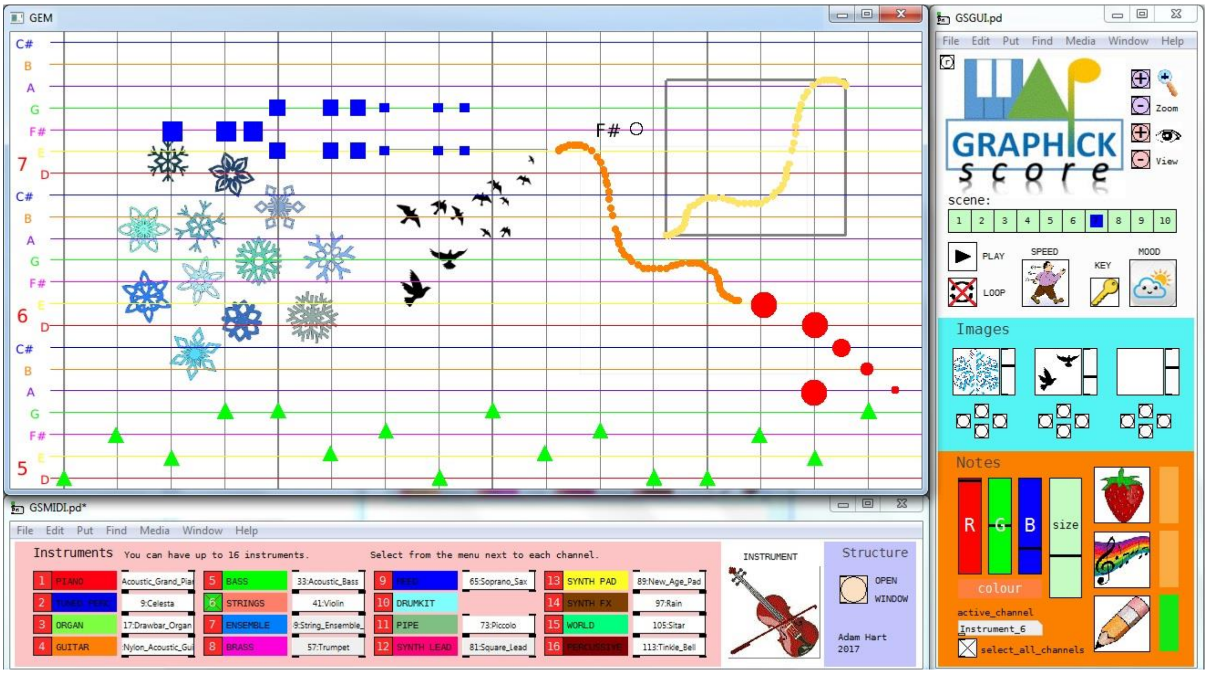


Figure 7.38 – *Graphick Score* in 2017. A version with a white canvas window was requested by the *London Review of Education* due to printing considerations.

The previous studies highlighted the significance of kinaesthetic connections between meaning and musical gestures; thought experiments, such as asking ‘how does the donkey feel in the song?’, led to experimentations with musical dimensions based upon these ideas of motion and action, while simple kinaesthetic patterns were composed and memorised using the *Rainbow Keyboard.* In these examples a result which is musically complex, or variable, is represented, understood and reproduced according to a simple kinaesthetic action. A precedent for this exists in pedagogic composition, for example, in Kurtág’s *Alapelemek* from *Játékok*[20] *vol. 6* (Figure 7.39). Notations exist as kinaesthetic actions which are easy to understand: raking up or down the piano, bashing a group of keys with the fist, etc. However,

[20] Incidentally, this translates to ‘games’

these identifiable structures act as a scaffold for other musical dimensions, such as reading differences in pitch or dynamics on a score. The novice player therefore has an accessible mode of interaction for engaging with these skills, circumventing the more complex demands of reading specific pitch and durational values.

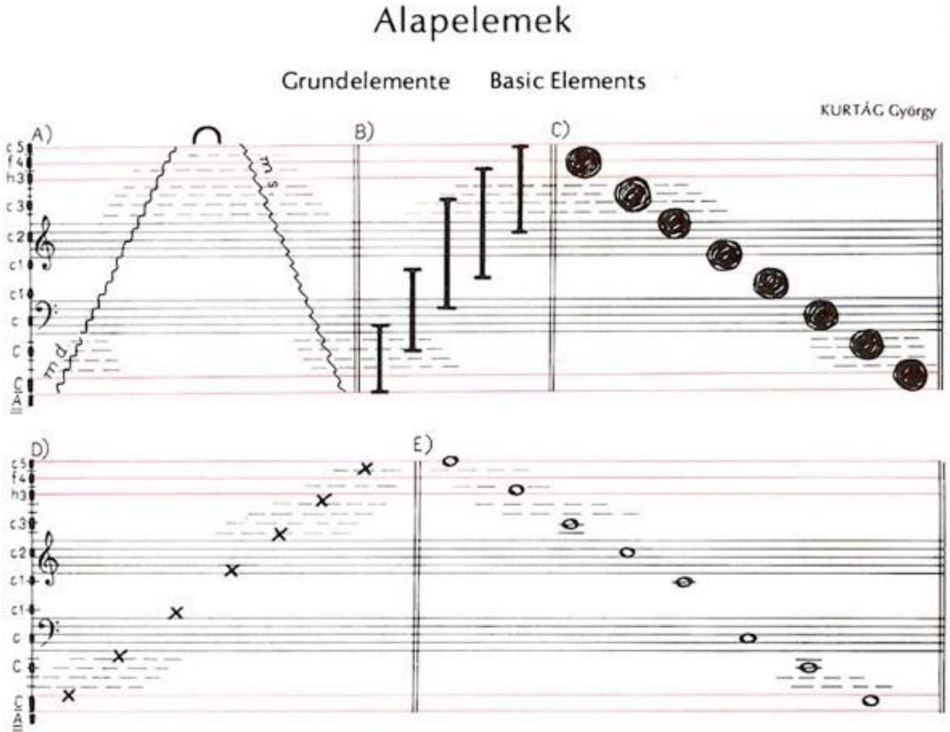


Figure 7.39 – Kurtág's *Alapelemek* from *Játékok vol. 6*

The most successful studies, in terms of creative outcome, had so far focused on telling a story as a scaffold for musical composition. I had observed how simple 'sound painting' gestures had been used as actions or events, and images or ideas had been taken as wider contexts, characters or settings (see 7.2). Drawing from Schaeffer's (1977) description of soundscapes, these images and ideas are like the 'keynote sounds' which provide a backdrop to the 'sound objects' which represent specific actions and events.

The menu of melodic tune-blocks in *Graphick Score* was replaced by a menu of kinaesthetic sound-objects (Table 7.1). This was aimed at facilitating accessible descriptions of musical gestures, devices which novice composers could understand and identify, and use as a creative vocabulary for telling a 'sound story'.

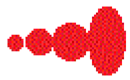
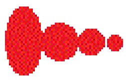
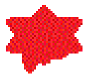
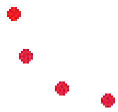
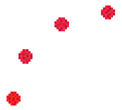
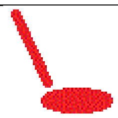
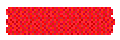
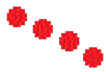
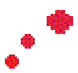
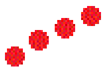
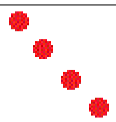
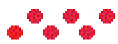
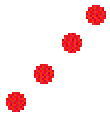
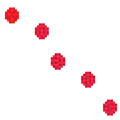
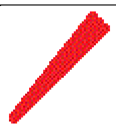
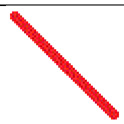
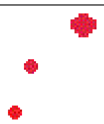
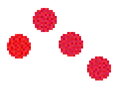
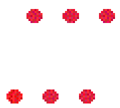
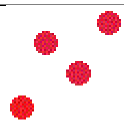
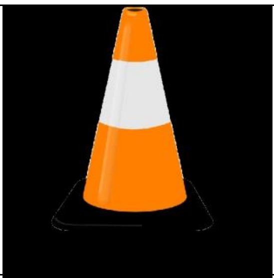
Name	**Shape**	**Musical Description**	**Name**	**Shape**	**Musical Description**
Burst		Crescendo	*Shrink*		Decrescendo
Crunch		Dissonant cluster, *sfz*	*Slide*		Descending arch over an octave
Float		Ascending arch over an octave	*Splat*		Descending glissando, *p* to *fff*
Glide		Long duration across a bar	*Step down*		Four steps down
Hop		Three quick steps up, *p* to *f*	*Step up*		Four steps up
Jump down		Four steps down in thirds	*Tickle*		Trill
Jump up		Four steps up in thirds	*Trickle*		Descending scale
Launch		Ascending crescendo	*Tumble*		Long descending glissando
Leap		Three quick leaps up (thirds), *p* to *f*	*Turn*		Turn
Shimmer		Tremolo a third apart	*Zigzag*		A third up, a step down, a third up

Table 7.1 – Table of sound objects

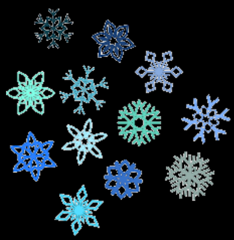
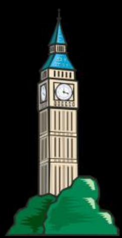
Many of these sound objects are recognisable musical ornaments given simple kinaesthetic descriptions such as *burst* and *tumble*. As with tune-blocks, these sound objects can be placed anywhere in the canvas window, copied, resized and rotated to form complex larger structures and sequences. This also addressed the pressing need for dimensions such as velocity to be changed through interaction with the canvas window (see 7.3.3); a variety of musical dimensional interplay could be presented by these scaffolding structures, created and manipulated through simple interactions.

To accompany the sound objects, and to support storyboard composition with *Graphick Score*, a menu of images was also added to the graphics menu. Each of these corresponds to an audio file, which loops when the scene is played (Table 7.2).

Name	**Image File**	**Audio File (description)**
Balloons		Cheering, party horns etc.
Brass Band		Marching band, brass instruments, percussion
Birds		Tweeting, birdsong
Car		Car horns, traffic sounds

Traffic Cone		Roadworks, diggers, drills
Cow		Cows mooing, pastoral sounds
Crowd		Crowd chatter
Fire		Fire crackling
Football		Unison crowd noises (disappointment, celebration)
Helicopter		Rotating helicopter blades

Lightning		Thunder clap
Moon		Owl hooting, crickets
Phone		Chirping ringtone
Plane		Jet engine passing
Raincloud		Rain falling
Ship		Ship horn, seagulls

Siren		Alarm, siren
Sun		Parents chatting, children playing in park, swings etc.
Snow		Footsteps crunching in snow
Tower		Clock tower striking the hour
Train		Train passing
Tree		Dog barking, footsteps in leaves, distant sounds of people talking etc.

Wind		Wind blowing leaves

Table 7.2 – Table of storyboard images and sound files

These audio files are all different lengths, meaning that they overlap when combined; this prevents the result from becoming too repetitive. Up to three can be added to each scene. Resizing the image alters the volume of the corresponding audio file, so the user can create a simple mix of sounds to tell a story, augmented by sound objects.

7.6 Storyboard Composition at School D, March 2017

7.6.1 Context

I was invited to run an afternoon class on music with a Year 5 class at School D, a primary school. The teacher had informed me that the class would be using graphic notation later in the term to tell the story of the *RMS Titanic*, so I suggested a lesson focusing on the link between sound and story. The purpose of the study was to further examine how *Graphick Score* may be used to facilitate music composition, following changes made to the interface. Previous studies highlighted the importance of a creative stimulus, such as a story, image or idea, in producing musical decisions. In an earlier study (see 7.2), I observed how the pupils used the story from the demonstration as a starting point, and many took the image of a sun or raincloud (indicating tonality) as a reference point for building narrative ideas. I therefore reasoned that further images and sounds of a recognisable nature could be used to enable or accelerate creative explorations, and that the examples of what I term *sound-painting* or *sound-sketching* might be shaped by this wider meaning, or conversely, may shape the meaning of the story. Because I wanted to promote reflection and discussion, I felt that these stories should be conducted in groups rather than individually.

A library of images and corresponding audio files were downloaded from royalty-free sources, and a new section of the graphics menu was added. This allowed the user to add images to a scene, which played looped audio files corresponding to the chosen image when the scene was played. These images could be resized and moved around the canvas window. As with geos, size was linked to volume, so larger images increased the volume of the linked audio file. Changes to the audio when images were moved were also initially planned but were not implemented in time; these included changes in panning of the audio files depending on the position of images in the X axis. Because I wanted the pupils to be selective about the combination of images, and to not focus exclusively on this feature, the number of image/audio files per scene was limited to three. Smaller changes included a re-arrangement of the layout to make room for this new feature, and an indication of the chosen MIDI instrument; a broken tonic chord of the chosen key was triggered when an instrument was selected, to give the user an idea of the timbre.

7.6.2 Method

Learning Objective: *To compose a musical story using graphic scores*

8 laptop computers running *Graphick Score* were set up in the classroom, each with a headphone splitter which allowed the audio output to be divided between up to 6 pairs of headphones. The programme was also installed on the teacher's desktop computer at the front of the class, which was connected to an interactive whiteboard (or smart board) and speakers. This allowed *Graphick Score* to be operated via touchscreen, as well as onscreen drawing using the smart board pen tools. During the lunch break, I set this up and gave a brief demonstration of the programme to the teacher, showing the basic operations and functions. We agreed that, though I would lead the session, the teacher would provide support, and that they would intervene at any time if they recognised learning opportunities or barriers.

The 27 pupils were divided into 8 groups of 3 or 4 per group. After being introduced by the teacher, I asked one student to draw a picture of a fish on the board, and another to draw an elephant. I then told the class that would play them two pieces of music; one about a fish and one about an elephant. These were *The Aquarium* and *The Elephants* from *The Carnival of the Animals* by Saint-Saëns (the titles were not given). The class were asked to identify which piece of music matched to which picture, and to explain why, linking characteristics of the music to the drawing.

The class were then shown a number of scenes using *Graphick Score* on the smart board, and were asked how the sounds and images communicated a story. The first involved thunder and rain sounds, as well as descending blue patterns of xylophone and glockenspiel notes, in a minor key. The second kept the same sound files and images, but was accompanied by a happy melody in a major key, with yellow and orange geos. The class were asked to suggest changes. Finally, two pupils were asked to come to the front of the class to select a sound file and then draw a pattern in the canvas window, to demonstrate how a scene could be started.

Each group was given 5 minutes to look and listen to the options in the programme, and then was given a piece of paper and a set of coloured pens, and asked to sketch out their chosen story. The rest of the lesson was spent using *Graphick Score*, with me and the teacher circulating the room to discuss the work of the group, and to ensure that all participants shared opportunities to use the programme. At the end of the lesson, the teacher directed the groups to play their pieces, and asked the rest of the class to guess the story, and to give reasons for their decision.

7.6.3 Results

The discussion of *The Carnival of the Animals* provided an engaging start to the lesson. The class immediately identified *The Aquarium* as being about fish, with appropriate observations on the melodic contour of the piece, such as ‘it flows and glides.’ These discussions could be linked to musical elements:

> Pupil: ‘It’s like magical… like the sea and… *oceany!*’
> Me: ‘Oceany? That’s an interesting verb. So what makes it sound like that?’
> Pupil: ‘Because it twinkles.’
> Me: ‘Okay. So what instrument gives it this twinkling sound?’
> Pupil: ‘Was it like… you know, like, chimes?’

Following this discussion, I played *The Elephant*. There was an outbreak of laughter from the class from the introductory clumsy waltz pattern of the piano, and again from the low melody of the tuba. Kinaesthetic reactions were also observed; stomping and slumping motions in time to the music, imitating the lumbering movement of a heavy animal. When asked what animal the piece represented, there was a resounding shout of ‘elephant!’ A discussion followed:

> Pupil: ‘It was like a stomp.’ ‘There was a trumpet.’
> Me: ‘Why would that suit an elephant?’
> Pupil: ‘Because of the trunk.’
> Me: ‘Yeah, and they make that noise.’ [I unsuccessfully attempt an elephant noise, responded by attempts by the rest of the class]

We then discussed how it was a similar instrument to the trumpet, also made of brass, called the tuba. I explained that this was a big instrument with lower notes (deepening my voice for effect). I then told the class that the music of these pieces told a story, and that we would make a musical story using a computer programme (indicating *Graphick Score* on the smart board); the class were engaged, and noticeably enthusiastic at the prospect.

The examples in *Graphick Score* followed a similar discussion to *The Carnival of the Animals*. Pupils noted that the downward motion of the first example 'sounds like rain, going down', and that a sun would be more suitable than a raincloud for the second example because the tune sounded happy. Moving on to a demonstration of a new scene, a pupil chose birds as the image and sound file, and another was asked to go through the instrument options for a suitable instrument, settling (as anticipated) on a flute. The class then identified this as suitable due to the similarity with tweeting and birdsong. By this point, the class were noticeably restless; many were chatting or otherwise distracted, and responses were less engaged. I therefore decided to let the class put on their headphones and try out the programme, while the teacher handed out paper for the graphic scores. This was met with a more enthusiastic response; the entire class were seen to be exploring the different possibilities, and none appeared confused or disengaged.

The teacher was notable very capable in providing support to the pupils on how to perform various features, remembering much of the details from the few minutes in which I demonstrated the programme before the lesson. The pedagogical training of the teacher was valuable in directing the class, having more classroom experience than me and, of course, knowing the group well. At the end of the lesson, we played all of the pieces through the smart board and speakers, and I asked the first group what the piece was about; the teacher instead suggested that we ask the other groups to guess. They then led the plenary, asking other pupils to guess the story, and to provide reasons. Their classroom management skills mitigated any issues here that I may have struggled to address, for example:

> 'I think if you'd have done a bit more, we'd have been able to realise your story' [moving on, when the students were unable to guess one of the least substantial pieces]
> 'You aren't ready to play yours, so we'll move on' [as a group were not paying attention]

Their encouraging attitude and rapport with the class also helped to facilitate a productive plenary session:

> 'Wow, well done! Give them a clap!'
> 'I've definitely got an image of what I think it means.'

The teacher later (after the lesson) told me that *Graphick Score* would be useful for the module on the HMS Titanic:

> ‘Maybe we could download the programme… I don’t know how much it costs…’

I told them that I was not trying to market the programme (it being an open-source *Pd* project and not a commercial software application) but that I would send them a copy along with the exported video clips of the pupils’ work.

The stories made with the programme have some interesting features. Some focused mostly on keynote sounds, while others made use of sound objects and ‘painting’ interactions. The written scores were also useful in clarifying the aims. Looking at the work of Group 1 (Figure 7.40), the two scenes are clearly discernible from the score. ‘Launch’ and ‘tumble’ sound objects have been used to represent the movement of birds, with melodic patterns on brass instruments, giving the first scene a tuneful and happy character. This contrasts with the droning metallic sounds in the second scene, when the rain starts. The dynamic changes within these sound objects appear to have directed the pupils to make dynamic variations of their own, as the overall velocity of these objects has been varied. Group 2 (Figure 7.41) demonstrate similar contrast; the first and third scenes (sun and snow) make use of a slow texture of overlapping tuneful patterns, while the second and third (rain and transport) are fast, with repetitions of the same pitch, suggesting duration and monotony. Cymbals and drums are also used here, indicating a focus on rhythm and timbre over melody. Also, it is interesting to note that each scene appears to end with a precursor of what will happen in the next, heralding not only the motivic gestures, but also the ‘colour key’ to be used in each scene.

Group 5 (Figure 7.42) made one graphic score to indicate the wider structure, before dividing this into smaller sections. The drawn flute line, representing the flight of birds, shows evidence of copying and rotating to create symmetrical patterns, and is clearly represented in the graphic score; interestingly, this has been copied and rotated to form a countermelody. A contrasting texture and timbre of busy drums and alarms in the following scenes is also clearly indicated. These ‘bird flight lines’ are also seen in the work of Group 7 (Figure 7.43), who supplement the images with other drawn additions, such as the ‘lemon tree’ in their second scene.

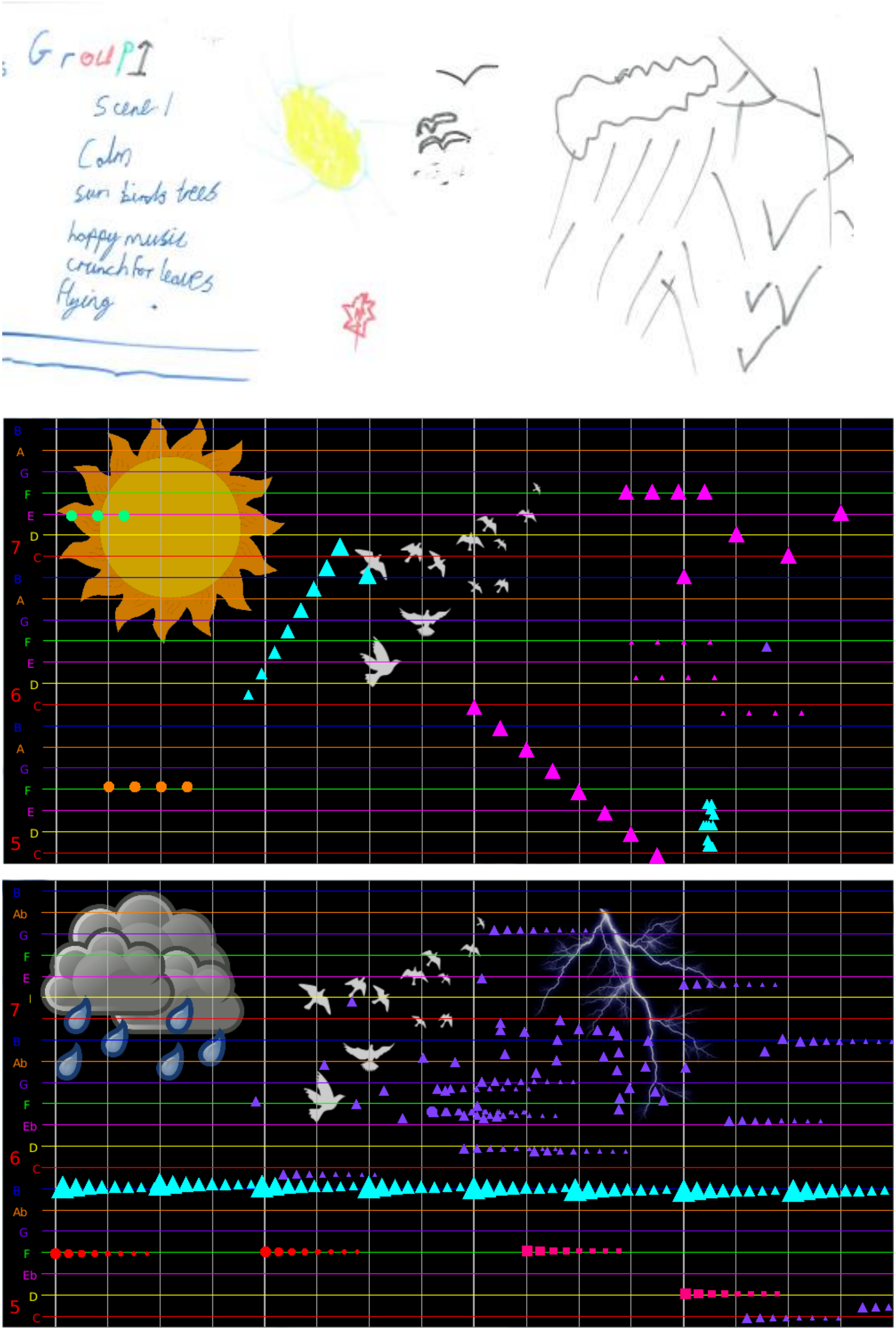


Figure 7.40 – Group 1

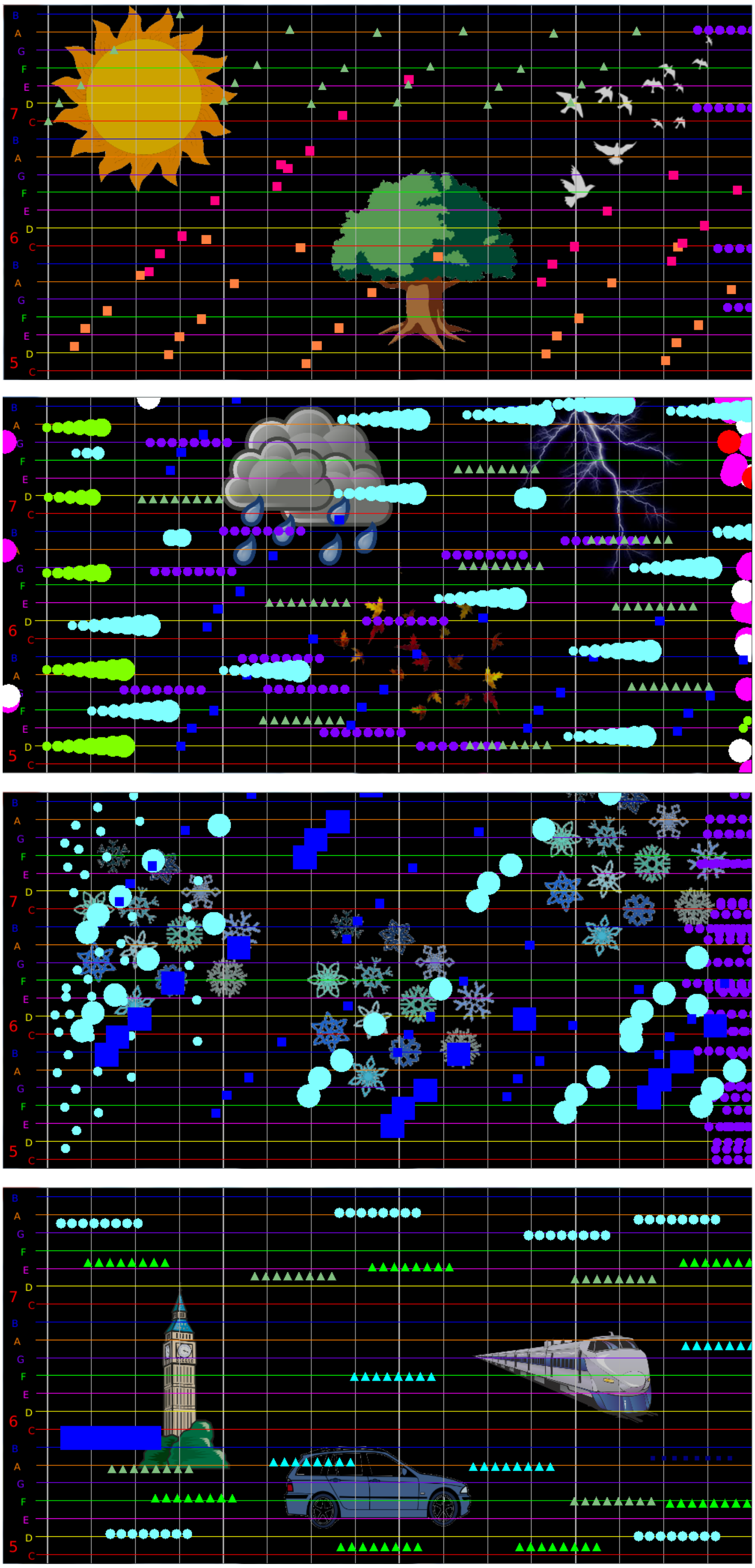


Figure 7.41 – Group 2

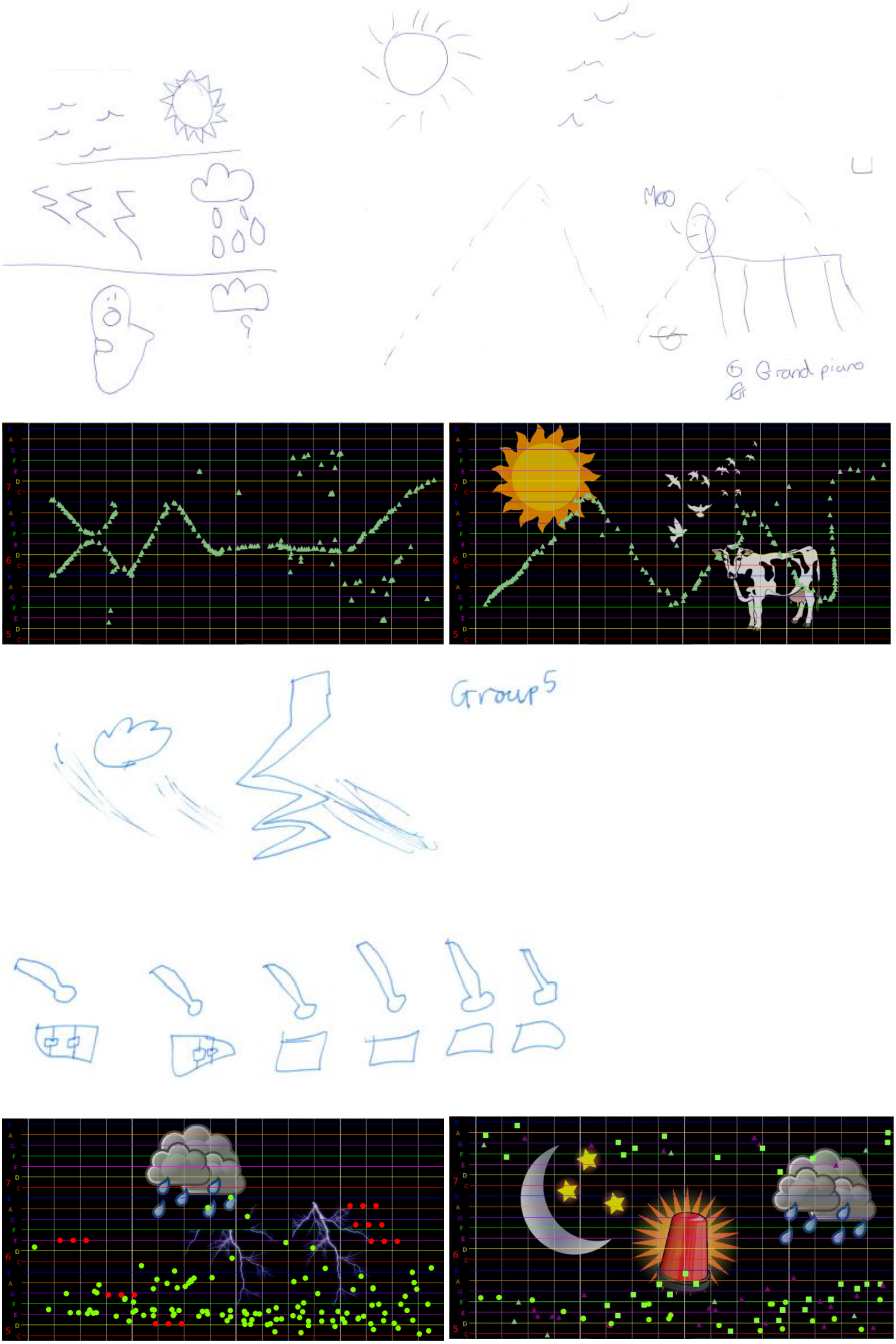


Figure 7.42 – Group 5

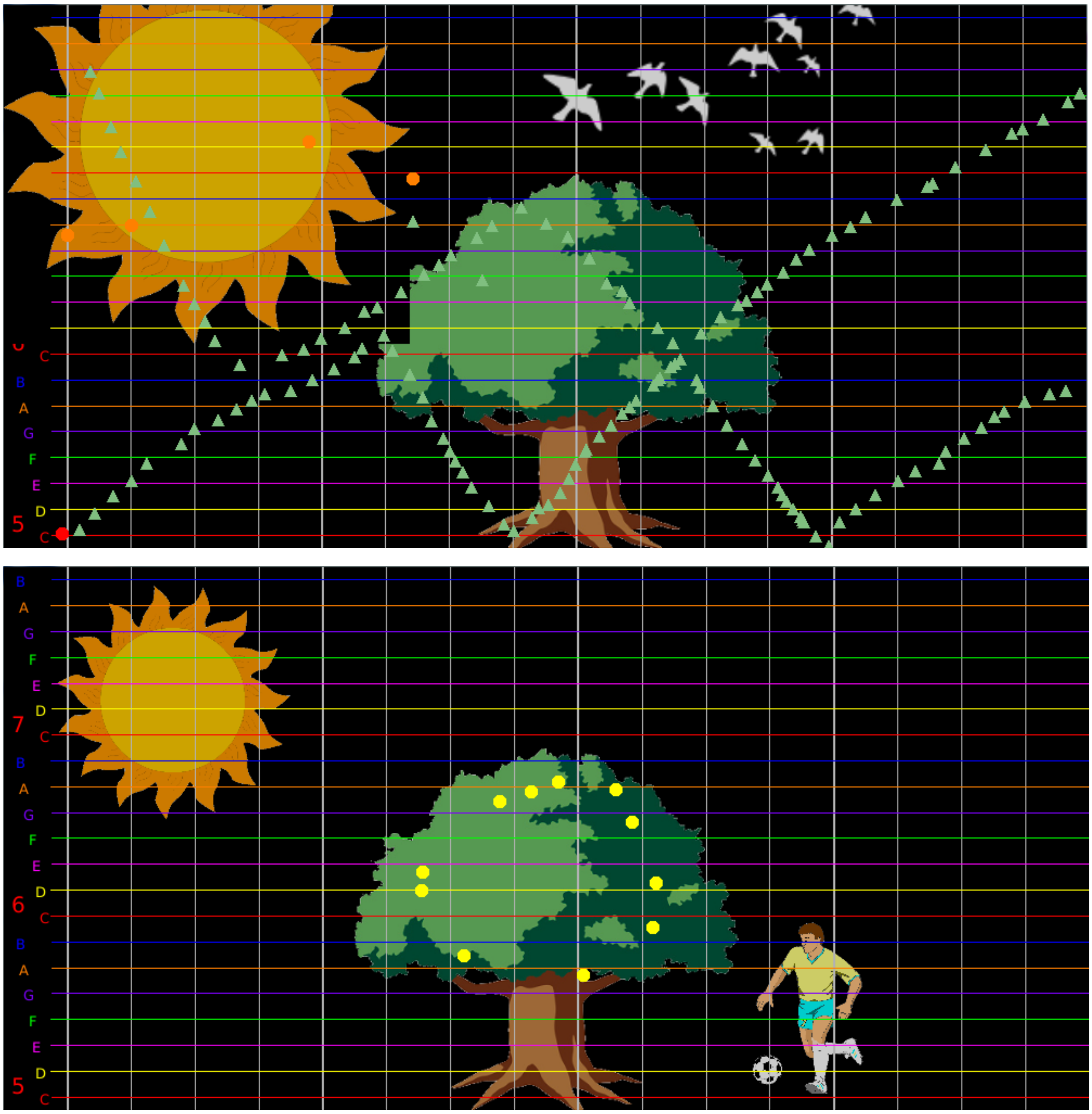


Figure 7.43 – Group 7

While some groups relied almost exclusively on keynote sounds, others focused on sound objects and drawing. The changing seasons score made by Group 6 (Figure 7.44) tells a clear story which is represented in the drawn materials. Bird flight and the business of crowds in the park are identifiably through patterns of movement and texture. The winter scene, with no keynote sounds but a texture of blue celesta tune-blocks, is surprisingly consonant and melodically coherent, though clearly built through an improvisatory arrangement of blocks.

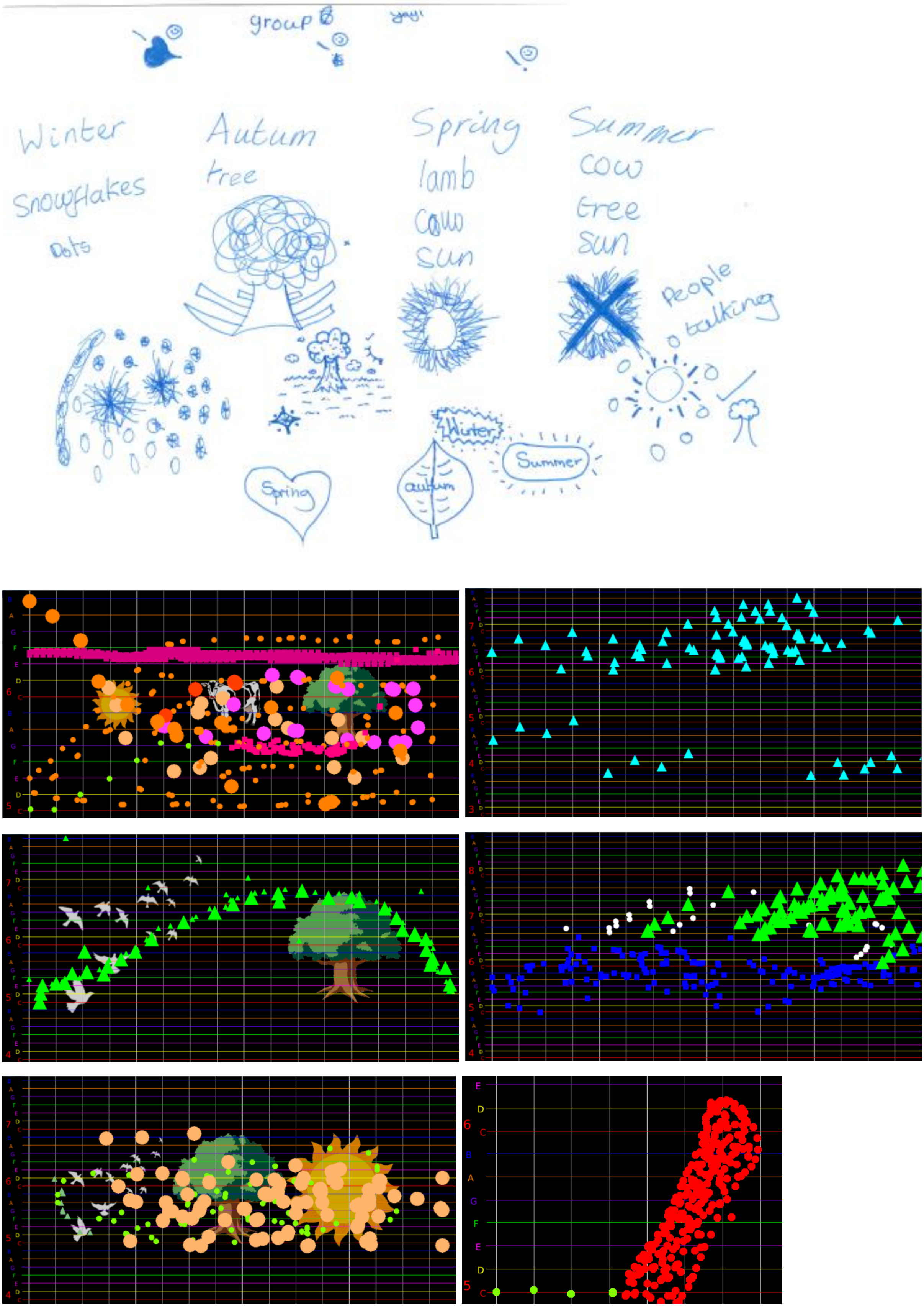


Figure 7.44 – Group 6

A particularly interesting example is Group 8 (Figure 7.45), who used musical terminology in their scores, suggesting that at least one member of the group has musical training, although the distinction of *ff* for the aeroplane and *mf* for the crowd appears to have been swapped around in the eventual realisation of the scene**.** In this example, the students wanted to tell a humorous story of going on holiday on a sunny day and arriving to a storm:

- Scene 1 – *Getting to the airport*
    - Samples – *Traffic and birdsong*
    - Music – *A clutter of brass instruments (car horns) at a low pitch (on the ground) moving across the screen (traffic)*
- Scene 2 – *On the flight*
    - Samples – *Aeroplane taking off, chatter of a crowd*
    - Music – *A rising sequence of notes of increasing volume (take-off) and a high-pitched happy melody (flying)*
- Scene 3 – *Arriving to bad weather*
    - Samples – *Rain, wind and thunder*
    - Music – *A descending sequence of notes (plane landing) and descending patterns played on xylophone and glockenspiel sounds (rainfall)*
- Scene 4 – *Night time*
    - Samples – *Owl noises, crickets*
    - Music – *Descending patterns cease (rain stops, sun goes down) then twinkling bell-like sounds (stars)*

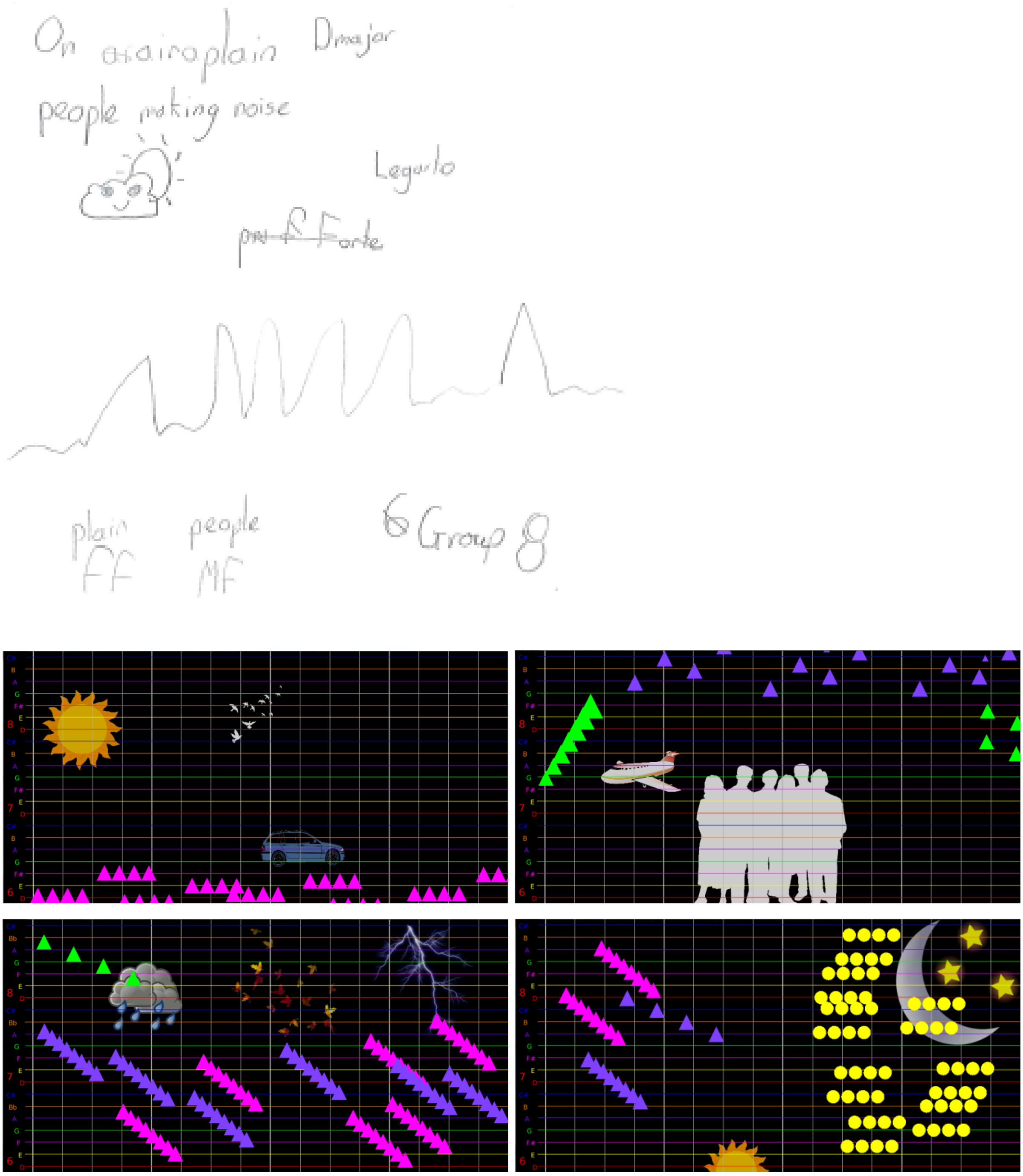


Figure 7.45 – Group 8

This was the last study conducted with *Graphick Score* for this research project. It was similar in structure to the study at School B (see 7.2) in that stories were constructed with sound. However, the addition of 'sound objects' and 'keynote sounds' appears to have provided a more substantial framework for creative exploration and reflection. It is more apparent, in these examples, how the intended stories relate to sound gestures, as demonstrated by the guessing game organised by the teacher. A more social application was engineered through the use of headphone splitters, though further collaborative approaches should continue to be explored.

It is notable that the pupils and teacher were able to use the programme with very little explanation; in hindsight, the starter activities preceding the project were perhaps excessive, as pupils were visibly impatient to start the main activity. It is also promising that the teacher expressed an interest in using the programme for an additional module. Though discussions often involved face value commentary upon the keynote sounds, the teacher was able to relate these discussions to musical dimensions:

> [playing a piece with owl keynote sounds]
> Pupil: 'Was it at night when you hear the owls?'
> Teacher: 'What else made it sound like night?'
> Pupil: 'It was quiet…'

This suggests that further educational opportunities may be presented by manipulation of these keynote sounds. The possibility to record audio and directly interact with it in the canvas window is an avenue which should be explored in future versions of *Graphick Score*. Migrating the design to a touchscreen app, and implementing further controls for recording and editing, as well as 'sound painting', will be a focus for future development.

7.7 Performance and Composition with iPads at School C, June – July 2017

7.7.1 Context 1

Brown (2007a) notes that the SoDaR researcher should be sensitive to unexpected outcomes emerging from research, especially where these present new educational opportunities. Though this project focused on interface design, and principally the development of *Graphick Score*, the study undertaken with iPads (see 7.4) had prompted interesting questions regarding the use of such devices for performance and composition. I felt that this avenue had been hitherto underexplored in my research, and decided to undertake a further series of studies to examine how the touchscreen tablet might be used for group music activities.

Figure 7.46 – Smart keyboard in *GarageBand*

Admittedly, it may have been preferable to conduct this kind of research earlier, to examine how pupils responded to existing digital resources. However, sensitivity to emergence is at the core of my methodology, and the importance of the touchscreen tablet as a classroom digital instrument only emerged during the course of my design process; indeed, when this project started in 2014, the tablet was still a fairly recent invention, and had not yet achieved the level of influence upon classroom activity seen today. However, the question of how it can be harnessed effectively for musical learning has received relatively little attention (see 3.2.1). Williams (2014, p.49) has argued that the iPad can function as an expressive musical instrument:

> When used to make music, the iPad is a musical instrument. It can be performed well or poorly. It takes practice to build performance technique on it. It will do nothing without musicianship, creativity, and imagination supplied by a person. It has musical limitations just like any instrument, but in the right circumstances, it can be used to make amazing music.

This resonates with the key finding of Fullan and Langworthy (2014, p.30) who report that, when using digital technologies it is 'the pedagogy of the application of technology in the classroom which is important: the how rather than the what.' As portable tools with a tactile mode of interaction, tablets might function like any other musical instrument. The National Curriculum tells us that children should 'play tuned and untuned instruments musically' from key stage 1 (DfE 2013, p.2). Instrument stocks in primary schools have generally consisted of miscellaneous inexpensive percussion instruments, along with rudimentary melodic instruments such as the recorder. Policies such as the Wider Opportunities and First Access schemes have had some success in bringing a greater range of instrumentation to the classroom, though this has been beset by various logistical and financial barriers, mainly attributed to the transportation and setting up of instrument stocks (MU 2014, p.3). Access to tuned instrumentation in the classroom must then be a more frequent opportunity, and while policies like First Access should continue, schools cannot rely completely on this for instrumental provision. The tablet can provide a scaffolding opportunity in the classroom by emulating a range of tuned and untuned instruments. In addition to many keyboard and piano interfaces, free apps to emulate the playing interface and timbres of instruments such as guitars, concertinas, drum kits, gamelans and Theremins are immediately accessible and plentiful. The capacity for customisation and communication between devices also opens up possibilities for musical performance unique to digital instruments.

I chose an existing app, *GarageBand*, due to the range of performative scaffolding tools; these include ‘smart keyboards’, where chords can be programmed into an assistive interface, and drum machine pads (Figure 7.46). The app also contains a sequencer layout similar to *Logic Pro or Ableton live*, making it suitable for both performance and composition. I also developed a sampling interface, *Sample-It*, using *MobMuPlat* (Figure 7.47). This enabled the recording and playback of audio clips, with basic editing functions such as pitch control and audio reverse**.**

To conduct this research, I returned to School C during the summer term. I proposed to deliver these sessions as an ‘iPad ensemble’, with each pupil ‘playing’ a tablet to produce a rendition of a popular song, *Happy* by Pharrell Williams. This song was chosen because it is well-known and popular among children, receiving a lot of airplay and appearing in the film *Despicable Me 2*. It also has a consistent lyrical theme of happiness that I felt could be clearly related to musical dimensions.

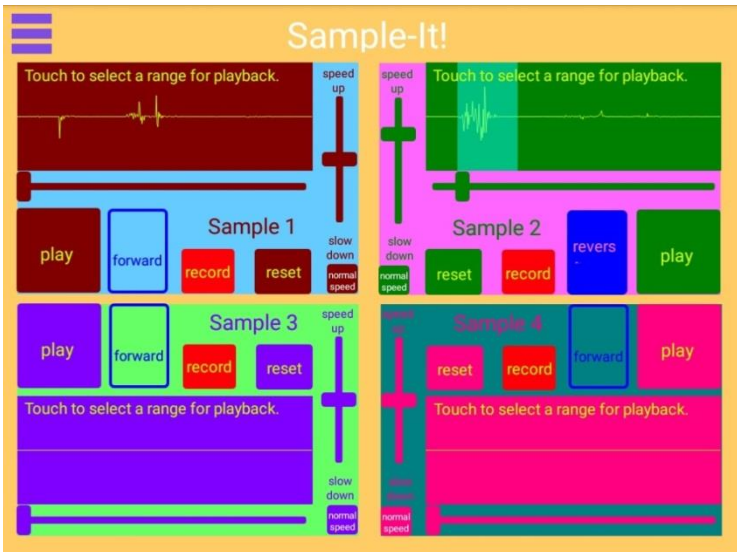


Figure 7.47 – *Sample-It*

7.7.2 Method 1

Learning Objective: *To perform 'Happy' as a class using* GarageBand

I was allocated the Year 3 class for an afternoon lesson. This group were younger than the other pupils I had worked with, but saw it as an opportunity to explore whether we could scaffold to some clear outcomes using digital technology. The class consistent of 26 pupils, sat in 4 groups. 30 iPads had been loaned, running *GarageBand* and *Sample-It.* Prior to the session, the class teacher forwarded some music targets for the group:

> To be able to recognise sounds that move in steps or leaps.
> To use musical vocabulary to describe a piece of music, discussing likes and dislikes - and why!
> To state how their work has been improved.
> Compose repeated patterns.
> Choose and combine different sounds to create an intended effect.

I decided to plan a session which would incorporate several of these targets within a simple, performance-based activity:

1. *The class introduces themselves by 'playing' their names on the drum pad interface, i.e. following the syllable pattern with drum hits.*
2. *Play 'Happy' and discuss likes and dislikes of the song; what makes it sound happy?*
3. *Compose a basic 4-beat drum loop, counting to 4, to establish the pulse*
4. *Sing the verse as a repeating call-and-response over this pulse, where each student answers the vocal line by 'playing' their name as before*
5. *Work in groups to add in the chords using the 'smart keyboard' – this can be followed from a simplified chord sheet*
6. *Perform the piece at the end, and discuss what went well, and what could be added*

7.7.3 Results 1

This session started promisingly, with pupils able to follow activities such as 'playing' their name using the drum pads, and some engaging discussion of the song. This discussion led to two features of the song being highlighted; the lively beat and the happy tune. We then tried to set the pulse of the tune with a kick drum pad so we could perform as a call and response, between the vocal of the verse and drum fills. This ultimately proved very difficult; the class were unable to maintain a consistent pulse. This was also attempted with clapping instead of iPads, but with similar results; the pulse very quickly fell apart. With the assistance of the teacher, we were eventually able to establish this coherently enough to continue with the call and response activity.

Having drawn a line under this task, I moved on to the chord accompaniment using the smart keyboard interface. Turning to the lyric and chord sheets, I asked the class what the symbols meant:

> Pupil: 'Are they notes?'
> Me: 'Sort of. The letters actually tell us a group of notes that we can play that will go with the tune.'

None of the group had heard the term 'chord' before, but this explanation seemed sufficient. I had planned to show the pupils how to set the chords up on the smart keyboard, reasoning that this would provide an opportunity for them to learn something which they might apply outside of the classroom to play other songs. This too proved far more complicated, in practice, than expected. It was possibly due to the unfamiliar nature of the symbols, plus the complications of sharps, flats and tonality, that many of the pupils struggled to navigate the menus and assign the chords listed on the lyric sheets. Upon trying to direct the pupils to follow the structure of the chord sheet, the issue of pulse again became a barrier. Eventually, I decided to set the class to working in groups on their tables to put the beat and chords together and to listen to these performances at the end, and circulated the room with the teacher providing support. The level of noise as four individual groups attempted this made the task exceptionally difficult, and the performances were ultimately more a case of singing with raucous and unsynchronised iPad accompaniment, though enthusiasm and engagement was, at least, a present factor here.

A great deal of disruption was encountered as the class became restless. This was particularly evident when structured activities became laborious or complicated, such as establishing a pulse and assigning the chords. Increasingly, the teacher intervened for classroom management as pupils took to pressing each other's screens, and other instances of misbehaviour. It was difficult to ascertain where interruptions came from; at several points, as one pupil was saying or demonstrating something, it was interrupted by a loud noise coming from an iPad at another part of the room, with the teacher trying to identify the responsible individual and an argument of denial and accusation ensuing among the pupils. Other issues were less clearly matters of behaviour; pupils frequently clicked the wrong button accessing some other part of the app, or turned the iPad off by mistake. This led to shouts of 'mine's gone off!' and similar protests, which required a lot of maintenance. Due to these issues, I decided not to use the *Sample-It* interface for the lesson as planned.

After the lesson, I gave my apologies to the teacher that the session had not run more smoothly. I explained that, in retrospect, the activities planned may not have been appropriate to the age level, and the whole-class dynamic had not been supported by the scaffolding structures in *GarageBand* as expected. The teacher offered a solution:

> Teacher: 'If I was a teacher and I was going to use that app, I would have probably, before that, told them about the chords, so it wasn't new for them…'

I then explained that my intentions for these sessions had been to encourage improvisatory creative behaviour, and to minimise reliance on explanation.

> Teacher: 'That wasn't as improvised because you were giving them specific chords to follow. They weren't really creating their own music as such… For these, it's understanding what the beat is, what the pulse is. That's very hard for a lot of children… As a teacher, I'd break it down into smaller parts, then put it together afterwards'

The teacher then noted that *Charanga* was useful for breaking down and explaining these concepts. It was clear that, in this instance, the successful outcomes I had observed with this approach in previous studies had not been replicated. There were a number of possible factors which contributed to this:

- The younger age of the group, and consequent change of ability level
- The use of commercial software, with a more complex layout
- The whole-class performance structure
- The reliance on non-exploratory features which had to be accomplished correctly by everyone, such as maintenance of a pulse and following the chords

7.7.4 Context 2

I returned to the school for two afternoon sessions the following week, working with a Year 6 class. Though this group were 3 years older than the previous class, I decided to abandon the 'iPad Ensemble' approach, wanting to avoid the same kinds of disruption where possible. To plan a new session, I requested the music targets for this year group:

> Evaluate their work and suggest improvements to the work of others.
> Use appropriate musical vocabulary stating what was successful/unsuccessful and why.
> Compare and contrast a variety of music indicating preferences.
> Identify different musical devices in a variety of musical genres and show awareness of the influence and place music has had in society over time.
> Use digital technologies to aid with the creation and recording of ideas

I decided to continue to use *GarageBand* and the song 'Happy', but instead to focus on how digital technology can be used to make a 'remix'. This would provide an opportunity to address all of these learning aims, with a particular focus on the last one.

7.7.5 Method 2

Learning Objective: *To make a remix of 'Happy' using* GarageBand

For both of these sessions, I was allocated a room and sent a group of students from the class. This was a different group of students for each session; 7 took part in the first session, and 10 took part in the second. Data was collected by note taking and from an audio recording, which was later transcribed. The *GarageBand* projects were saved, and were later sent to the class teacher to distribute back to the pupils. These could then be reopened in the app, or shared on *iTunes.*

We started by discussing what a remix is, how it involves copying some parts of a song and changing others. We then listened to 'Happy', and discussed which parts we might keep or change. We then turned to the iPads and *GarageBand.* I had set up each iPad with a new *GarageBand* project, setting the tempo and assigning the correct chords to the smart keyboard interface. I demonstrated how a looping beat could be written by counting to 4 and choosing drum pads for each number, then 'filled in' the gaps by adding drum pads at some of the half-beat measures ('1 and 2 and 3 and 4 and…'). I also quickly demonstrated recording a pattern using the chords and recording a vocal part. For the most of the rest of the lesson, the pupils worked at their own pace with an iPad and headphones each, supported by me or supporting each other. As we neared the end of the session, I directed them to the *Sample-It* app, and encouraged them to use it in their compositions. We listened to the pieces and discussed them at the end.

7.7.6 Results 2

These sessions[21] proved to be more productive than the previous lesson with Year 3. Levels of engagement were high, and there was no disruptive behaviour. Because of the small group sizes, and the less sequential and formulaic structure, a lot of discussion took place throughout the lesson, all of which focused on the task or programme.

The demonstration at the start of the lesson was met with an unexpected level of interest; the comments of the pupils indicate that they had not used a sequencing workstation like *GarageBand* before, and were not familiar with the kind of results that could be relatively easily engineered:

> 'Did you make that?'
> 'Are you an expert at making stuff like that?'

Consequently, the groups were eager to start using the app. In many cases, the exploratory mode of use led to the pupils happening upon something that intrigued them:

> 'It sounds good even if you just click on random ones' [using the drum pads]
> 'Mine sounds weird' [finding an arpeggiator]
> 'It's a banjo' [followed by rapid succession of notes, possibly imitating Bluegrass playing]

This format meant that I could respond to interesting occurrences as they happened. However, it also meant that a lot of time was spent experimenting with different presets and

[21] Due to the similar structure and outcomes of the two sessions, these results will be presented as one account.

instruments. Though this engaged the pupils, and led to a lot of discussion, they often had to be encouraged to record something with these options, or to make any gradual changes which would cause them to reflect on how a particular sound has been shaped. These directed instances were often stalled by the interface, which though simpler in layout than audio workstations such as *Logic Pro* or *Ableton Live,* was still fairly advanced for the novice user. I often had to make quite unclear references to the graphical user interface:

> 'Now we go to section B, so we click this button up here to add a new section…'
> 'Do you see this button that looks like three squares?'
> 'It's that button that looks like a bunch of lines.'

This led to a lot of uncertainty from the pupils, who frequently asked for help at times:

> 'How do you go onto that?'
> 'How do you get different sounds?'
> 'Something's happened to mine. It's gone bad.'

These less productive sections of the lesson were reminiscent of the barriers faced in the previous Year 3 study, though the open format and smaller group size meant that they were shorter in duration and less of a barrier to progress.

More positive outcomes emerged as the pupils began to hear their remixes take shape, often after the drum loops had been recorded. Musical features were discovered through exploration, and came to the attention of the group through demonstration:

> Pupil: 'It says tempo' [finding and altering the control for beats-per-minute]
> Me: 'That means speed. You can change the speed from there.'

Rather than stopping the class to demonstrate chords, this too emerged from exploration:

> Pupil 1: 'What are these symbols?'
> Pupil 2: 'The notes?'
> Pupil 1: 'Oh…' [as if something suddenly became clear]
> Me: 'These tell us a group of notes we can use.'

The use of the smart keyboard then led to some comments on the features of different genres. In this way, the explorations of presets had some reflective significance to the target on musical devices in genres:

> 'I'm being a rocker' 'I'm going to be hard rock'
> 'I've found dubstep'
> 'It's the 80s all over again!' [when playing back a synthesizer arpeggiator]

Pupils were visibly surprised at possibilities such as the smart guitar interface, allowing them to 'strum' or pick out a guitar pattern; this encouraged more recording. Also, this led to other new instances of discovery learning:

> 'I didn't know there was such a thing as an electric piano.'
> 'What does *dry* mean?' [followed by a discussion on dry and wet as a metaphor for the amount of effects processing; 'think of the effect like a liquid']

Though not all of the pupils were able to follow the chords to match the song exactly, the remix task gave license to experiment and improvise:

> Pupil 1: 'But that's not going to sound like that… Mine doesn't sound anything like 'Happy''
> Pupil 2: 'But you're making music'
> Pupil 1: 'I've got something good!' [after a few moments]

This kind of discussion and social interaction was observed throughout the lesson. Far from being a disruptive influence, it appeared to provide a source of intrinsic motivation, as the pupils showed each other their pieces, and swapped techniques for getting different results. There was a lot of good-natured discussion on the respective differences between their pieces, often with reference to musical dimensions:

> 'What songs do you listen to? You must have, like, fifty songs playing at once' [remarking on the busy texture of their friend's remix]

On occasion, pupils took it upon themselves to demonstrate something to their peers, and help them to get the same result:

> 'I'll come round and do it for you now… Has everyone got it?'

This emergent sense of organisation was also seen when the pupils decided it would be better if they all sang and recorded the vocals together:

> 'We should all sing it together' 'We'll all sing it at the same time'
> 'Everybody get ready to sing'

It appears that, in such instances, the open format of the session generated intrinsic motivation – to share an idea, to do something together, to demonstrate something – that was grounded in the possibilities afforded by the technology.

The *Sample-It* interface, being used later in the session, was met with interest. As we had more than enough iPads, this could be set up on a second device, allowing pupils to record from one to another. In a similar fashion to the earlier studies with *Graphick Score*, links were pointed out to functions found on social media platforms:

> 'Is that like a *Snapchat* filter? Like, it makes your voice sound like a chipmunk?'

We were then able to discuss how the 'chipmunk' effect is created (increasing the pitch, speeding up) and the consequent prevalence of this effect in electronic dance music. The pupils were able to cut up, loop and trigger their vocal samples, leading to various experimentations:

> Pupil 1: 'Listen, this is it high… this is it slow…'
> Pupil 2: 'We sound like minions!' [referencing the characters from *Despicable Me*]

One pupil worked out how to imitate the sound of an EDM 'build-up', where the number of repetitions in a cycle increases to build tension. The tilt-filter function was also discovered, which prompted instances of 'jamming' between the pupils, as they tried to stay in time with each other. This record and edit function, particularly the capacity to reverse audio and change speed, led to a lot of experimentation with recording and editing different sounds. The pupils were noticeably listening to, and communicating with, one another here, rather than being solely focused on what they were doing themselves. As such, this section of both lessons became a very collaborative and reflective activity, which may have benefitted from further explorations outside of the allocated classroom, looking for interesting sounds. One pupil, Jonah, made extensive use of the *Sample-It* interface to edit vocal sounds and record them into his *GarageBand* project. This emerged from experimenting with different vocal noises, with alterations in pitch, and then alternately playing them backwards and forwards ('it's like a helicopter'). This sampling and resampling of improvised vocal sounds was carefully recorded into *GarageBand* by Jonah to produce unusual effects which punctuated his remix at timely intervals.

Toward the end of the second session, the class teacher entered to take some photographs, and the pupils were keen to show their work. As with the earlier study at School D, the rapport between the teacher and the pupils offered opportunities for engagement and reflection:

> Teacher: 'Jonah's really into technology. He wants to be a *YouTuber* when he's older.' [as Jonah demonstrated his interest in *Sample-It*]
> Teacher: 'That's a Taylor Swift country version.' [listening to a smart guitar based remix by another pupil]

We ended with a discussion on how different the remixes were from the original song, but how this had meant that we created something original of our own. The pupils indicated that they wanted to continue with these activities:

> 'When will we be doing this again?'
> 'My mum won't let me download anything like this on my iPad'
> 'Can you get this on tablet… on Samsung?'

They wrote down the name of the app, and I suggested some other sampling apps that they might use at home. I also told them I would send the *GarageBand* projects, as they could continue working on these in the app, or stream to *iTunes* to show friends and family.

The barriers faced in the 'iPad Ensemble' session with Year 3 were largely mitigated by the open format of the later sessions. As the class teacher pointed out, the first session did not involve much opportunity for improvisation; there was a formulaic structure and certain materials which had to be learned in a very specific way. My approach of minimising explanation therefore acted against the flow of the lesson. The later sessions were, no doubt, improved by the smaller group size and older participants, but were lacking certain other supportive structures, such as the presence of the teacher. The open format here, offering more opportunities for improvisation, allowed pupils to work at their own pace, to discover opportunities, and to support each other. The flexible nature of the activity, and capacity for independent work, meant that pupils had the option of following the chord structure or experimenting with different possibilities; this emerged from an inability to follow the chords, a disinterest in doing so, or simply from mistakes in attempting to do so. Crucially, this freedom allowed for a differentiation that maintained the flow of the lesson for all pupils, as they were 'given musical and technological information as they needed it' (Pitts & Kwami 2002, p.69).

Demonstration played an important role in clarifying the objective. The pupils of the later sessions were unexpectedly impressed by my demonstration, which they considered an expert level. Collins *et al.* (1991, p.13) note how modelling helps students to 'observe and build a conceptual model of the processes that are required to accomplish it'. Similar results are seen in the research with *Graphick Score*; the appropriation of features from the demonstration to individual creative outcomes in each of the studies. As with earlier studies, pupils listened to sounds and attributed meaning, though this was mostly confined to reflections on genre. However, with *Sample-It*, discussions took on much more impressionistic form similar to that which has been observed with *Graphick Score* ('it's like a helicopter'). This is perhaps due to the gradual changes to the sounds presented by this interface, which were less preset-based than the genre-oriented *GarageBand.* It is also notable how this interface directed the focus away from screen-based interactions and toward imaginative discussion and exploration of the sounds made by each other. This occurrence was unexpected, but it was clear that the pupils were reflecting more on the musical results of their actions here than when, to paraphrase one of the pupils, just clicking random buttons.

While the range of options in *GarageBand* promoted engagement, a lot of 'teaching the software' was still required. Even some of the scaffolding tools, such as the smart keyboard interface, proved challenging for some pupils. In many cases, this seemed to be due to reliance on musical representations and language that was not intuitive for the pupils. By contrast, when using the *Rainbow Keyboard*, the pupils were able to devise kinaesthetic patterns, and even came up with their own notations (see 7.4.5). It seems that the openness of format, and the lack of a sense of 'right and wrong' ways of completing the task, afforded the pupils the opportunity to come up with their own methods and 'influence the problem manipulation space' (see 4.1). The open format may also assist the generalist teacher by focusing on the creative activity rather than the concepts involved, as we saw in the study at School D (see 7.6).

7.8 Theoretical Summary

In my attempts to develop a sandbox composing environment which enables pupils to interact creatively with the inter-related dimensions of music, certain core concepts have emerged. This has been grounded in the process of my literature review, formulating and addressing the research questions (the conclusions to which will be provided in Chapter 8), my development and testing of *Graphick Score*, and the application of these considerations to other bespoke and existing applications (notably utilising the iPad for performance and composition). We have observed instances of what may be termed *sound-painting, sound-sculpting* or *sound-sketching* (depending upon the mode of interaction involved) whereby the user interacts directly with musical structures, benefitting from real-time visual and kinaesthetic (as well as auditory) feedback. Crucially, digital technology offers a means for transparency between these manifestations of musical ideas; they become *objects-to-think-with*, with the potential for *embedded meaning* (see 3.1). In this way, this approach is an example of what Fullan and Langworthy (2013, p.4) term 'new pedagogies… enabled and accelerated by digital technology' (Fullan & Langworthy 2013, p.4).

The approach detailed by this theoretical summary relates to Bamberger's theory of tune-blocks (see 3.2.4) which has been used extensively in this research (see 6.4). For the purposes of early-years music education, a familiar musical phrase, as a structure of multiple notes and durational values, is simpler than the first note in isolation, because the child has a context for understanding the phrase as a whole. They can recognize it, replicate it in a variety of possible ways, and possibly modify it for creative and expressive purposes. In this way, the musical language derived from culture becomes the starting point, the knowledge that children bring to the learning process. This offers a creative framework within which students can explore musical ideas with a degree of freedom; we observed the potential benefits on lesson structure of this freedom in this research (see, for example, 7.7). Where musical outcomes are intertwined with the modes of interaction and representation employed, and generally easy to comprehend for both student and teacher, these structures become effective resources for the ‘Bloom’s 21’ model of learning (see 2.2.1). This was observed with *Graphick Score* as the user interface developed to the point where it could be used for experiential music composition, by both students and teacher, with minimal instruction (see 7.6).

This research has highlighted that to ‘compose… using the inter-related dimensions of music’ (DfE 2013, p.2) is not, in itself, an effective starting point or approach. The reason why these dimensions are inter-related is because they manifest through larger meaningful structures. We can explore our own idea of these concepts when we can utilise these scaffolding structures for creative purposes. The original application of this idea in my research has been to investigate how digital technology can enable us to utilise such structures in open-ended ‘sandbox’ environments; to arrange and mould digital embodiments of inter-connected musical dimensions into something that demands only imagination, or a willingness to experiment. By moving away from melodic and harmonic ideas and toward a more open framework of ‘sound objects’, *Graphick Score* has opened up a new mode of digital interaction which has had promising results, and which bears further exploration, especially to examine the musical dimensions which have perhaps been less thoroughly applied (see 8.3.3). This open-format exploration of sound and attributing of meaning has also been seen through digital recording and manipulation with *Sample-It* (see 7.7.6) which presented further examples of social and kinaesthetic interaction using iPads; this too should be examined further.

8. Conclusion

Figure 8.1

In the concluding chapter to this document, the outcomes are presented as answers to the wider questions, and directions for further research are highlighted. I will briefly summarise the outputs of this project, before answering each of the four research questions, and discussing the implications and recommendations for future research. I will then critically evaluate the project, focusing on any limitations and alternative possibilities which have emerged.

8.1 Summary of Outcomes

8.1.1 Practical Outcomes

This research project produced a number of software artefacts through an iterative and continuous process of classroom application and development. For the purposes of this thesis, these artefacts are thought of as the research tools; the means by which the research questions are addressed. However, they have also been shown to lead to instances of creative engagement and learning in the classroom, and will continue to be developed and utilised beyond the completion of this project. These artefacts are submitted in the electronic appendix, which accompanies this thesis, alongside instructions for installation. Updated versions will be continually available at my Wordpress account:
www.adammatthewhart.wordpress.com

8.1.2 Theoretical Outcomes

The application of grounded theory to the literature review, practice and research, has led to a central theoretical outcome, describing how abstract musical dimensions may be learned experientially through digital scaffolding structures in sandbox environments. This is summarised at the end of the previous chapter (see 7.9) and elaborated upon in the answer to the research questions (see 8.2). The implications of these findings for new research and development follow these answers (see 8.2.5). Also, by undertaking a new practice-led model, this project serves as an examination of how software development may be utilised for educational research.

Through the methodological approach of SoDaR supported by grounded theory, the resultant practical and emergent method has reached a point of theoretical saturation (see Glaser & Strauss 2017, pp.224-8). The various codes emerging from the application of this method, with respect to our definition of musical learning (see 1.1.1) within digitally-supported environments, have, through the process of data collection and analysis, developed into wider concepts and ultimately a summative theory (see 7.8). This emergent process of theoretical development and saturation is described by Figure 8.2. I propose that this model, being a newly adapted method for researching creative musical learning through technology and a theoretical outcome in its own right, is an appropriate approach for future research in this particular field (see 8.3).

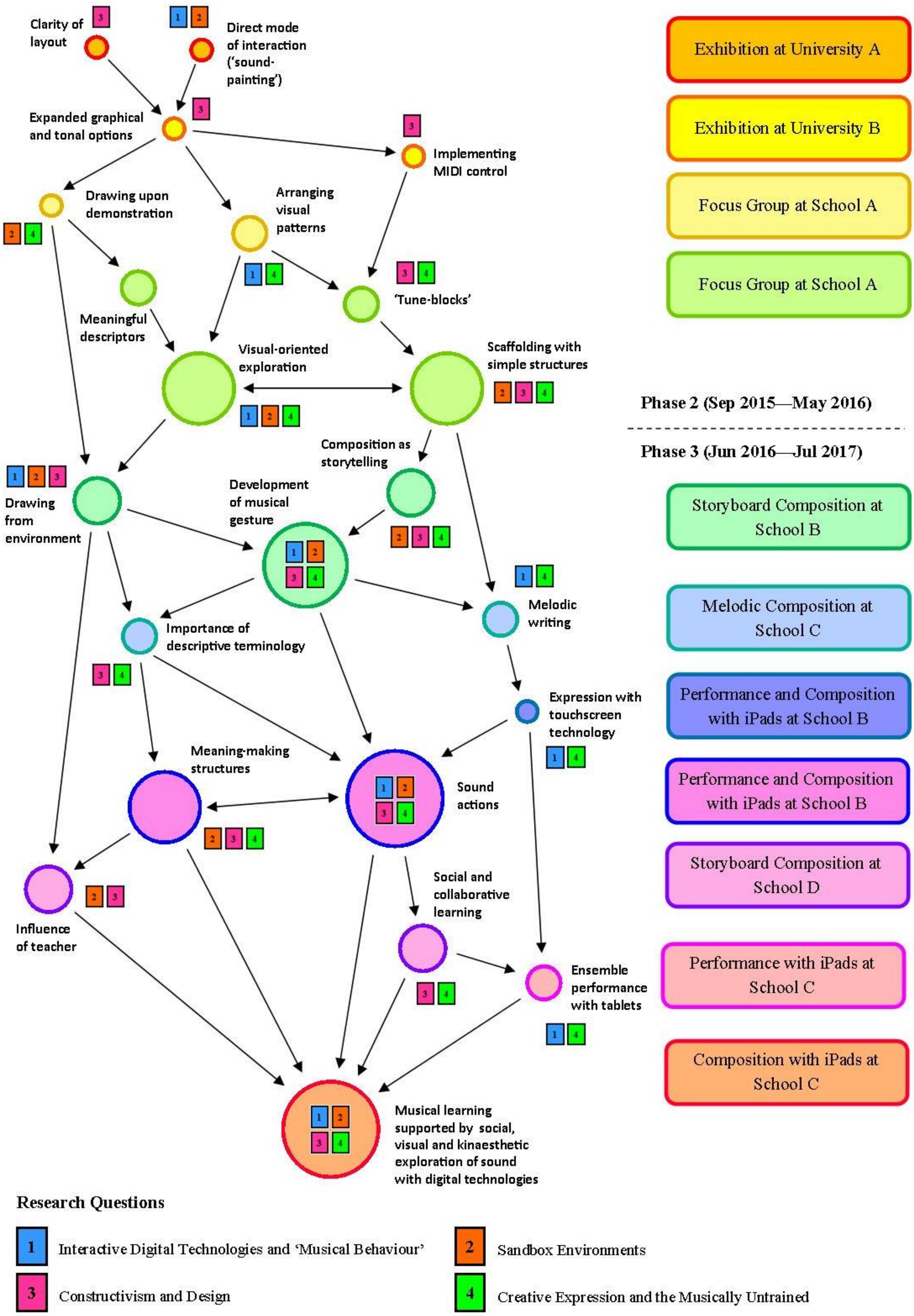


Figure 8.2 – The theoretical codes emerging from the studies and analytical process, and their relevance to the four research questions.

8.1.3 Other Outcomes

Besides the practical and theoretical outcomes documented in this thesis, there are other achievements of this project which can be acknowledged here. Firstly, the research conducted has had a substantial impact in terms of musical learning and creativity in many cases, as the evidence documents. Of course, this occurs more prominently in some studies than others, but all were planned for positive impact, and the findings (even from those where the session did not go exactly as intended) have informed my future practice and led to the wider outcomes of this thesis. We have seen impact on musical creativity in the classroom, as well as influence on teachers and school practices in some cases. Furthermore, this has led to the definition of new projects, with expressions of interest obtained from some of the schools who were involved in this research. Finally, this project has so far produced two new publications (Hart 2017a; 2017b) as well as dissemination at several major international conferences.

8.2 Research Questions

8.2.1 Question 1: Interactive Digital Technologies and 'Musical Behaviour'

To what extent have interactive digital technologies hitherto succeeded in encouraging musical behaviour in the classroom?

It is clear from our survey of existing software resources that many options are available for classroom use, though the range of software actually used is, by contrast, very limited (see 3.2). Software packages such as *Charanga*, offering sequential guidance for students and teachers, help to bridge the skills gap in music education by offering a digital, interactive curriculum which breaks down concepts into accessible activities. Digital audio workstations such as *GarageBand* and *Logic* are less frequently used in primary education, but more common in secondary education where pupils are more likely to work on long-term compositional projects; the construction of a *meaningful public entity*. Research has highlighted the scaffolding benefits of music interfaces following a simplified design, such as *eJay* and *jam2jam*. A wider systematic review is requred, on a nationwide level, to examine the range of technologies utilised by teachers, both specialist and non-specialist, to achieve different musical outcomes. Even the wide-ranging reports of OFSTED are limited in their attention to this issue, noting ‘insufficient improvements’ (see 2.2.3). These reports pre-date the relatively recent emergence of *Charanga*, and increased affordability and implementation of digital devices such as the touchscreen tablet in recent years, as well as recognition of the ‘new pedagogies’ (Fullan & Langworthy 2014) suggested by such technologies, points to the current need for a review of digital resources in music education and the wider creative curriculum.

In terms of the extent to which this question is addressed by this research project, we must first consider what we have interpreted as ‘real musical behaviour in the classroom’. Current models for classroom practice focus on creating behaviours, followed by reflection and synthesis of new knowledge leading to new creative interactions. This is reflected in the experiential learning cycle (Kolb 1984) as well as more recent proposals such as ‘Bloom’s 21’ (Wright 2012). By promoting these ‘doing dispositions’ in supportive, collaborative and reflexive environments, we are enabling students to extend their learning and understanding outside of the classroom, facilitating ‘deep learning’ (Fullan & Langworthy 2014, p.i). Such creating behaviours are important to musical learning, as the literature review demonstrates (see 2.2). We therefore must ask whether interactive digital technology has hitherto supported such behaviours.

One of the benefits of interactive digital technology is the capacity to present abstract concepts in a visually and tangibly accessible format, as seen in the research of Papert (see 4.1.4; 3.1.1). Where software is not oriented toward a pedagogic design, much time has to be directed toward learning the software, to the detriment of the learning outcomes. This would only further exacerbate the problem identified by OFSTED concerning the prevalence of explanatory behaviours in music lessons (see 2.2.3). The research with *GarageBand* highlighted how pupils require more direction if the interface is not designed for this kind of accessibility, and may require guidance to relate their explorations to creative musical decisions. By contrast, the research with *Graphick Score* saw the need for such explanations decrease as the interface developed toward a more open-ended environment (this will be addressed in the response to question 2). Though limitations are still present with this resource, this change indicates the importance of pedagogic interface design in minimising the time spent ‘learning the software’. However, this must also be balanced against the stability of professionally developed commercial software, which is often marketed to a wider demographic, and not built with pedagogic outcomes in mind. This will be addressed in the answer to question 3.

Early in this research project, the importance of the social element of musical learning became apparent. Integrating these aims with digital technology has admittedly been a challenge. In *jam2jam*, Brown and Dillon address this issue by implementing jamming and text messaging functions over WiFi networks (see 2.2.3). In *GarageBand*, users have the option to 'share' the song by sending directly to *iTunes* (see 3.2.4). In this project, I explored a range of approaches, such as splitting headphone signals (see 7.4; 7.6), using touchscreen tablets (see 7.4; 7.7), and even streaming performance commands over wireless networks (see 7.4.2). These were attempted with varying success, though it ultimately became apparent that considering how the software fits into the wider environment of the classroom, and planning sessions that incorporated digital technology while not being encapsulated by it, was the most effective approach. In the best of these examples, the digital technology is seen to accelerate and augment the socially creative as well as individually creative aspects of learning (see 7.2.3; 7.4.6; 7.6.3; 7.7.6). A focus of future research should be the consideration of how interactive digital technology can facilitate a range of social musical learning environments, away from computer screen and headphone based workstations.

It is noteworthy that the digital resources available for classroom music-making are almost exclusively screen based in their mode of interaction. While touchscreen tablets have a higher capacity for portability and collaborative learning, making them more versatile classroom tools in many respects, very little research exists on their suitability for active musical learning. This research explored some approaches, with positive results where small groups composed and performed with iPads and accessible music interfaces. However, the visually-dependent mode of interaction, lack of haptic feedback, and lack of clarity concerning the source of individual sounds, led to less promising results in larger groups, with less evidence of listening and communication within the ensemble. To make use of the scaffolding and processing potential of these tools within a context of real musical behaviour, we must consider how they might be utilised in a manner that also guides attention away from the device in our hands and toward the social and sound environments around us. This will be addressed in the response to question 4.

8.2.2 Question 2: Sandbox Environments

What conditions prompt musical learning in 'sandbox' environments?

The term 'sandbox' is applied in a variety of recreational and educational contexts. Within the constructivist paradigm, learning and play are linked or, within some interpretations, indistinguishable from one another (Piaget 1951). This project has offered a specific interpretation of the term that recognises a model for digitally-augmented, play-based discovery learning: A sandbox environment is one where the learning materials, whatever they may be, are at hand, and shaped by the imagination of the learner to construct something meaningful, through which the intended learning outcomes are ultimately achieved. A key feature is the use of scaffolding structures as creative triggers, just as moulds are used to build sandcastles and other recognisable shapes, and combined or manipulated to construct larger patterns or structures.

Research has demonstrated how sandbox computer games such as *Minecraft* and *Sim City* have been used in the classroom for the creative, interactive and collaborative learning of abstract topics. In these examples, the blocks, structures and sprites become *objects-to-think-with*, infused with the abstract learning concepts in question. In the research with *Graphick Score*, the learning materials – the *inter-related dimensions of music* – are represented by the shapes and structures arranged and manipulated by the user. A simple action, such as clicking or drawing in the canvas window, produces not a single note but a recognisable structure, which becomes the trigger for formation of more complex patterns and structures. It is the capacity for the learners to ascribe their own meaning to this, to exercise their creative imagination, reflect on their decisions, and use this as an impetus for further decisions, which enables them to explore and discover these abstract concepts for themselves.

Constructivism tells us that interplay between new experience and existing ideas leads to learning. Supportive structures which enable learners to attribute meaning to their creative explorations are therefore vital in sandbox environments. In *Graphick Score*, the addition of keynote sounds and images, as storyboarding tools, allow the user to construct a scenario, which they then augment through sound objects. We also see that children are quick to adopt and alter suggestions, such as those given in demonstrations. For this reason, the possibility to directly change the objects-to-think-with as a bridge between creative ideas and new occurrences is a valuable feature. These functions can be extended further in *Graphick Score;* the possibility to record and edit sound files (harnessing the social and creative engagement we saw with the *Sample-It* app) and to further manipulate keynote sounds by directly interacting with images (perhaps with rotating functions such as those used with sound-objects) should be explored.

In some cases, the presence of an unexpected change may be required to further stimulate creative outcomes and challenge existing intentions and goals. In *Minecraft* and *Sim City*, such occurrences are present in the features of the game over which the player has no control; the actions of autonomous sprites and events, such as changes in weather. Implementing such wider processes into *Graphick Score*, perhaps whereby the user discovers or 'unlocks' control over such processes, is another possible avenue for investigation. It may be that generative interfaces, such as *MetroNotes* and *SoundWorlds*, offer a means of addressing this possibility as this research continues.

Finally, we should not assume that sandbox environments, and the processes involved, must be limited to digital interfaces. This research has shown that these environments can be supported by digital technology, but that this is most effective when the relevant skills can be applied to non-virtual contexts. Commercially-produced digital resources tend toward a wholly software-oriented mode of interaction, and are consequently screen-based. Conversely, educational research in this area may consider the wider classroom environment as part of the sandbox, augmented by the pedagogical instincts of the teacher, and the creative imagination of the pupils. This was evidenced by the introduction of games (see 7.2.3; 7.6.3) and collaborative activities (see 7.7.6) in my research. In retrospect, focusing entirely on computerised playback in *Graphick Score* missed an opportunity to challenge creative decisions and stimulate further reflection on the learning materials. Building upon the game of the class teacher in School D, the graphic score made by one group could be given to another to be performed with rudimentary instrumentation or voice, and then compared with the computer playback, generating opportunities for comparison and reflection on musical interpretations, as well as the realisation of shared conceptual ideas. This will be explored in further research.

8.2.3 Question 3: Constructivism and Design

How can constructivist educational theory be applied to software design as a means of facilitating creative musical learning?

This question relates not just to the musical learning of the pupils as a result of constructivist design, but also to my developing practice of interface design, and how constructivism helps me to understand this progress. Jonassen (2006) argues that constructivism is not a design strategy, but a lens through which to analyse our methods. If we mistake ontology for strategy, we risk perceiving outcomes that would have occurred anyway as fruits of design; this is factual relativism (see 2.1.4). However, we can adopt a design strategy that is informed by constructivism. The sandbox environment is an example of this, as it presents an environment for exploring new possibilities while facilitating the meaning-making processes that constructivism tells us leads to new knowledge. Similarly, the bottom-up design process acknowledges constructivist theory by emphasising responsiveness to emergent meanings and possibilities which only become apparent to the developer when engaged in the design activity.

It has been demonstrated that research and innovation is needed to help classrooms keep pace with technological change, and harness new learning opportunities (see 2.2.3). Research in investigative pedagogic interface design, informed by educational theory and grounded in classroom research, is therefore a worthwhile pursuit. In music, precedents to this kind of research, where educators use software development as a tool to investigate new creative pedaogiges, is to be found in the work of Bamberger and Hernandez (2000), as well as Brown (2007a) and Dillon (2004) among others. This project has investigated a new practice-led model for combining teaching experience with software design; the benefits of this approach include a sensitivity to pedagogic considerations and wider learning outcomes and environments that may now be found in commercial software development, though this necessarily also demands a recognition of the limitations of the researcher-programmer compared to that of a professional developer (see 6.2.3). Where areas of skill and experience are combined in pursuit of a new practical model, this is perhaps inevitable.

In this project, grounded theory was identified as a methodology compatible with the constructivist ontology (see 4.1.4). This allowed me to apply this lens to the practical methods of SoDaR, and to critically reflect on my own practice as it occurred. Sensitivity to emergence, emphasised by both Glaser (1992) and Brown (2007a) with respect to these methodologies, meant that SoDaR was not followed as a sequential formula but adapted to meet the requirements of emerging learning opportunities. This is particularly seen in the shift away from melodic scaffolding structures and toward kinaesthetic 'sound-objects' (see 7.4; 7.5; 7.6) and the later examination of iPads as performance tools (see 7.7; 7.8). In addressing these emerging considerations and opportunities, maintaining equilibrium between these new ideas and those already established, and adapting the trajectory of research to accommodate this change, I have developed a working interface which will continue to be applied and updated in response to educational outcomes. This is a reflexive and dynamic cycle that has seen both the software artefacts of my practice, and my practice itself, continually improve in response to the opportunities of the music classroom.

Constructivism accounts for understanding; it tells us that this comes only from the learner, it is their creation, and it is the role of the teacher to provide an environment which facilitates this process. Similarly, inspiration can be understood as only part of an experiential process; a function of the creative imagination, which can be exercised. Thinking leads to more thinking, and creative behaviour leads to more creative behaviour. If we take a creative exercise that children can already do – telling a story – and use this as a scaffold for what we want them to learn – composing a piece of music – we have to help them to understand a creative connection between the materials they are used to and the new materials we are introducing. In *Graphick Score*, this led to the development of *sound-painting/sound-sculpting* structures which facilitate these creative 'doing' behaviours. Inspiration is merely part of this process, where exploration leads to realisation and further creative exploration.

8.2.4 Question 4: Creative Expression and the Musically Untrained

How might interactive digital technology be harnessed to facilitate creative expression in the musically untrained?

In many creative subjects, the learning materials are very much 'at hand'; we sculpt clay, splash paint, and sketch with pencil and pen. Music is different, and altogether less tangible. The learning materials, too often, are abstract concepts like the inter-related dimensions of music, apparent only in the results of creative expression. In this project, I have used interactive digital technology to make these materials altogether more visible, tangible and accessible. I have examined how structural scaffolds may be made of interconnected musical concepts, to act as an interactive framework for expressive activities which children understand from an early age, such as telling a story or painting a picture. The interface of *Graphick Score* can make these interactions more musically coherent (see 7.2.3) while also providing a format for reflection. We have seen that children are quick to attribute meaning to creative outcomes. Digital technology may be used to engineer transparency between action and result, as well as the consequent change in musical dimensions; a simple action can produce a complex result (see 7.4; 7.5; 7.6). Children are therefore more readily able to engage in creative activities without having to first understand the smaller mechanisms involved, promoting a more free and exploratory environment in which they can form these concepts for themselves.

Papert describes how children explore concepts where they can produce a meaningful public artefact (see 3.1.1)**.** It is notable that not all the creative explorations of children yield such tangible artefacts. Drawings and paintings are produced from a young age, and parents will often display these on the fridge, and ask the children what they represent; the children reflect upon these visual-kinaesthetic creations, attach meaning to them etc. Children also indulge in sound-based creative expressions, make up or alter songs, or something as rudimentary as exploring unusual sounds. However, we less frequently make artefacts of this due to the more ephemeral nature of these activities. Without a piece of paper or a sculpture to act as a record that these activities took place, they often go unnoticed and uncommented upon, and are consequently less of a focus for reflection. It is therefore perhaps no surprise that visual-kinaesthetic interactions, as seen in the experimentations with *Graphick Score*, provide a useful scaffold for attributing meaning to sound. Therefore, we may ask how digital technological can promote creative and imaginative attitudes to sound, in terms of both making and listening.

Though the benefits of making a sound-artefact were explored through *Graphick Score*, it was admittedly a challenge to make these screen-based interactions part of a social learning dynamic. This was achieved in some respect through group work and discussion. When using iPads, a different dynamic was often achieved, due to the more kinaesthetic and portative modes of engagement. However, the ensemble musicianship and group work seen in study 7.4 could ultimately not be replicated with a larger group (although the unsuitability of the task to sandbox learning no doubt played a factor here). One of the most prominent examples of social creative expression through digital technology within this research was seen when pupils edited sounds using the *Sample-It* interface. This led to an unexpected degree of listening and creative exploration, even 'jamming' interactions (see 7.7). We also saw how this made a creative and changing artefact of actions such as making sounds with voice; the kinds of rudimentary, or 'childish', actions which would typically have little significance to music curriculum targets. In this case, by manipulating and sequencing these sounds, the pupil in question did something of significant creative expression, engaging with changing musical dimensions through voice and digital technology (see 7.7.6).

The findings from *Sample-It*, though brief, present an opportunity to use digital technology to move away from screen based interaction and turn focus to the sounds around us, or those which we are capable of making. For example, how can we capture and change these sounds to express a story? These then become *sound objects to think with*, much like the scaffolding structures employed in *Graphick Score*. Changes to these sounds can also be made with non-screen based functions, such as tilt, while learning can extend outside of the classroom, into the playground or at home. I therefore feel that this presents an application of digital technology which has tremendous potential for music education; to get children interested in sound, to listen with imagination, change sound to express creative ideas, and reflect on this process.

8.2.5 Recommendations

This research has implications for the design of new technologies, but also for curriculum change. We took, as our design strategy, 'composition with the inter-related dimensions of music'. However, these ideas only arise from creative efforts, in how they combine to form complex musical structures, with the potential for embedded meaning. They are inherently inter-related, and we therefore cannot simply 'compose with' such concepts. It is therefore illogical to teach these concepts in the isolated abstract. Garnett (2013) argues that these are the components of a constructivist curriculum which are too often taught in a behaviourist way. The 1992 curriculum framed these ideas within a range of experiential strategies, while 1999 revision focused on mood, meaning and feelings as a way of engaging with these concepts (see 2.2.1). As of 2013, these concepts are presented in the isolated abstract. This is problematic, as these musical dimensions only emerge from creative and practical musical experience, and are only 'used' in the sense that they are present in the results of our creative efforts. By themselves, they are arguably meaningless, from a perspective of musical activity.

This suggests that instructional design in music education should focus on making opportunities for creative musical experience available. In this project, I have explored how this can be made accessible through interactive digital technologies.

Digital resources like *Charanga* have been useful in breaking down concepts for pupil, and in supporting generalist teachers who may otherwise struggle to teach an active music curriculum (see 2.2). The findings of this research suggest that musical experiences can be made accessible without prior engagement of musical concepts, through digitally-augmented sandbox environments. Further research should be undertaken on how the recording and editing of sounds with simple digital apps can provide an accessible, exploratory and experiential format for engaging with musical concepts. This is akin to the traditions of tape music; digital technology brings these possibilities more readily into our classrooms, as evidenced by the simple handheld interface of *Sample-It* (see 7.7). *Graphick Score* will continue to be developed to accommodate this. Also, it should be noted that this is an open-source and freeware application, and I encourage these findings being used for further non-commercial development for educational purposes. I hope that further practice-led projects such as this can forge closer links between research and practice in this area, to make a positive impact on promoting music in the classroom and at home.

8.3 Critical Evaluation

8.3.1 Scope

This has been an exploratory research project, and as such, has been characterised by an emerging focus on some areas while others might bear closer observation. In particular, more research is required to investigate how gender, age and other factors impact creative use of digital technology. As indicated, the findings generated may have significance in other areas beyond music composition, presenting other avenues which could have been explored in this project, but certainly should be considered going forward. This includes the potential benefits of these creative experiential approaches to digital technology in music therapy, social inclusion and assistive musical environments for pupils with special educational needs. The principle of sound-painting or –sculpting sandbox environments may also be applied in a cross-curricular context, by forging links between visual-kinaesthetic and auditory arts. The general findings and hypotheses of this research could be directed toward any of these further investigations.

8.3.2 Methodology

The wider methodological model of this project was grounded theory; this informed the research aims and questions, directed the data collection and analysis process, and led to the emergence of a theoretical outcome. This encompassing application is favoured by Glaser (1992, p.32) when he argues that ‘grounded theory must be free from the idea of working on someone else’s work or problems’. A secondary model was provided by SoDaR, though the step-by-step process outlined by Brown underwent some changes due to sensitivity to emergence and unexpected outcome, an attitude whose importance is emphasised in both of the methodologies applied.

This approach, perhaps inevitably, led to some changes in direction. Early data collection methods, such as the use of surveys, were abandoned as the nature of the studies became more resembling of music lessons, though ultimately this led to more opportunities for evidence of creative learning. Other qualitative methods might have been utilised more consistently and exhaustively, in hindsight. For example, the interviewing of teachers, though only used on several brief occasions (notably in 7.8) proved a useful resource, the significance of these perspectives only becoming apparent as the focus moved away from the interface itself and toward the mode of application. When building upon these findings, I intend to make much more prominent use of teacher perspectives.

A potential criticism of the methodological approach is that it relies too heavily on my own practice and perspective as a musician, programmer and teacher, especially considering that my experience across these three areas is not in equal proportion. However, one of the advantages of the methodology used in this research project is that, as the researcher-programmer, I am in possession of the domain knowledge, the evolving research considerations and the means to pursue a software solution. This enabled me to take an exploratory and experiential approach, being able to respond directly to findings with immediate and appropriate changes in my programming practice. Schön (2017) argues that practitioners respond to problems and adapt their practice in real-time, a theory supported by Kolb’s (1984) experiential learning model. The key, then, is to adopt an approach which allows the practitioner to step back and view the process, to be able to document and analyse it as a component of research. By using grounded theory, and by viewing my own developing practice through the constructivist lens, I have sought to document this process as part of this project.

In addition to the principal practical and theoretical outcomes, this research has provided a case study example of SoDaR, which, as a new methodology, bears further experimentation. When applying Brown's methods, and asking his suggested questions, the resulting model was actually much less structurally formulaic, with reflexive and cyclical characteristics. These changes are, in part, due to the combination with grounded theory, but it is this mixed methodology approach that has allowed a clear commentary upon the process. Crucially, the methodology is reproducible (Glaser 1992, pp.116-7); the same software artefact may be used, and the context of each study may be replicated (as close as possible) with a similar group. Certain variables may be altered for comparison, such as the age of the group, changes to the software, and different approaches to lesson structure and activity. Conversely, some variables may not be accounted for, such as unexpected outcomes from pupils, and the question of how effective or ineffective I might have been in providing support, or leading the lesson. Though I have attempted to clearly document and analyse any significant occurrences of this nature through audio transcription, it may be that more exhaustive methods of documentation and analysis are required. In particular, video recording of the lessons may be implemented, and transcription may account for reactions and other behaviours besides speech; specifically, I feel that the system of qualitative presentation proposed by Roth (2017, p.11) could address this deficiency in future research.

8.3.3 Design and Development

By developing this myself, I have faced advantages and disadvantages. The design process has been more thoroughly embedded in the other considerations of research, such as the literature review, methodology and testing. Another advantage is that this process has allowed me to develop my practice, with substantial improvements in my programming ability, and in recognising opportunities for learning and creative expression in this practice. These advantages are noted by Brown is his description of SoDaR (see 4.3.2). However, this approach also presented disadvantages, and there are certain functions which perhaps should have been explored differently.

Graphick Score itself has presented some original modes of interaction, yielding promising results with respect to creative pedagogy. The core design features will continue to be developed, while perhaps addressing some limitations. I feel that the drawing function, being an original feature, should remain, but perhaps this should be achieved by generating single complex geos rather than multiple individual ones. This would save processing power, but it should be ensured that the same flexibility and malleability of the resulting sound object is maintained. I also feel that this function could relate to shaping other musical parameters, with promising results; the idea of visualising, interacting with musical ideas presented by sound painting need not be restricted to making note events. There are certain restrictions to the 4-bar grid structure utilised in later versions; we saw this when pupils asked whether the speed of the canvas window could be varied (7.2.3). The aforementioned function of 'drawing' envelopes for dimensions such as tempo could resolve this issue. Perhaps the non-linear and real-time responsive designs of *MetroNotes* and *SoundWorlds* present a more open-ended interface. These possibilities will be reviewed in future research.

I feel that the domain knowledge of musical dimensions was well represented in *Graphick Score*. Some of these functions were in place from early versions (see 5.3) while others emerged following later refinement. Dimensions such as timbre, the shape and character of a sound, as well as dynamic variation, emerged from the implementation of sound-objects, consisting of multiple geos, as single sound events (see 7.5). This enables users to see these meaningful structures – manifestations of interrelated dimensions – rather than thinking in terms of single musical dimensions. Though the polarity of major and minor tonality was a useful concept, I feel that this could be extended further. In particular, I am keen to reintroduce non-Western scales such as the Indonesian *slendro*. Perhaps such functions could be 'unlocked' through use (see 8.2.2).

Velocity and size seemed to present an intuitive connection during initial design (see 5.3), but this ultimately generated a conflict with the concept of duration, as the size of a shape is related to its length. I incorporated certain solutions, such as drawing a long line with the draw function, and longer joined structures of sound-objects. Early studies indicated the need to avoid, where possible, convoluted navigation of menus to change note events already created (see 6.2). It may be that icons of different tools could be used: For example, painting a line can create a note of certain length, while moving up and down produces a a portamento. A different tool, such as a stamp or felt pen, could be used for strings of single note events. An alternative to velocity is found in many digital audio workstations, which tend to use changes in colour to indicate dynamics (see 3.2.4). However, this presents an issue with my design, as overlapping textures of different voices would become unclear.

Pd proved an appropriate environment to use for this project. The deprecation of *Pd-extended* (see 4.2.1) proved an issue, but *Graphick Score* has now been successfully transferred to *Pd-vanilla* for submission and future development. A new alternative version of *Pd*, with an extended library and user friendly interface, *Purr Data*, is now also available. This raises the question of whether *Graphick Score* could be transferred to this platform for development by less experienced programmers. In the spirit of open-source programming, I would like to continue to work on *Graphick Score* in such a way that it invites development as well as utilisation by others[22].

8.3.4 Application

The process of development was augmented and accelerated by application in the classroom. The most valuable of these sessions were conducted during phase 3, where the focus shifted away from the design of the interface and toward learning objectives and outcomes, as promising developments were defined by measurable added value. I do feel that this approach could have been applied earlier, perhaps by testing the prototype interface for smaller activities. However, this is an exploratory project, and the significance of such an approach only emerged through the application of my methodology, and the findings which emerged in phase 2. It is for this reason that phase 3 constitutes the most substantial presentation of results in this document. This also presented an opportunity to examine further applications of interactive digital technology, such as the touchscreen tablet.

In all cases, I delivered and lead these sessions, as was necessitated by the developmental model. To have teachers use these prototype interfaces was never an aim of this project, due to the focus on development, refinement and application of bespoke technology, and application of comparative technology. I am keen, however, to address the consideration of class teachers using these technologies in future research.

[22] As of July 2018, ongoing development of the interface, for educational and research purposes, has been transferred to the game development platform *Unity*. Project files for iOS and Android platforms will be made available from www.adammatthewhart.wordpress.com for the purposes of free non-commercial use and development.

8.3.5 Originality

This project has yielded an original composing environment, as well as a series of variations and additional resources. The mode of interaction employed from the early stages of *Graphick Score*, sound-painting (see 5.2.4) is both original and highly suited to pedagogical creative expression. Some analogues to this mode of interaction exist (see 3.2.4) although this is the first instance where this kind visual-kinaesthetic mode of drawing and manipulating gestures to produce graphic scores has been observed (see 7.2.3). In some respects, the non-linear approach, similar to canvas painting or sketching, demands other modes of playback beyond the standard left-to-right format. For this reason, variations such as *MetroNotes* and *SoundWorlds* will be revisited in future research. As these presented their own issues (see 6.6) I must consider how these designs could now be implemented within the developed framework of *Graphick Score*. It may be that multiple modes of playback are required.

The concept of tune-blocks is drawn from Bamberger (1996; 2000; see 3.2.4). I built upon this idea by moving away from the idea of melodic composition and toward impressionistic sound objects, which can be manipulated to tell a story. In a sense, this approach is partly rooted in the experimental electroacoustic music tradition of soundscapes and tape music. Applying these forms to the classroom, and recognising the pedagogical value, has a precedent in the work of Paynter and Savage (see 2.2). My application opens up new questions about how these musical forms might be suited to the classroom, and argues that the curriculum could further accommodate these forms (see 8.2.5).

Finally, I have offered a constructivist perspective on musical learning with digital technology, but also the practice of developing such technologies as a research project. As an educational community, we are still looking for approaches which are informed by these ideas to augment our practice, not because of slavish adherence to an ideology, but because the lens of constructivism can bring to light learning processes that may otherwise go unobserved. One of the outcomes of this research is that I have gained an improved understanding of what this ontology tells us about learning, and how this can support practice. This has included an application and examination of Brown's methodology (see 4.1), examining the role of the researcher/teacher/developer. I hope that this model can offer some insight to work in future projects of this atypical yet valuable form of research.

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