The Computer and the Controller: Dismantling Performance and Pedagogic Barriers to Music Composition

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Abstract

Over the last decade, many new 'clever' technologies with expertise built in as part of their design have been developed with the novice market in mind, to enable the production of professional sounding music at home. Alongside these technologies, social media platforms and social channels support informal learning and instruction; the result is that the scope for producing and creating music within informal contexts has seen a significant step change. Within the school music classroom, the model of a single keyboard connected to a computer remains the primary default position from which music technology-based composing is facilitated. This model has largely remained unchanged for a significant time period, and there is much existing research that points to the dissonance between the formal (school) and informal (out of school) contexts.

The aim of this research is grounded in a desire to seek to dismantle performance barriers to music composition, through disrupting the composer – keyboard – computer model. Set in the context of three UK secondary schools, this thesis frames five cycles of action research. The first three action cycles explore the potential of computer game controllers as an alternative to the keyboard at the centre of the model. The game controllers represent an example of a digitally native technology and are thus positioned as a user-relevant and 'meaningful' technology. As part of the research process undertaken within the first three action cycles, bespoke software was developed to enable the game controllers to work as a performance interface with classroom computers and to enable the mapping of controller functionality to music related parameters. The developed software is revised for each action cycle, in order to respond to the findings from pupil use within music lessons.

The findings from the first three action cycles feed into the design and development of new hardware and software technologies within action cycles four and five. These new technologies are built from scratch as part of this research, harnessing electronics, software development and 3D printing to inform the realisation of a flexible controller to support individual approaches to composing. This redefines the previous position of a 'meaningful device' through moving away from a device considered externally relevant and towards supporting the construction of intrinsic relevance. Using the developed technology presented as part of this research, pupils are able construct their own meaningful device from building blocks. This supports the construction of a device that is unique to them, and enables influence to be drawn from current perceived musical expertise. Crucially this enables dynamic two-way conversations to take place between pupils, and between pupils and teachers, to discuss the rationale behind, and the approach taken to construct their device.

The trajectory of this research over the course of the action cycles gradually moves away from the scenario where pupils must be able to translate their musical ideas through performing them via an instrument or defined interface, and towards supporting opportunities for greater experimentation of musical ideas through flexible, individualised and evidenced-based processes. This in turn enables the development and experimentation of musical ideas to be disconnected from the need for them to be performed via a keyboard as part of the compositional process. The implication of this, is that it enables a more accessible starting point to music composition in and beyond education sectors, including the academia.

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1. Introduction

As a child, I loved performing on the piano and the trombone. The piano gave me an avenue to explore music individually, and the trombone the opportunity to make music in ensembles. However, it was through music technology that I made sense of composing – allowing the sequencing of musical ideas into multi-layered compositions. My undergraduate degree enabled deep immersion with music technology and composing, and my career to date has been influenced by my interest in programming, electronics and music, and seeking to blend these areas together.

As a music teacher teaching in secondary schools, I observed very similar set-ups to facilitate music composition that existed when I was a secondary school aged pupil; in the decades that had passed, very little had changed. The primary position of the keyboard remained as the main performance interface, and whilst the computers themselves had changed (they were no longer Ataris), the software running on the computers remained similar in scope, and it was still the case that a single keyboard connected to a computer, formed the default position to enable 'music technology' - based composing.

For pupils that struggled to play the keyboard, I witnessed the significant challenge they faced to create and develop musical ideas in their music lessons that they were pleased with, or that matched their expectations of what they felt music should 'sound-like' based on their cultural musical interests. For non-keyboard players, but players of other instruments, I observed a regular sense of frustration at the need to 'convert' musical ideas through a keyboard interface in order to engage with the music technologies found in their music classroom. As a music educator, I have always been aware that through practical engagement with music, many core musical skills are able to be developed. However, there are also significant 'other' transferable skills that music education can provide: confidence gained through performing, collaboration, teamwork and leadership skills gained through leading and being part of ensembles as well as listening skills and perseverance. As such, I believe it to be very important to address the challenges that pupils face in their music lessons, particularly where such challenges impact on their motivation to engage.

Research informed practice is a key hallmark of effective education, but relevance for pupils, and the need to be culturally ethical is also another significant characteristic. Earlier in my career, as a newly qualified teacher, I found myself working in a secondary school with very limited resources for music. Faced with a cohort of pupils that showed a lack of enthusiasm for their music lessons, I found enabling the integration of their mobile phones, to host their compositions and performances as ringtones, had a very positive influence on their perceived relevance of music lessons. This in turn also enhanced their motivation to involve themselves with musical tasks through their desire to have their performances on their phones as their ringtone. This particular technology also enabled the music they created in the classroom to also exist outside of the music classroom.

The core aim of this research, connects directly to my experiences of working in schools, and pertains to a desire to seek to dismantle performance barriers to music composition. Through this investigation, the model of the 'composer – keyboard – computer' comes under scrutiny. The core driver of this research is framed around the contributing factors that impact on the motivation to engage with keyboard-based activities, and the initial research questions seek to position the frame of focus towards that of finding a solution to support pupils with limited motivation for keyboard activities.

Within this research, the review of literature in chapter two confirms that the music classroom is still 'predominantly technologically conservative' (Savage 2007a), and that this is in part due to teacher perceptions, including their perception of their own skills, their cultural backgrounds, along with physical challenges relating to an adequate provision of resources. Against this backdrop, the case for keyboards in schools is considered, and is also viewed through the lens of the expert and non-expert user. Outside of school music, a range of developments are shaping both novice and professional approaches to creating music: 'Clever' technologies, and loop-based composition tools are amongst various products that seek to create more accessible entry points through in-built intelligence. Alongside this, a broad range of social media technologies and platforms support the creation of flexible learning opportunities within informal contexts, and a learning model that very much supports a 'how to do X' approach. Easy access to video content enables musical learning and instruction to be supported through observing others (Waldron et at 2020) and forums, and channels, provide 'training' on solutions to specific 'wants', processes or tasks. A simple search of a key term or question starts the learning process within these contexts. The challenge for music in schools is the fact that the technology landscape within the music classroom has remained largely static and rooted in scope with what has existed for many years previously. Equally, the broader process of music education to support the wide pursuit of connected knowledge, skills, and development is different to the training approach relating to solving a particular 'specific'. As such, there is resultant dissonance between the formal (school) and informal (out of school) environment. In order to inform the development of both the hardware and software that is created as part of this research project, connected areas of relevance relating to the reconceptualising of the computer are reviewed, drawing out in particular key elements relating to mobile technologies, and the reconceptualisation of technology-informed instruments.

After presenting the founding research questions in this thesis, chapter three presents and critically evaluates the theoretical foundations and assumptions of this research. The methodology employed is framed around action research, with the investigation presented in this thesis taking place over five evolving action cycles. Aligned to Elliot's (1991) model, reconnaissance and observation inform the focus of investigation and this sets the priorities of the next cycle of action research taken.

Whilst pupils who were already able to demonstrate developed keyboard skills were not excluded from taking part in the first cycles of this research, the primary objective was to develop an appropriate solution in order to appropriately target pupils who do not play an instrument, as well as pupils who play a different musical instrument to the keyboard, in order to support their music compositional work. The research in these early stages attempted to connect to cultural relevance, through the replacement of the keyboard at the centre of the 'composer – keyboard – computer' model with USB computer game controllers, as a culturally relevant and 'digitally native' (Prensky 2001) technology that is regularly engaged with outside of school.

It is important to acknowledge in this introductory chapter that alternative MIDI capable controllers to that of the keyboard do already exist, and have done for a significant period of time. Controllers along the lines of the Akai EWI 5000 facilitate the converting of blowing, air pressure and bite, to MIDI data through complex sensors. Indeed, the Roland Aerophone is similar, with fingering aligned to that of the saxophone. A variety of MIDI guitars exist, where the conversion of string vibrations to MIDI data is amongst just one of the processes used to capture performance information. There has also been a proliferation of grid controllers and Digital Audio Workstation (DAW) controllers entering the market. For schools however, the high cost of these technologies often presents a significant barrier to access. The use of game controllers therefore permits a similar approach to that of the mobile phones used in the project from my first year of teaching to be taken: If pupils are able to bring in and use their own interface (a game controller), the challenges of resourcing can be mitigated. The integration of a 'bring your own device' (BYOD) approach offers the potential for full-class access and full-class engagement.

As part of the research process within action cycle one (the initial pilot project) through to action cycle three, I develop software to enable the game controllers to communicate with the host computers, and through this developed software layer also sought to respond to the findings discovered along the way through pupil usage. The software layer within each action cycle builds on providing further functionality, along with seeking to enable better access or engagement with existing functionality from earlier cycles. The theories of Csikszentmihalyi (1992): 'flow' and the creation of an ideal learning state, Bandura et al (1960): learning as a consequence of social interaction and imitation, Vygotsky (1978): Zone of proximal development through guidance and collaboration with capable peers, and Bruner (1984): scaffolding, underpin the observations made on the impact on motivation and engagement, as well as informing the ongoing search for appropriate solutions to enable the dismantling of performance barriers.

At the end of action cycle three, there are a series of problems pertaining to the continued use of game controllers, however the case of a pupil 'Andrew' is presented. Andrew is a talented musician and keyboard player, and as such demonstrates competencies that place him outside the initial objective and expected scope of the first cycles of this research. A compelling sequence of self-directed learning and experimentation sets an important train in motion, and provides a clear indication that the work completed within the first action cycles, particularly so in the developed software layers, is also highly relevant to pupils well on the way in their own musical journeys. From this point forward, the research focus is sharpened: The overarching aim of dismantling performance barriers to music composition remains, as does scrutiny of the 'composer – keyboard – computer' model, but the continued investigation seeks to explore these areas through the lens of striving to enable 'sustainable progression' (Machover 1992). Just as novice musicians have development needs, experienced musicians have 'specialist' needs that also must be met in order to secure their development. Such needs should not preclude them from engaging in work to harness technologies to support music education. Through the lens of sustainable progression, action cycle four and five build on this further, along with integrating the findings from the previous cycles into the development of new hardware.

Action cycle four draws influence from the guitar-inspired game controllers that formed part of the substantial, but short-lived, commercial successes of music games wrapped within a 'Rockstar' context. The developed modular interface seeks to enhance the guitar-based game controller interface through providing opportunities for user customisation at the interface level. The flexible construction approach enables the interchangeability of the guitar body and guitar neck, and seeks to enable the users to take a practical approach to the construction of an interface in order to dismantle performance barriers.

The hardware and software technologies developed through the process of action cycle five have not yet been able to be tested in schools, due to the global Covid-19 pandemic that caused significant disruption to face-to-face teaching. This cycle however draws together all of the findings captured over the preceding action cycles, and positions through a discussion, a rationale for the way ahead. The hardware and software development work builds further on the positive findings from action cycle four relating to flexibility and interchangeability, and in the process, severs ties to game controller influence. Development is focussed around the creation of a fully flexible and expandable hardware interface, and this forms part of the 'contribution' of this research.

The journey of this research, through all the cycles of investigation, informs the final scope of the hardware rationale: the rationale to seek to position pupils as key stakeholders through the construction of their own 'meaningful' musical interface that can be designed around their position of perceived, performance expertise. This constructionist approach provides the opportunity to better visualise decisions taken by pupils through the process employed to build and assign parameters to their interfaces, enables the potential, as educators, to engage in dialogue with pupils relating to the approaches they have taken, and supports the scaffolding of next steps through the potential afforded to make modifications.

All names in this thesis have been changed in order to protect anonymity. Substitute names are used throughout.

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2. A Case for the Research

According to the 2018 Measuring Music report, in the year 2017, the total GVA contribution generated by the UK music industry, stood at £4.5 billion. £2.6 billion was the total export revenue generated, and total full-time equivalent UK employment sustained by music increased by 3% on 2016 to 145,815. This figure draws from sectors representing musicians, composers, songwriters, lyricists, those working in recorded music, live music, music publishing, music representatives, music producers, and recording studios (UK Music 2018).

The current broad state of UK Music Education represents a very different picture, and there are a number of factors external to the music classroom now applying pressure on the very presence of music education as a taught subject within formal (school) contexts. The Musician's Union highlights that the academisation of many schools, together with the establishment of Free Schools, has changed the ways in which schools are accountable, and has also enabled the freedom to design and implement individual curriculum arrangements (Savage & Barnard 2019:9). The Incorporated Society of Musicians further highlights that music is no longer taught across key stage 3 in more than 50% of state-funded secondary schools, and that time allocated to music in the key stage 3 curriculum has reduced, in order to ensure that more time can be devoted to subjects within the English Baccalaureate (EBacc) (Daubney et al 2019). The uptake of non-compulsory conventional music education, perhaps as a direct impact to the provision changes at key stage 3 appears to be very challenged. Whilst there are a range of study routes, such as National Vocational Qualifications (NVQs), and the Business and Technology Education Council awards (BTECs), which aim to focus more on practical training, Carroll & Gill (2018) point to music GCSE uptake rates of only 7%. The percentage of those studying at the higher level of A-Level, (either Music or Music Technology) drops significantly further. With music (and indeed every arts-based subject) noticeably absent from the EBacc, Daubney (2015 cited in Ford 2017) suggests uptake rates will likely fall further, and that by 2020, music as a taught subject 'could be facing extinction'.

It is not however just external factors that have challenged the place of music education within schools. Cultural dissonance, authenticity of school music, curriculum relevance and pupil's own self-perceptions have received much debate and research over a substantial time period, much of which pre-dates the more recent external factors impacting on the provision of music education. There appears to be a disconnect too between informal music learning outside of school and formal learning inside school. The 2019 audience survey commissioned by UK Music for the Greater Manchester Music Review (Manchester being an area of the UK in which the report highlights as having a large catalogue of 'creative legends from almost every genre,' and a deep musical heritage) identifies less than 29% of the population surveyed as citing school music as the reason they '*got into*' music (UK Music 2019:18).

2.1. 'Clever' Technologies

Outside of schools and formal educational contexts, the development of music technology is very fast paced. Successful businesses are very aware of the need to continually innovate, evolve provision of their products, and evolve the consumer markets that they strive to target. As the numbers of high-end studios have diminished, so too has the need for very high end and often large format studio products with their associated high purchase costs. The Focusrite brand is one such example of this evolution; originally established in 1985 to serve high-end professional recording studios, its products were focused on high quality recording and production equipment for professionals. More recently its focus has switched to broadening its range of products to serve a wider customer base, to include professional, commercial and hobbyist (including young) musicians. One of the company's current key straplines is '*We make music easy to make*'. (Focusrite n.d)

This specific targeting of the novice market, and the creation of products that are designed to be easy to learn how to use, yet importantly enable users to craft a 'professional sound', has further proliferated the non-formal educational routes to enable music production. 'Bedroom production' is arguably the new apprenticeship model, and companies that make these products know this. Whereas previously, profits were made from the sale of a few large format 'professional-end' products, now the cheaper product, with 'expertise built in' that can be billed to help a music producer or composer (or aspiring music producer or composer) achieve a desired sound, is where sustainable music product design and development is situated. Substantial demand for these well-designed 'clever' technologies exists - there are of course substantially many more bedrooms than professional studios. A 'clever' technological tool is therefore a product that can automate certain production strategies or tasks; expertise is built into the product in order to enable functions that are designed to quickly enhance music or sound, as well as be simple to apply, and this helps with creating the perception that the tools and products themselves are important to creative flow and music realisation. One example is the 'drag & drop' loop-based functions in programs such as GarageBand, which makes music technology and music creation highly accessible, and is often used as a first entry point into music technology. The main advantage of loop-based applications is that they allow a user to assemble a composition from a defined set of building blocks, enabling music to be built up very quickly. The result often sounds slick and has a polished sense of flow, the user feels proud of their 'arrangement' and generally feels that they have achieved something 'musical'; naturally this can be highly intrinsically motivational. Tavana (2015) defines GarageBand's two revolutionary design points as 'amusing simplicity and egalitarianism'. The fact that this software is included free with Apple products means that there is strong potential for a very large audience reach, although the initial cost of purchasing the hardware (ie the computer, phone or tablet to run the software) is high.

Learning from others both formally and informally is a well-established practice within the area of music, but the rapid development of technologies and social media avenues has also enabled the rapid creation of learning opportunities from increasingly widening settings, along with a much broader range of ways to access these. Motivation and learning as a consequence of social interaction and imitation relates back to the social learning and cognitive theories put forward by Bandura et al in the 1960s. The concept being that people learn from one another, via observation, imitation and modelling. Social media technologies offer flexible learning opportunities and also a rich range of mediums in which to learn new knowledge and techniques - video sharing, wikis, online courses, blogs, and hosted chats to name but a few. Whilst not necessarily originally developed for learning purposes, Liu 2010 highlights that social media tools are 'wonderful communication tools' with social engagement, options for direct communication, speed of feedback and results amongst the main reasons driving social media adoption. As such, the learning landscape is much broader now – people have much easier access to music production software and hardware tools at hobbyist level prices, enabling these tools to exist in the bedroom or the project studio (Baxter 2019). If an element of 'automated experience' is also built into these tools in order to simplify the music production / creation process, effective results are achievable without years of training. This, coupled with videos shared on social media platforms, especially those platforms where video sharing is the core functionality, means that users have a place to go when they want to find a solution to a problem they face. These videos tend to support the 'how to do X' model of learning, but crucially allows for a highly individualised learning approach, especially relating to pace, enabling the watcher to go at a speed that is comfortable for them and rewinding sections that may need more time to be comprehended. McGoogan (2016) reports that in 2015, more people visited YouTube than Google, making it the second most visited website in the world (after Facebook – another social media platform). Commonplace now is the enhanced video learning model, where a paid subscription to a video training series includes the ability to submit individual questions for answering in a later video or resource. Where then does this leave the formalised school context for learning music production, music composition, or music creation, if devices and tools are designed to be 'clever' and an abundance of informal learning resources via social media platforms are available to provide the training?

2.2. School Music – Have the students given up?

By year 9, many students have given up hope of gaining the identity of a musician as defined by success in school music (QCA 2005). At the same time, they are experimenting with who they are musically by exercising their musical preferences out of school as they become attached to particular forms of musical expression. In view of the central role that pop music plays in young people's lives, this 'identity', so argue Hargreaves at al (2003) and Lamont et al (2003), is constituted by popular music. Hein (2017) argues that 'the large ensemble model from European conservatories is incompatible with the riot of polyglot individualism in the kids' earbuds', and that 'school music trains kids for music experiences that are unavailable outside of school'. Behles (cited in Mertens 2017) argues that the definition of 'musician' now has changed to encompass many roles, the music maker being 'the person who writes the song, the composer, but then often times, they're the instrumentalist, they play the music, and then they are their own engineer. They are also designing their own sounds, and so on and so forth'. Outside of school music the term 'producer' is used, but inside of school the terms 'performing' and 'composing' are still the common terminologies used for the practical aspects of music making, and are often referred to as separate entities and distinctions.

During my years of teaching in music in secondary schools, I observed the strength of musical identities in my daily encounters with my students. I noted the enthusiasm with which students 'lent me an ear piece' of their personal music player, and I have been intrigued by the extent of their knowledge as they told me about *their* music. In this process, I have learnt to discern subtle differences within a whole range of musical styles previously unknown to me, and this chimes well with Swanwick's position that as students place such an importance on their own musical identity, that music that falls outside of that identity is likely to be rejected, and with this comes the potential rejection of school music.

> The accessibility of music from the ends of the earth and high levels of music specific information technology compete with conventional school activities. One consequence is that students can have very little time for school music and may probably see it as a quaint musical subculture. (Swanwick 1999, p36-7).

Research carried out into students' perceptions of music at home verses music at school has previously viewed music teachers as being at the 'heart of the problem', for they are seen as being products of the western classical tradition and the conservatoires that maintain that tradition (Sloboda 2001, Hargreaves et al 2003). Dalladay's (2011) findings also appear to further support this notion, with 71% of student teachers surveyed from traditional backgrounds (western classical music and theory focus) agreeing with the statement that 'music lessons are designed to engage and interest most children but do not develop "real musicians". This compares to 38% of student teachers from applied backgrounds (music technology and industry focus), and 33% of student teachers from performance backgrounds (practical performance focus such as instrumental/vocal performing arts) agreeing with the same statement.

Using popular music in the classroom may appear to be one obvious solution - using music that the students 'identify' with, and what they are creating, consuming or working with using technology tools outside of the classroom. Yet if, as Elliott points out, 'music (including one's conception of what music is) divides people as much as it unites them' (Elliott 1989:12), then any style selected is likely to create a good degree of discord. A scheme of work focusing on popular music or aspects of popular music needs to be expertly planned in order to cater for students, to be of relevance, and overcome sectarian responses. A selected popular musical style or genre for whole class exploration, chosen by the teacher, therefore runs the risk of at best limited bridging (or worse, further widening) the cultural dissonance between teacher and students. Arguably one potential antidote lies in embedding the more informal learning approach to music education; such an approach draws heavily on how popular musicians learn (Green 2001), but also offering an extension to this by drawing from the social interaction possibilities now afforded via social media and other web-based technologies. This informal approach has seen substantial traction over the past 15 years with initiatives such as Musical Futures supporting and developing pedagogical approaches through bringing non-formal teaching and informal learning approaches into formal school music contexts. At its core is the experience of practical music making that is relevant and engaging, using real instruments such as drum kits and guitars that have 'credibility outside the classroom' (D'Amore 2008:78). The aim is to motivate students first by making use of aural learning that integrates listening with practical music making, improvising, and composing. Traditional instruction such as technique, notation and written elements can be part of the process but are rarely the starting point. This process of informal learning sees a change to the traditionally conceived role of the teacher, with a move away from leading, to instead standing back, supporting, facilitating, emphasising with learner goals, and acting as a musical model and resource to support the meeting of students' personal musical interests.

The work of Tobias (2015) seeks to offer further enhancement to this model by supporting the inclusion of curricular offerings that allow for 'crossfading' or overlap between students' in school and outside of school (extra-curricular) musical experiences; specifically, the use of popular music as a resource and inspiration but for the creation of new music, rather than reproducing the sound of particular bands or individuals. Whilst all participants within this specific project had experience with instruments and software outside of school (arguably not typical of the conventional school music classroom), common within the participant feedback was the appreciation of opportunities to engage and view themselves as musicians in ways relevant to their present and future lives, in essence the belief that the experience could have some positive impact on life goals.

On face value this appears to offer a number of substantial gains to the problems posed so far by Hargreaves, Dalladay and Elliot. Improvements to intrinsic motivation as identified by the students in Tobias' study are supported by the heightened sense of perceived relevance, and the encouraged change of role of the teacher within the musical futures framework, thus ensuring that a teacher's skills and experience can be channelled to offer more bespoke approaches to supporting students in realising their involvement in creating music that interests them.

Whilst Hargreaves et al argue that it is teachers that may affect the authenticity of school music, D'Amore's point on credibility outside of the classroom highlights another important branch of authenticity, in the form of the authenticity of resources available to music teachers and their students, which causes further questioning of the viability of music in school. Green makes a compelling statement:

> When school resources do not match the cultural expectations students have of the subject, the result is cultural dissonance. Metallophones and tambourines are no substitute for electric guitars and drum kits; try to make them so and the results are seen as a bit of a joke. (Green 1988, p142-3)

Over thirty years on from Green's statement, the concept of cultural expectation (and avoiding dissonance) from a resource perspective still very much relates, and whilst the use of credible musical instruments such as guitars and drum kits forms one of the key elements of heightening the sense of relevance within Musical Futures, it is interesting to note that the musical interests of young people have also changed over this period, and substantially so in the 15 years that Musical Futures has been embedded within school music curriculums. Popular music, and chart music in particular, has seen the substantial popularity gain of electronic music created via purely electronic means, using computers to create and process samples and synthesised sounds, with a decline in featured music created with physical instruments. Indeed, the Neilson music report (2017) identifies that R&B and Hip-Hop surpassed rock as the most popular genre in the US for the first time ever in 2017, that seven out of 10 of the most-consumed albums of 2017 (including streaming) came from the R&B / Hip-Hop genre, and that nine of the top 10 most streamed artists were R&B / Hip-Hop artists. This arguably causes a challenging disposition for approaches to learning and teaching like Musical Futures, which seek to place important value on authenticity and 'relevance' of musical styles to the students in school music classes. In the same way that metallophones and tambourines are no substitute for electric guitars and drum kits, to quote Green (1998), neither so are electric guitars and drum kits a true substitute for music created solely via electronic means. Relevance and authenticity are always likely to be impacted whilst teaching recourses 'catch up' with shifts in musical taste. Musical Futures is now valiantly seeking to keep pace by creating music technology focused schema to support engagement in authentic learning in the classroom which reflects students' musical interests. These are centred around its 'in the style of…' resources, but at the time of writing has only four offerings – 'in the style of Ed Sheeran', and 'in the style of Dua Lipa', 'in the style of Stomzy', and 'in the style of Ariana Grande'. Such a small snapshot arguably risks some return to Swanwick's previous concerns of musical sub-cultures. In addition, Allup's (2008) critique equating informal learning practices to specific styles of popular music warns of the 'un-intended consequence of narrowing musical possibilities rather than expanding them' and suggests that further consideration should be anticipating the 'second-wave' of framework development for popular music's intersection with music education and learning in schools.

When considering the move forward, the positives of the informal approach (gains in intrinsic motivation, relevance, authenticity and credibility) need to continue. It would however be a poor decision to simply seek to replace conventional instruments with technology-based equivalents in order to just meet and keep up with the changing musical tastes of young people. This chimes with Dale's (2017) views that technology should be placed alongside the existing range of established options in music education as another option which can aid general engagement. Dale argues that new technologies should be embraced as 'musical tools' which can make more learners feel that music is 'do-able', than traditional methods and modes of music education have been able to. The question to now consider therefore, is what technology is available within schools in order to make students feel that music is 'do-able'?

2.3. Technology in School Music

Pitts and Kwami (2002) identify the development of micro-technology and thus electronic keyboards, computers, and their abilities to communicate with each other via communication protocols such as MIDI, as a defining point in education, revolutionising many of the traditional activities involved in music education. Savage (2010) identifies the use of keyboards as the most dominant method of musical instruction within school music contexts, with 87% of teachers within his survey using keyboards to teach basic piano technique and about melody, harmony and timbre. In addition, he highlights that approximately two thirds of teachers use keyboards as MIDI controllers of some sort, with the software of Cubase (for music sequencing) and Sibelius (for music notation) being the most predominantly used. The use of such software to sequence musical ideas or support the creation of traditionally notated scores remains popular and amongst the common tools of choice for teachers (Wise et al, 2011; Eyles, 2018), with Savage (2007a) identifying that the music classroom is still 'predominantly technologically conservative'. Given the time period that has elapsed since the birth of MIDI in 1982, Gall (2017) argues that there remains very limited use of technologies for creative activities within Key Stage 3 music education, other than paired work at computer workstations using sequencing software, and highlights that this is a national issue confirmed by the latest triennial Government report which suggests that technology should be better used to 'promote creativity' as well as to widen participation and make assessment musical (Ofsted 2012).

Somekh (2008) offers some justification for the 'conservative adoption' of music technologies to support learning as reported on by Savage, identifying that much of the research on teachers' use of information communication technology (ICT) in their teaching describes low levels of usage and minimal pedagogical change because schools and classrooms cannot be understood in isolation; there is the influence of regulatory frameworks and policies of national educational systems, national cultures etc. However, Somekh further identifies importantly, that teachers' use of ICT for teaching and learning depends on the interlocking cultural, social and organisational contexts in which they live and work. In simple terms, teachers' beliefs and attitudes, confidence and competence with ICT is centrally important in their adoption of ICT into their pedagogy. To an extent, this draws parallels to the research considered earlier in this chapter by Sloboda and Hargreaves et al (teachers being at the heart of the problem) with the notion that teacher background acts as one of the barriers to embedding technology to support and promote creativity and widen participation in classrooms. Wise (2016); Mills and Murray (2000); Pitts and Kwami (2002) identify that teachers' pedagogical approaches are concerned with developing successful operation of software before creative work takes place, with Uptis and Brook (2017) describing new developed tools, without appropriate and extensive teacher support, as the 'Achilles' heel of technological innovation in education; and that without such teacher support, they are unlikely to be utilised to support student learning'. This further supports the concept put forward by Prensky (2001) that our students are 'digital natives' and that teachers are 'digital immigrants', and whilst striving to 'adapt' to the new environment, always retain to some degree, 'their foot in the past'.

Eyles (2018) offers a connecting perspective that teacher confidence is directly affected by professional development opportunities, but also cites adequate resourcing, specifically the continued lack thereof of ICT resources; availability, familiarity and reliability as a reason why teachers limit their pedagogy to whole class activities which rely on a limited number of ICT resources. Many of these concerns and findings can be traced back to the research of Rogers (1997), highlighting over 20 years on, that progress supporting resource access within educational contexts remains slow, and that many of the innovative newer music technologies are not making their way into the majority of music classrooms.

Music technology does though form a key element of music education, especially from key stages 3 upward – the heart of this technology being the computer. A variety of literature explores how best to integrate music technology and the computer into musical learning (Pitts and Kwami 2002; Dillon (2007), varying in use from music tutors, simulators, toolboxes, canvases, to pupil behaviour controllers. There is general agreement amongst teachers, teacher educators and pupils that 'computer systems provide tools for musical learning which are not matched by any other equipment' (Rogers 1997) providing there is adequate provision. Salaman (2008) indeed supports Rogers and the case of the computer by concluding that 'the range of musical possibilities is huge'.

The keyboard, notation software and software sequencers are the mainstay within the music classroom, and have been for a long period of time, but these tools, especially keyboards and notation software, which effectively provides a digital representation of the conventional manuscript score, whilst offering the benefit of being able to play back ideas, are deeply rooted in traditional methods and modes of music and music education – the layout of notes on the keyboard dates back to the eighteenth century and notation dates back even further. This strong connection to past western-traditional music arguably offers the sense of 'familiarity' as put forward by Eyles, that is sought by teachers. However, Dale's (2017) point about 'embracing new technologies' is clearly aiming for music education contexts to draw from a broader range of music technologies (ie not just keyboards, notation software and sequencing), especially given that Dale's research is well grounded in DJ decks, urban music and child-centred learning.

2.4. The case of Keyboards in Schools

There is much research on the wider benefits of playing the piano: Piano lessons and the link supporting children's developing language skills (Trafton 2018), supporting academic achievement, school performance and benefits to self-esteem (Costa-Giomi 2004), supporting the development of learning mathematics (Gardiner et at 1996; Holmes and Hallam 2017). Bach on the contrary, suggests that there is 'nothing remarkable' about the keyboard:

'All you have to do is hit the right key at the right time and the instrument plays itself.'

(JS Bach cited in McCoy 2009:511)

Bach's statement, whilst arguably a touch in jest, does offer some exemplification as to the logical reasoning behind the prominence of keyboard-orientated instruments in musical education, with the element of pitch arguably receiving prime focus. All notes are provided ready for the user to call on at the 'right time', no breath pressure need be applied to alter octaves, and same pitches cannot be achieved from alternative positions or through differing combinations of depressed keys. The logic extends further with lower pitches available to the left and higher pitches available to the right; furthermore, the octave is clearly patterned, with keys representing specific notes in higher or lower octaves found in the same place per octave respectively. This format also extends to numerous pitched percussion instruments, glockenspiels and xylophones etc (championed for their use within education by Carl Orff), which are also regularly found in music classrooms albeit often in various states of repair. Stroud (2018) highlights further advantages, citing no requirement to tune the instrument each time it is played, no discomfort when learning the instrument (often common when learning stringed instruments), before emphasising the longer-term benefits for supporting the understanding of music theory, along with the fact that keyboard skills make it easier and quicker to enter music into notation and Digital Audio Workstation (DAW) software(s). Roels and Petegem (2015) argue that the layout and design of the keyboard enables a user to 'experiment visually and spatially', and so create highly diverse results from simple conceptions, to genuinely original and sophisticated ideas, using exploratory and problem-solving strategies by introducing chromaticism, parallels and symmetries and by progressing across the keys using sequences. 'The structure of the keyboard to transpose melodic patterns, work out game rules, derive musical phrases and apply geometrical–mathematical principles, results in new concepts and unexpected musical structures' (Roels and Petegem 2015:392).

The notable positives of the electronic keyboard extend the keyboard interface further, making use of touch sensitive keys to aid in the enabling of an 'expressive performance', although sadly in cheaper models (sometimes found in schools) this feature is often omitted. The electronic keyboard's great strength however and probable reason as to why it does indeed remain the fundamental resource for classroom music making, lies in its ability to be a 'sound chameleon,' allowing users to employ for example the sound of a trumpet one moment and the sound of a wood block the next, with very little, if any, technique adjustment – something which would be impossible if one played a real trumpet in the same way that one would play a real wood block! Perhaps it is the popularity of the piano, and the concept of traditional instrument design as perfection explored by Bijsterveld and Schulp (2004), that defines the success of the keyboard interface. Bijsterveld and Schulp indeed argue that one of the notable successes of the Moog Synthesiser was Moog's volt-per-octave keyboard control, resulting in the embedding of the synthesiser within conventional musical culture. Arguably the keyboard connected to a computer is an extension of this model, and perhaps coined originally to align consumer music technology with conventional musical culture.

The use of keyboards as the most dominant method of musical instruction within school music contexts, does however present some challenges. Kirkman (2007) finds that an over-reliance upon keyboard-type interfaces means that the potential offered by different hardware is not widely realised. If the MIDI capabilities of a computer-based system are accessed only through a music keyboard, computer keypad or mouse, then this puts non-keyboard instrumentalists or non-instrumentalists at a disadvantage. A number of publications in support of computer-based technologies in the secondary classroom also show a lack of diversity in the hardware and user interfaces employed in secondary classrooms however (Pitts 2000; Ashworth 2007; Ruthmann 2008). In 2021, the Midi keyboard still remains the primary performance interface between composer and computer. From working as a school teacher within key stages 3 to 5, my own pupil observations and published research (Baxter 2007) reveal similar findings to Kirkman, specifically that the keyboard can be barrier to the development of musical ideas with technology. Whilst the keyboard is fit for purpose and well designed for those skilled in using it, it does require years of dedicated study, it is not intuitive, and structured lessons are often neither a practical option nor available to most children. The model of composer – keyboard interface – computer therefore does not promote the most effective transfer of compositional ideas into composition reality by composers with limited or no grounding in keyboard performance.

> In the secondary schools visited, over-emphasising instrumental competence acted as a ceiling on achievement for many students who, in fact, could achieve the highest levels through demonstrating their understanding in other ways…some tasks make it impossible for pupils whose instrumental skills are less well developed to achieve as well as they could. (Ofsted 2009:56).

Salaman (1997) points to an 'eerie silence regarding electronic keyboards [within schools]… where no [individual] has come forward to support their presence'. Attempts have been made by manufacturers with the implementation of single finger chords, and liquid crystal displays mapping depressed keys, but no effort is made by manufacturers to develop the physical layout of the keys in order to promote learning – this is reserved for teaching professionals to scaffold learning through the setting of increasingly harder tasks or by personal perseverance from the user's point of view. The layout and design of the keyboard remains the same, regardless of whether the user is a novice or professional.

> 'My composing improves as I get better at playing my own instrument'
>
> (Pupil comment cited in Patterson 2000)

Pupil observations from my own teaching practice reveal that this aforementioned pupil is by no means alone. A grounding in keyboard skills does appear to aid the outward flow of compositional engagement, especially if school music lessons are backed up by external practice and/or peripatetic lessons. What then are the opportunities for instrumentalists with specialisms in other musical instruments? A common example is the guitarist who is often seen working out phrases and ideas on a guitar only to then have to convert the application of these phases and ideas via a keyboard interface to engage with common ICT found in music classrooms. The MIDI guitar is a possible solution to this problem, but the monetary costs of these products still remains high, making them largely out of reach financially to most music departments.

Numerous studies (Bunting 1987; Kratus 1994; Younker and Smith 1996) focus on approaches to musical composition within the classroom. Pitts and Kwami (2002) notably observe that composing supported by ICT requires 'mastery' of three elements: musical knowledge, instrumental skills and technology handling.' (Pitts and Kwami 2002). Their study is highly relevant as it reveals that under the common model of composer – keyboard interface – computer, that performance ability and the development of compositional maturity are linked. The keyboard interface therefore places non-expert players and other instrumentalists at a distinct disadvantage. Dillon's (2007) research reveals that many students consider playing the keyboard difficult, and poses the solution that teachers should encourage and support students with their playing skills. Such an approach creates debate however, on one side there are benefits to improving keyboard skills, and the argument that it may support individual musical growth, but on the other side, the approach fails to offer a practical solution for those who play other instruments. Furthermore, Wristen (cited in Demus 2005) reports from an ergonomics perspective that traditional-size keyboards are often too big for many (mature) pianists, causing pain and injury, this further intensifies the debate over whether the keyboard deserves to remain the staple interface for engaging musically with a computer, counteracting the widely regarded view on the importance of keyboards in school music containing full size keys (Odam 2000; Muro 2006).

2.5. Motivation to Compose

Csikszentmihalyi (1992) suggests that the ideal learning state is one that combines high levels of challenge with low levels of stress, something that he refers to as 'flow'; this is allied to the concept of losing track of time due to being fully immersed in a task. Gee further supports this by drawing from cognitive science theories and the 'regime of competence principle' - suggesting that in videogames, it is this underlying architecture that enables them to become teaching machines. 'Each level dances around the outer limits of the player's abilities, seeking at every point to be hard enough to be just doable' (Gee 2003) resulting in a feeling of simultaneous pleasure and frustration. A keyboard interface may well provide high levels of challenge, but if the user believes the challenge is too great, then higher levels of stress occur, in turn making the learning state less than ideal, this all stems from an incompatible match of performance interface to user.

Levitin offers a useful insight into musical instrument design by further cementing the writing of Gee and Csikszentmihalyi, suggesting that musical instruments 'must strike the right balance between challenge, frustration and boredom: devices that are too simple tend not to provide rich experiences, and devices that are too complex alienate the user before their richness can be extracted from them' (Levitin et al 2002:173). The theories of Oore also support this notion, suggesting that if instruments were designed to be 'easy to master' they would quite possibly not be that interesting to play or to listen to once the initial novelty of the instrument or controller had worn off. (Oore 2005). On face value, the keyboard interface arguably supports Levitin's requirements of a balance between challenge, frustration and boredom - indeed it is also not too easy to master, satisfying Oore's requirements. However, it must be noted that for a number of schools, keyboard activities appear to feature in almost every lesson, providing an over-diet of keyboard centred activity (Kirkman 2007). Of the schools that I have worked in and visited, there are rarely enough headphones, or indeed enough keyboards to go around – resulting in two (sometimes three) pupils huddled around a keyboard attempting to play it simultaneously. It is this lack of variety and conditions not conducive to creative work that have, I believe, a significant adverse effect on pupil creativity and indeed motivation to be creative. One pupil summarises 'It's good to have a change from playing keyboards, we always use keyboards and they're boring (pupil comment cited in Baxter 2004).

The theories of Vygotsky and the 'Zone of Proximal Development (ZPD)' also need careful consideration when reflecting on pupils' motivation to compose music. Vygotsky defines the ZPD as…

> …the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers. (Vygotsky 1978:86)

Bruner (1984) builds on Vygotsky's theories by introducing the notion of 'scaffolding', a metaphor for an individual supporting another to master a task or concept that they initially were unable to grasp independently; whilst the findings of Burland and Davidson (2001), reveal that grouping can positively influence the work atmosphere, and allow the sharing and development of ideas, the effectiveness of this depends on how the groups are defined, such as friendship groups. Groupwork and ensemble collaboration is very common within school music, with much acoustic exploration in music education focusing on ensemble performance and composition. However, music technology within schools still places a heavy focus on the individual, with any peer collaboration usually due to limited resources, hence the need to share, rather than encourage group interaction.

2.6. Scaffolding Composition or a New Direction?

Incorporating loop-based composition into the curriculum offers the potential to harness clever technologies found outside of school (as detailed earlier in this chapter), and to use them in a way to support the scaffolding of learning to compose. As a teacher, I originally had mixed feelings when it came to loop-based composition. I enjoyed the fact that pupils did not necessarily need any prior knowledge of traditional music fundamentals, and found it excellent that (especially in the case of GarageBand) there are options to make the context 'real' – pupils can create podcasts, export their work as a ringtone to their mobile phone, or export to popular music distribution platforms, which all helps to ensure that created music inside the classroom can then exist outside of it. The problem that I had was that I liked to see pupils composing their *own* building blocks for compositional use, instead of relying on externally pre-composed musical building blocks (or loops) and arranging these into a composition. It can be very difficult weaning pupils off the 'slick and polished' results of loop-based music-making and on to other approaches of technology-based composition such as MIDI sequencing, where pupils need to first consider, develop (and indeed come up with) musical ideas, before inputting them (perhaps via a keyboard) into the sequencer for structuring into a composition (ie the conventional classroom music technology composition approach). This does however highlight a very live example (within my own practice) of myself as the teacher 'being part of the problem' (Hargreaves) with my own background and (at the time) pre-conceived thoughts of what '*should'* constitute music composition affecting my judgement. Loop-based composition is not simply just a transitional step to traditional means of composing using a computer with a connected keyboard. Indeed, drag and drop approaches are no longer limited to 'arranging' pre-supplied musical ideas, instead technology has evolved significantly in order to bring out the number of ways to manipulate these to a high degree. Flex based functionalities such as flex time / stretching and flex pitch enable loops to be converted seamlessly between the audio domain and the MIDI domain and back again, offering the full range of potential creative manipulations that these domains offer. Technological advances in this area have ensured full control and manipulation of pitch for transposition of individual notes and whole phrases, rhythm, timbre (including replacing the timbre with another), and all of the musical elements regularly considered within the traditional music classroom. Hein (2017b) acknowledges that loop manipulation can entail 'significant microlevel musical thinking', raising the question 'where does loop manipulation end and composition begin?' (ibid 2017:389).

Schiller argues that there is 'a cause and effect between any type of creativity and its creation platform' and that 'machine learning, as in systems and software that will enable more ability to help anticipate what someone wants to do, will be of value' moving forward. (Schiller cited in Wang 2019). Products such as GarageBand are designed to help the user create something 'good', and in order to do this, there is a large amount of the design process that is based on attempting to understand and anticipate what the user wants to do, and presenting the tools to do it conveniently and efficiently. Abbasi et al (2017) argue that the commonplace of technologies in the creative industries are used as a means to directly enhance creativity, with

Loveless (2006) arguing their contribution to developing culture. This approach to composition and providing automation to efficiently support the realisation of a determined creative end goal is now highly developed. The potential afforded here results in beneficial outcomes for all users, offering convenience to professional or commercial users, and a 'quality' sounding result for the hobbyist or novice – there are indeed a number of trade articles that identify the use of GarageBand processes within the realisation of a range of commercially released music. To an extent, this causes a direct challenge to Pitts and Kwami's previously outlined notion that composing supported by ICT requires the 'mastery' of the three elements of musical knowledge, instrumental skills and technology handling. Here the need for instrumental skill is arguably removed, and the need for musical knowledge (in the conventional sense) arguably reduced. This creation of a more accessible entry point, resulting in the 'democratisation of sound' (Tavana 2015), potentially results in the 'homogenization of culture', agues Koval (2008), when technology has such a profound impact on the texture of sound culture in this way.

2.7. Reconceptualising the computer – the growth of 'mobile' computers

Somekh (2007) provides a consideration that chimes well with the previously considered notions of relevance and credibility by arguing that any mismatch between ICT use at home and at school is as a cause for concern, mainly because it indicates the extent of the loss potential for ICT to transform schooling. This offers scope to attempt to bridge between the two worlds of music outside of school (clever interfaces, learning through social media, technologies found within the home), and music inside of school (reliance on the keyboard and computer workstations as the focal point for music technology). Kemp (2019) identifies that within the United Kingdom, there were 49.68 million unique mobile users, and that 92% of the adult population used a mobile phone (any type), 77% used a smart phone, 74% used a laptop or a desktop computer, and 53% a tablet computer in the year 2018.

With the proliferation of mobile devices now extending much further than simply mobile phones, and the growth and popularity of tablet devices and portable computers, scope for implementation of these technologies within school environments exists. Utilisation of such devices arguably offers many opportunities to move the enhancement of learning opportunities forward in a positive way, connecting the technological divide between inside and outside of school by addressing the mismatch of ICT resources (Somekh 2007), as well as harnessing a key technology of the 'digital native' (Prensky 2001) and using a recognisable device, therefore supporting teacher comfort and confidence (Eyles 2018). There is now a large number of applications (apps) specifically designed for tablet platforms that target the enhancement of learning as well as educational contexts; it is quite clear to see the beginning of what could be the end of the exercise book and textbook - the realisation that potentially one day, all pupils' learning tasks will be centered around their own personal tablet / mobile computer device. However, whilst much has happened in the development of technology since Rogers' findings in 1997 highlighted earlier in this chapter, the need for 'adequate provision' still rings very true. Whilst some schools have begun to purchase a small number of tablet / mobile computing devices, their high costs still mean that it is often difficult to ensure the 'adequate provision' of these types of devices. Other schools have moved to a much larger embracement model, through 'Bring your Own Device' (BYOD) schemes. The positives here include enabling the outsourcing of the upfront costs of suppling the technology (as pupils bring and use their own device from home), though this often requires careful consideration of area affluence and naturally raises equality concerns (Stager 2011). A range of different types of devices, and differing operating systems within a classroom setting also arguably leads to greater concerns with technical support and compatibility, and if not properly mitigated may impact on the learning process, with Chen (2019) finding equipment set up and technical support as two very common concerns for teachers, with regards to mobile learning technologies.

The use of tablet computers in schools in recent years has now led to growing research focusing more on the development of 'tablet pedagogies' with Geer et al 2017 finding that there are 'promising signs' that tablet use is bringing about a pedagogical shift to support 'enhanced' learning. Geer's study uses the SAMR model (Puentedura 2009), which identifies the 'enhancement' stage as representing substitution (S) and augmentation (A); specifically, the technology acts as a direct substitute to whatever existed previously, with augmentation then leading to some functional change and improvement. The SAMR model however also highlights scope for 'transformational' learning, specifically the encouragement of modification (M) and redefinition (R). Within this area, technology allows for significant task redesign, and then the potential for the creation of new tasks, previously inconceivable. Arguably this is the area that new technologies supporting learning should focus in on.

Roblin et al (2018) positions congruence with previous practice within an inter-connected dimension, where areas such as cost-benefit relationship (not necessarily monetary, but in terms of time, perceived added value, potential disruption within the classroom setting), and instrumentality (availability of technical support, infrastructure, connection to school policy) impact on the practical considerations for teachers integrating tablets within their lessons. This also links back to the concept of teacher confidence and background, discussed earlier in this chapter. This particular research project identifies two common strategies to teacher use of tablets; one strategy consisting of purposefully searching apps that would fit with already defined course content, (effectively aligning to the enhancement element of Puentedura's SAMR model), and the other strategy reflecting upon the affordances of various apps and then exploring possible connections with the course content (arguably acting as more of a nod to the transformational element of the SAMR model).

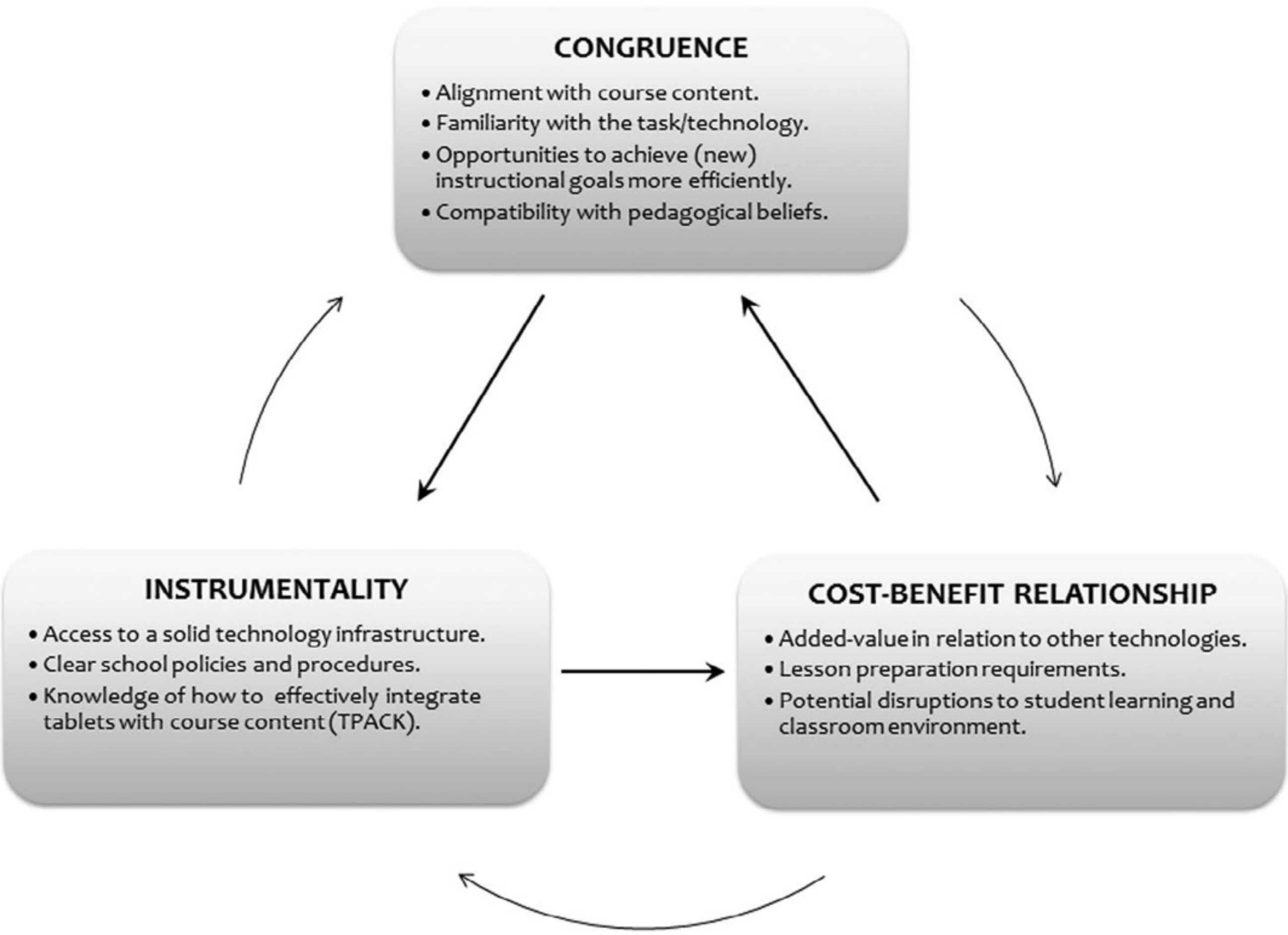

Figure. 2.1. The congruence dimension (cited in Roblin et al 2018)

Within the scope of music education, Riley (2013) identifies seven categories of use for tablets (specifically iPads) in supporting teachers: rehearsal / performance assistance (eg tuners, metronomes, notation displays), supporting music creation, in instrument teaching (eg using chord apps, and note games), making virtual instruments available, facilitating audio recording, enabling access to listening resources, and offering organisational support. Arguably such usage draws heavy allegiance to the enhancement stage of Puentedura's SAMR model – all of these elements have previously been achievable prior to the invention of tablet computers. Williams (2014) takes a much more transformative approach, arguing the case for the iPad as a 'real instrument' by first identifying what makes a musical instrument before highlighting the possibilities and similarities between the tablet and conventional musical instruments; identifying the role of the human as the common feature that provides the point where 'musicianship, creativity and imagination originate'. Williams acknowledges that 'every app used does something very well, but will be limited in some way' and this is appears a useful message. There are many music apps available, but no single solution to everything, the flexibility such a broad range of apps offer, provides a range of scaffolding opportunities because it is unlikely that any one app would be the only one used to progress from the level of a beginner to advanced practitioner. This differs from a traditional musical instrument where the design remains the same. Kucirkova 2014 (cited in Burton and Pearsall 2016) identifies (as is often the case with a technology not specifically designed for education), that many apps have not been assessed for educational value, and it attempts to help support time-poor teachers (referencing Roblin's cost-benefit relationship), leading to a plethora of publications attempting to direct teachers to the 'good ones.' Hallas (N.D) provides one such example of a publication, but of the 11 'endorsed' apps in the article, four focus on emulations of traditional or recent electronic instruments, and a further four provide 'tools' such as tuners, tablature, and a 'real' book; with only the final three apps listed offering something transformatively 'new'.

2.8. Reconceptualising the musical instrument

Williams (2014) argues that one of our mistakes in traditional music education is that 'we elevate the importance and worthiness of certain instruments', and continue to believe there is only a short list of real musical instruments and high-quality musical styles. There is the need to embrace pedagogical technique that is very different from the traditional band / choir / orchestra paradigm, and that 'our profession does too much ignoring' of the powerful effects of other types of music making'. Indeed, Mantie (2017a) makes a compelling argument that we need to change how we think and talk about what we do as music educators with technology:

> The basic framework we use to discuss these new concepts and ideas remains largely the same. We still speak of a 'role' for technology and of 'teaching', 'embedding', or 'incorporating' technology, as if it were a tool or a thing discreet from the norms of music learning and teaching.
>
> The ways in which we discuss music learning and teaching today are not appreciably different from the way they were discussed 50 (if not 100) years ago. Thus, while we can point to and label new devices (or "gadgets"), our fundamental understandings are likely to remain unaltered if we do not generate new conceptual and metaphorical ways of thinking. (Mantie 2017a:340).

Outside of school music, the number of cutting-edge interface developments that support live collaboration is steadily increasing, particularly those found at NIME (the annual conference relating to New Interfaces for Musical Expression) which provides a strong outlet for professional experimentation within this field, highlights the interest in this area within the academic community, and provides opportunities to explore the interdisciplinary creations of artists and scientists. Along this vein, Turchet (2019) identifies a number of distinctions between modern digital musical instruments. 'Augmented instruments' which build on the cultural traditions of conventional instruments, whilst expanding their range of creative expression; the typical setup of these instruments involves connection to an external computing unit. 'Self-contained instruments' which exist without the need for an external connection to work; therefore, benefitting from advantages in compactness, and stability (no connected computer device means that manufacturer updates to the connected computer device do not risk impacting on the future functionality of the instrument). 'Retrieval Instruments' which focus on methods of extracting information from the sound produced, and 'collaborative instruments' which facilitate areas such as networked performance and audience participation. However, it is the transformational value of when these elements are seamlessly integrated 'embedded computation, real-time feature extraction and sensor fusion, networked communication, and combination of gesture-to-sound parameters mapping with familiar playing techniques of conventional instruments' that leads Turchet to define when a digital musical instrument progresses to be a 'smart musical instrument'.

Funding and budget challenges facing school education are well documented (Andrews and Lawrence 2018; OCED 2017; Ratcliffe 2017). Turchet's definitions of digital and smart music instruments, and indeed the instruments that fall into these categories such as the Roli Seaboard, Eigenlabs' Eigenharp, Roger Linn's Linnstrument, are all highly innovative products but their purchase costs make them an unrealistic option for school environments. Purchasing a single one of these instruments would likely exhaust, or use a significant part of a school music budget for a year, and if only one instrument is purchased, it makes achieving 'adequate provision' (Rogers 1997) impossible. Joncas 2019, a teacher, provides an alternative view of what constitutes a smart musical instrument in education, placing greater focus on the concept of scaffolding learning and the 'sound before sight music philosophy' to offer the opportunity for students to 'do music and hear music' before they learn the written theoretical concepts. Turchet and Joncas' differing views centre around flexibility, but in the case of Joncas, it is the flexibility to support the learning process that is arguably prioritised. Just as the electronic keyboard offers flexibility of a single device able to be a 'sound chameleon', the mobile tablet computer offers flexibility in that it can be used across multiple subject areas and disciplines, and that many different apps can be used on the device to scaffold a variety of learning in a variety of subject areas, and this is likely driving its popularity.

Although loop-based composition can negate the need for a connected instrument to be used to 'play' musical ideas into a computer, just as is the case with a connected midi keyboard found so commonly in the music classroom setting, there remains a key place for a performance interface to enable greater opportunities for idea experimentation, as well enabling the possibility to capture elements of the performance of how the musical ideas are played. Whilst the computer digital audio workstation (DAW) was originally conceived as a replacement for the tape recorder, acting as a multitrack recorder to enable the recording and sequencing together of musical ideas for simultaneous playback, it has in recent years re-defined itself to become a tool for live performance as well. Performance interfaces are moving away from the traditional idea of an 'instrument' capable of producing the sound(s) to be captured, and instead towards 'controllers' often containing an arbitrary number of different control options such as buttons, sliders and knobs, that connect to a computer, enabling the real-time, human control of audio, with exactly 'what' is being 'controlled' being open to user interpretation and definition. 'Whereas turntablism was born out of hip-hop and electronic music, we are now seeing a new form of electronic music performance born of the computer music age with entirely different skills and outcomes.' (Collier 2012). Hein (2017b) argues that '*Controllerism,* erases the distinction between the computer as a recording playback device and a musical instrument' (ibid 388), with the controller and the computer becoming one, and this merger offers new possibilities, with (Fortner 2014) arguing that 'there is a growing dissatisfaction with the "press play" mentality and [artists] are growing large fan bases as a result of not only their music, but also their live performance'.

Gower and McDowell (2012) argue that interactive music video games are important to students, and something that they take an interest in, further suggesting that teachers should take this into consideration when developing lessons and curricula. This approach offers further opportunities to attempt to bridge the informal and formal learning contexts, draws further connections between technology differences between school and home as previously identified by Somekh, and offers the potential to seek to motivate learners through the integration of learning and play as a platform for the acquisition of personally relevant and educationally appropriate knowledge and skills (Groff et al 2012). Music-based games have indeed proved very popular, especially those that indulge inner rock star fantasies, and this is highlighted further by Activision (the console game publisher responsible for *Guitar Hero*) announcing in January 2008 that the *Guitar Hero* franchise alone had set an industry record - surpassing $1 billion worth of retail sales in North America in just 26 months. *Rock Band* set the ensemble precedence by releasing a package of controllers enabling gamers to not only play guitars in time to music, but also to sing and bang drums. Gamers in 'bands' not only supports Vygotsky's theories of social interaction, but also provides an alternative to the heavily centered individual approach to interfacing with music technology.

> Music games are a valuable vehicle to connect formal and informal music participation in the 21st century, embodying fundamental musical concepts in gameplay and authenticating formal participation to the wider musical world of the learner…[and these create] game based experiences that necessitate music performance, appreciation, or creation, including off-the-shelf entertainment. (Paisley and Cassidy 2016:134)

Missingham 2007 (cited in Gower and McDowell 2012) argues that one of the benefits to interactive music-based video games, is the introduction to young people of many of the skills needed to play 'real' instruments (the development of dexterity, inter-limb coordination, hand eye coordination, pitch and rhythm). Missingham argues that these skills can then be transferred to other learning, such 'real' instruments, but interestingly also acknowledges that despite this, there are perception issues, in that most young people do not believe that interacting with gaming is as significant as making music on the real instruments. Blaine (2005) offers a potential reason with the argument that the very notion of using a controller to 'win' a game rather than being 'played' as a musical instrument, runs somewhat contrary to the notion of a musical instrument designed novel performance, and furthers her observations by suggesting 'the physical shape and functionality of specialty game controllers in combination with rhythmic prompts displayed via an onscreen interface effectively advocate playing music to win a game.' (Blaine 2005).

The challenge (where there is a need to 'win' a game) is that this places an importance on a specific criterion of success. Hoggins defines the products of Guitar Hero and Rock Band as competing 'beat-matching' products, with the controllers themselves offering 'a tactile link to the music beyond the control pad' (Hoggins 2008). Despite the rapid initial success, popularity waned significantly with Stuart 2011 citing the 'lack of game-changing innovation' as one of the core problems for development. Pressing a button in time with a visual whilst simple to learn, scalable and measurable, and the achievement of proficiency within the game meant mastering this; there was no need to learn new skills, there was no opportunity to 'gamify' other elements that could constitute 'success' such as the ability to use the controller for musical composition, and effectively the initial novelty of the controller wore off (Oore 2005). At the height of popularity, there was broadly supportive adoption within the classroom environment, with the most notable benefits being the enhancement of motivation, encouraging pupil-led approaches to learning, and also affording the opportunity (therefore supporting adoption) for pupils to bring in their own device (BYOD).

More recent developments in music and video game integration see the re-appropriation of the importance of mastering instrumental skill (Pitts and Kwami). *Rocksmith* (Ubisoft) places its focus on the development of musical instrument (guitar) skills, but in order to advance on from the earlier beat-matching products of *Guitar Hero* and *Rock Band*, the user is required to connect a real electric guitar or bass guitar to a computer or games console using a special USB / Jack cable. Beat-matching remains one of the functionalities available (in learn a song mode), but other modes contain a much more developed set of opportunities in order to support instrument learning. These include interactive video lessons where the user is required to practice certain skills, but they crucially receive feedback on their practice, they can 'jam' with a virtual band in Jam session mode to support ensemble awareness, they can use the guitar as a controller to play typical arcade style games in arcade mode, and use and experiment with a selection of virtual amplifiers and effects in amplifier mode. This broadening of the range of possibilities, can contribute to 'transforming our perceptions and experiences of what musicianship and music educatorship can be', and 'help to construct new learning practices that use real instruments in learning real repertoires, argues Harve et al (2018). Yet, for all of this scaffolded support, and the opportunities for the learner to immerse themselves in a range of modes to support their learning at their own pace, there are arguably concerns with the learning approach. The advertised concept of 'dynamic difficulty' was clearly intended to adjust to the user (supporting Gee's concept of 'dancing around the outer limits of the player's abilities to be just about do-able'), but Kuchera (2011) describes this example as 'chasing goalposts that are always moving' - the parts that a user struggles with are made simpler and the parts the user is proficient with are made harder, the result being 'it never feels like you are getting anywhere and this turned the game into a treadmill where it is impossible to find a good place' (ibid). Equally, despite Ubisoft describing the product as 'nothing plastic, nothing fake, just the most authentic guitar experience in music gaming', effectively a nod to the improvements over Guitar Hero / Rock Band, Kuchera challenges this 'authenticity' by arguing that a key part of buying a new amplifier, effects pedal or guitar is experimenting with the possible sounds that the new product offers. The fact that these are locked away (to be unlocked later, satisfying the gamification requirement of moving up levels) means that it 'feels like it goes against the nature of what it *should* feel like to pick up a new instrument'. Given the latest release is dated 2014, and the listed software requirements somewhat outdated, with no indication of a 64-bit release to support modern computing, it does appear that these challenges are arguably a stumbling block, therefore hampering wide target audience adoption.

Grid controllers such as the Akai MPCs, Monome, and more recently Ableton Push, and Novation Launchpads have further led the way in supporting the performance possibilities of computer music, with the latter of these products in particular targeting the more affordable end of the consumer market, in turn helping to provide access to bedroom producer novices through to professionals. Adoption of these products in schools however remains (from my own observations) low, despite the levels of popularity outside of school music. Ableton, in a quest to support education and bridge the gap between inside and outside of school music use, launched an innovate trade-in initiative at the point of the release of their Push 2 product, encouraging owners of the first-generation product to trade their old device in for money off the new device, with the first-generation products then refurbished and sent to schools for free. Reidy (2016) details that over 6000 Push devices were returned and sent to schools that had applied for them, but Parker (cited in Reidy 2016) acknowledges as a teacher, that due to the school curriculum being very classically based, she had to really push for her school to move in an electronic music direction, and ‘convince a lot of people from the school and the department’ in order to receive approval for her belief that this was the right way to move forward.

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3. Research Foundations and Methodology

The need for researchers to be explicit about the assumptions and theories that underpin their work, including addressing the central philosophical arguments that shape various paradigms of enquiry is an important call by Burnard (2006) in order to ensure that as researchers we tell the whole story. This is further echoed in the work of Crotty who argues that at every point of our research we 'inject a host of assumptions', and that such assumptions made about human knowledge and our encountered realities shape our research questions. However, 'without unpacking these assumptions and clarifying them, no one can really divine what our research has been about or is saying' (Crotty 1998:17).

Bassey (1992) identifies three realms of research in education. These are as follows:

- *Empirical Research:* where data collection is centre stage; where data is systematically collected by strict procedures, critically analysed, interpreted and conclusions drawn.
- *Reflective Research:* where the findings of empirical research are the starting point for review and argument about educational issues.
- *Creative Research:* where the development of novel solutions, and the formulation of new ideas, by systematic and critical enquiry.

3.1. The Initial Research Questions

In chapter one, I introduced my personal background, and the challenge I faced as a music teacher to bridge students' perceptions of school music, and the dissonance between this and the music they consumed outside of school. The literature in chapter two identifies the use of keyboards as the most dominant method of musical instruction within school. However, within this previous chapter, I argue that the over-reliance on keyboard interfaces can be a barrier to the development of musical ideas with technology, and that the model of composer – keyboard interface – computer therefore does not promote the most effective transfer of compositional ideas into composition reality by composers with limited or no grounding in keyboard performance.

Children’s mastery of modern consumer technology, especially video game and phone technology, provides an opportunity for the use of a variety of control interfaces where they are ‘digitally native’ (Prensky 2001), and offers further opportunities to address the mis-match of ICT recourses found inside and outside of school as presented by Somekh (2007), as also identified in chapter two.

The initial research questions formed around the use of game controllers were:

- Would the use of a popular ‘digitally native’ product that is regularly engaged with outside of school lead to greater levels of motivation?
- Would such a ‘digitally native’ technology provide any inherent benefits over the keyboard for pupils who had little or no previous experience in using the controller before?
- Would the controller provide any inherent benefits over the keyboard for pupils who had little or limited motivation for keyboard activities?

These questions align in scope to the domain of creative research presented within Bassey’s realms of research in education.

3.2. Research Foundation and Framework

In Crotty’s (1998) framework for grounding a research perspective, he illustrates the relationships between four different elements that form an approach to the research process. These represent distinct hierarchal levels of decision making within the research design process. They are:

- *Epistemology:* the theory of knowledge embedded in the theoretical perspective and thereby in the methodology. This underpins the entire research process.
- *Theoretical perspective:* the philosophical stance informing the methodology and thus providing a context for the process and grounding its logic and criteria.
- *Methodology:* the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes.
- *Methods:* the techniques or procedures used to gather and analyse data related to some research question or hypothesis.

(modified from Crotty 1998:2).

3.3. A Constructionist Epistemology

At baseline, an appropriate epistemology forms the foundation, so as to ensure that the knowledge acquired within this study is valid and true. Crotty presents three groups of epistemological positions: Objectivism, Subjectivism and Constructionism, and when considering these three positions it is useful to consider the relationship of the individual (known also as a subject), and object (something external to the individual). Crotty positions Objectivism as 'meaning, and therefore meaningful reality, exists as such apart from the operation of any consciousness.' (Crotty 1998:8). Diesing (1966) offers clarity on this position by acknowledging that this requires 'publicly observable, replicable facts'. Gray (2018) summarises as 'reality exists independent of consciousness'. On the position of subjectivism, Crotty identifies this as where 'meaning does not come out of an interplay between subject and object but is imposed on the object by the subject', with Gray (2018) suggesting that 'subjects construct meaning but do it from within collective unconsciousness, from dreams, from religious beliefs etc' (ibid 2017:22). Neither of these positions however are the appropriate position for this study due to the importance of fostering a musical learning experience in schools through practical activities, with this further supported by the literature presented in chapter two.

Crotty presents the position of constructionism as follows:

> …all knowledge, and therefore all meaningful reality as such, is contingent upon human practices, being constructed in and out of interaction between human beings and their world, and developed and transmitted within an essentially social context. (Crotty 1998:42).

Here, the relationship between the individual and object is constructed through interaction between individual and object. Crotty's definition contains a number of important terms: 'interaction between humans', 'their world', 'social context'; and this indeed aligns in terms of compatibility with the proposed research questions. The world here is the music classroom, and interaction aligns with the position put forward by Kirkman that 'students are agents in their own learning; to learn musically they must actively engage with music'. (Kirkman 2012:36).

Interestingly, Gray presents a similar definition for constructivism:

> 'truth and meaning do not exist in some external world, but are created by the subject's interactions with the world…Meaning is constructed not discovered, so subjects construct their own meaning in different ways, even in relation to the same phenomenon.' (Gray 2018:21).

Literature often presents constructionism and constructivism as interchangeable terms, and this study, for the purpose of defining the research design, will draw reference to literature using both terms. However, in order to present a clear difference, and present a clear assumption, Crotty again provides a useful distinction; reserving the use of the term constructivism as creating a 'unique experience in each of us', and that 'each one's way of making sense of the world is as valid and worthy of respect as any other', and constructionism as emphasising the 'hold our culture has on us' (Crotty 1998:58) Under this definition, constructionism remains the appropriate epistemology as this also supports the need to acknowledge any specific individuality, or former experience, affecting the interaction process between the individual and object.

3.4. Theoretical Perspectives

With a constructionist epistemology defined, an appropriate philosophy or theoretical perspective, to inform the methodology was required. The initial research questions required the need to acknowledge students' individual experiences, as well as the need to gain an insight into their understanding. Saunders et at (2019) present a 'Research Onion' (see figure 3.1), where the philosophical stance is represented by the outer layer of the onion.

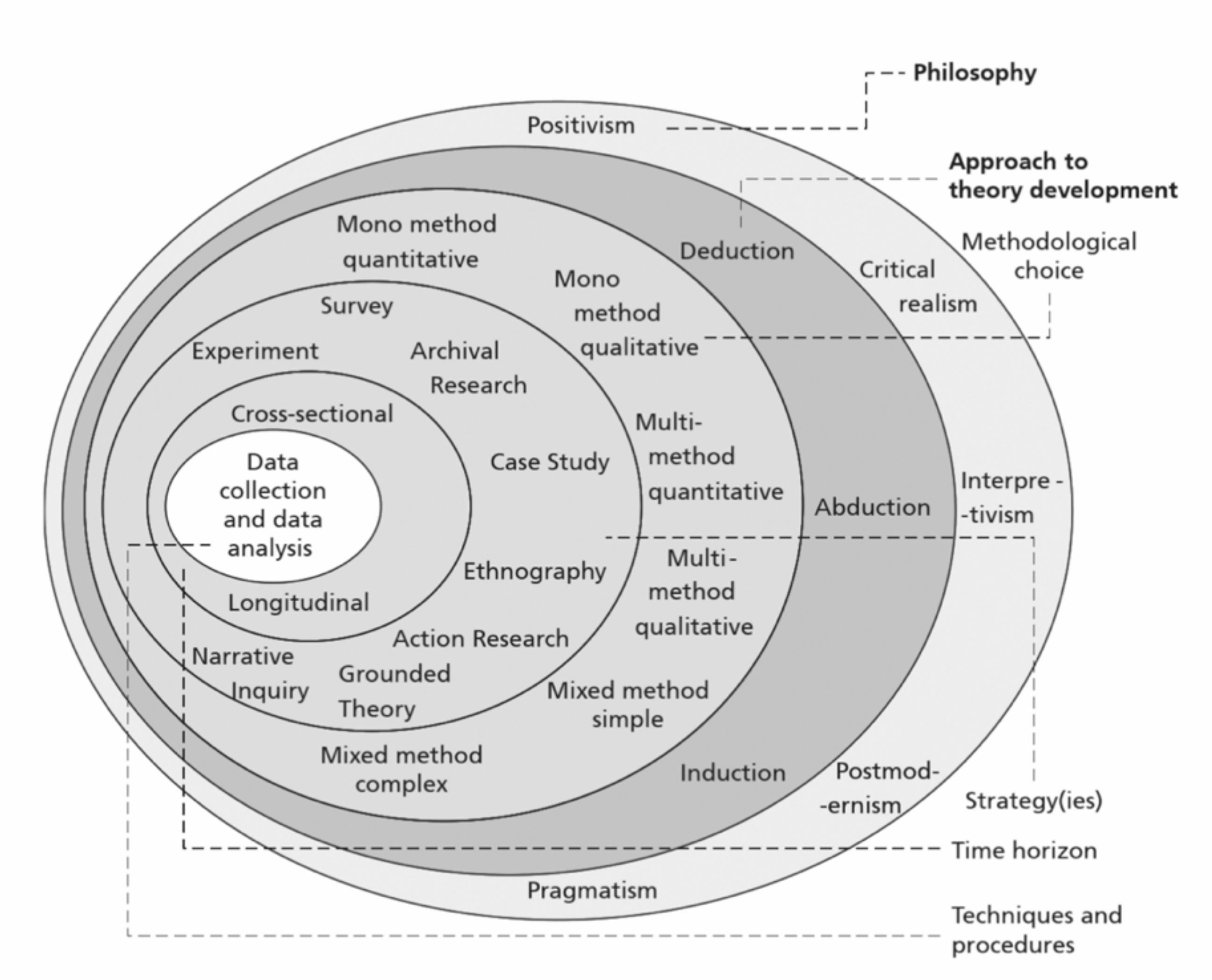

Figure 3.1 The 'Research Onion' presented by Saunders et al (2019:130).

Gray (2018) positions positivism and the various strands of interpretivism as the most influential of the theoretical perspectives. Crotty (1998) acknowledges that positivism seeks to apply the principles of scientific and empirical inquiry, and that it is through scientific observation, as opposed to philosophical speculation, that theory is developed, with results tending to be presented as objective facts and truths. The initial research questions therefore required a theoretical perspective that is positioned around the other side of the research onion, given the need to explore perception of accessibility to existing technology (in the form of the keyboard) and any positive effects upon students' sense of being able to compose and perform their musical ideas.

Schwandt (1994) stakes the claim that constructivist epistemology often generally aligns to an interpretivist approach, and Orlikowski and Baroudi (1991) suggest that the aim of interpretivist research should seek to 'understand how members of a social group, through their participation in social processes, enact their particular realities and endow them with meaning, and to show how these meanings, beliefs and intentions of the members help to constitute their actions' (ibid 1991:14). There are various sub-flavours of interpretivism that draw different emphases for applying research in practice, but the terms of 'meaning' and 'action' as presented in Orlikowski and Baroudi's definition, have strong groundings in this research. Goldkuhl (2012) argues that the core idea of interpretivism is to work with subjective meanings that already exist within the social world: 'to acknowledge their existence, to reconstruct them, to understand them, to avoid distorting them, to use them as building blocks in theorising.' (ibid:138). Whilst positivism and interpretivism are seen as opposing theoretical perspectives, Goles & Hirschheim (2000) suggest that there is indeed a middle ground, or dual position between these two perspectives, and present the perspective of pragmatism as filling this space. Goldkuhl (2012) sees this perspective as being associated with action, change, intervention, constructive knowledge and interplay between knowledge and action, making it an appropriate basis for research approaches that intervene, rather than just observe the world.

Braa & Vidgen (1999) present a research-methodological framework consisting of three orientations (see figure 3.2). Reduction to enable prediction (bottom left) represents a typically positivist approach, with interpretation leading to understanding (bottom right) representing an approach typically focussed in interpretivism. Change is shown as the outcome of intervention at the top of the triangle, and it is argued that it should be 'implicit that the intervention should be motivated by a desire to make improvements in the problem situation. Interpretations that are successful bring out insider rationality and promote understanding' (ibid 1999:28).

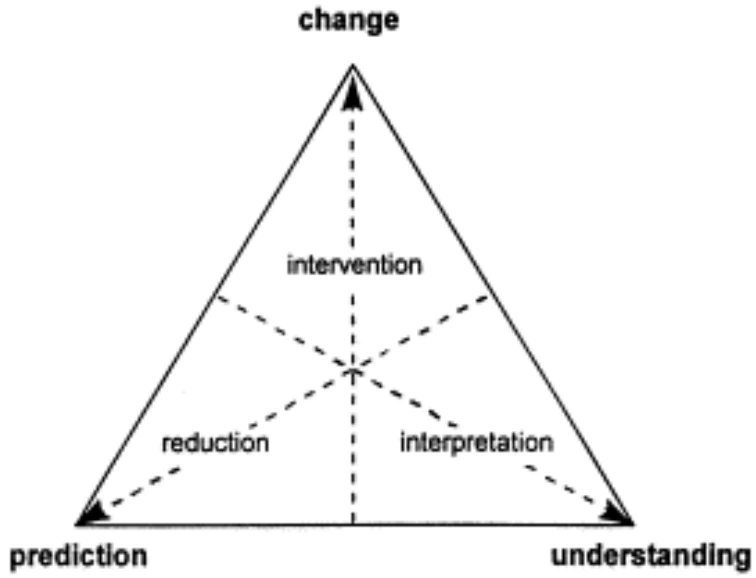

Figure 3.2 Braa & Vidgen's (1999) research-methodological framework

Whilst Braa & Vidgen (1999) do not explicitly locate change as the outcome of intervention as pragmatist theory, they do acknowledge that whilst the points of the triangle represent ideal type approaches to research, they are in practice not attainable, and that in reality, research exists somewhere within the constrained space within the outline of the triangle.

The area of phenomenology, located within the perspective of interpretivism, focusses on 'lived experience', including recollections and interpretations of those experiences, and whilst personal experience (or indeed lack of personal experience in the case of the second research question) is an important consideration, English and English (1958) argue that in phenomenology, behaviour is determined by experience, rather than by the external realty. Arguably this therefore limits the appropriateness of this approach on its own for this study, given the need to evaluate the impact of the implemented technology (ie the external reality) on motivation, and on reducing performance barriers.

In a contrasting perspective, Blumer (1969) asserts the principle of 'meaning' as being central to the interpretivist approach of symbolic interactionism, and provides three main assumptions:

- Human beings act toward things on the basis of the meanings that these things have for them.
- The meaning of such things is derived from, and arises out of, the social interaction that one has with others.

- These meanings are handled in, and modified through, an interpretive process used by the person in dealing with the things he or she encounters.

Adapted from Blumer 1969, cited in Crotty 1998.

Crotty (1998) argues that in order to do these assumptions justice, they should be set against the backdrop of pragmatist philosophy, whilst Goldkuhl (2012) asserts this position further by defining symbolic interactionism as a 'fusion of the pragmatic and interpretive' (ibid 2012:11). The principle of 'meaning' also draws allegiance to the previously discussed aims of Orlikowski and Baroudi.

Symbolic interactionism proposes that action depends on meaning, but that, as different people assign different meanings to 'things', and any meaning of something that is held by an individual can change, it is not permanently fixed. Existing research has, for a long time, shown digital technologies as cultural tools that are inherently social (Fölkestad 1996, Pitts and Kwami 2002). Furthermore, Hedman and Gimpel (2010) include 'social value' as part of their five value types that influence individual technology adoption – functional, social, epistemic, emotional and conditional. Thus, for the purpose of this research, it is the <u>change</u> in meaning, as presented through the lens of symbolic interactionism, that is the focus – the change in meaning derived by the use of the created digital tools, and the change in meaning derived from keyboard use to the created and alternative technologies to support the process of musical composition for students with limited background in keyboard skills. The change in meaning that the created alternative technologies has on students' approaches to composing needs qualitative understanding, and indeed Fetterman (1998) adds the dimension that symbolic interactionism should also focus on thoughts and ideas interpreted by individuals (students, teachers and other potential stakeholders). It is Paré however that argues that 'in order to understand how people think and know, researchers must go beyond the individual mind to the collaborative projects in which that mind participates' (Paré cited in McCulloch and Crook 2013:90), and this opens the door for the complementary sociocultural lens of Activity Theory to further sharpen the theoretical perspective of this research.

Activity Theory originates with Vygotsky's proposition that 'human experience of the external world is mediated – that is, shaped or influenced – through tools and signs' (ibid 2013:90). Indeed, Hasan and Banna (2010) draw on the work of other researchers (Kuutti, 1996;

Engestrom 2005) to offer a definition on the essential principles: 'Activity as the basic unit of analysis, object-oriented, tool mediation, history and development, the dual concept of internalization/externalization, and zone of proximal development, and contradictions and conflicts' (Hasan and Banna 2010:6).

It is however Kaptelinin and Nardi whose take on activity theory has seen specific influence on the domain of Human-Computer Interaction, and due to the design and development of technologies as part of this research to mediate between human and computer, offers a further strong theoretical perspective for this research. They view activity theory as a conceptual framework that enables the possibility 'to bridge the gap between motivation and action [and] provide a coherent account for processes at various levels of acting in the world' (Kaptelinin and Nardi 2006:62). At baseline, the argument here is that understanding and design of technology, should be based on analysis of its role and place in activity.

These theoretical perspectives therefore position this research study as a hybrid form of interpretation and intervention, located in the area between intervention (leading to change) and interpretation (leading to understanding) in Braa & Vidgen's research-methodological framework (see figure 3.2). Goldkuhl provides a useful table (see table 3.1) in order to provide guidance for shaping the focus, and investigation within this hybridised area by identifying the key differences between interpretation (interpretivism) and intervention (pragmatism). Dewey (1931) acknowledges the shared orientation of these areas towards understanding, but highlights an important difference: In pure interpretivism, understanding is seen as value of its own; in pragmatism it is seen as instrumental in relation to the change and improvement, with the action taken seen as the intermediary in causing the change.

	Pragmatism	**Interpretivism**
Ontology / Epistemology	Symbolic Realism	Constructionism / Constructivism
Empirical Focus	Actions and changes	Beliefs (socially constructed cognition)
Type of Knowledge	Constructive Knowledge	Understanding
Role of Knowledge	Useful for Action	Interesting
Type of Investigation	Inquiry	Field Study
Data Generation	Data through assessment and intervention	Data through Interpretation
Role of Researcher	Engaged in Change	Engaged in Understanding

Table 3.1. Pragmatism vs. Interpretivism: ideal-typical differentiation. (Goldkuhl 2012:142)

The two sociocultural lenses of symbolic interactionism, and activity theory combined, provided the appropriate theoretical grounding for this research in order to view and consider students' change in the meaning of their musical identities through their own compositional development, and any impact on their compositional process (symbolic interactionism). Activity theory locates the context of this through the observing of students' interactions with the technologies developed within this research project with the design aim of enabling the better bridging of musical engagement using computer-mediated environments, with change of action over time.

3.5. The Case for Action Research as a Methodology

Goldkuhl (2012) suggests that within Braa & Vidgen's (1999) hybrid research position between interpretation and intervention, exploration takes the form of interpretivist action research, where interpretivism is combined with both functional and methodological pragmatism. Goldkuhl positions functional pragmatism as equal to constructive knowledge, where knowledge is used as the basis for action, whilst positioning methodological pragmatism as being concerned with how such knowledge is created, in addition to highlighting that experimentation is pivotal to the process. 'The researcher is participating in practice in order to explore - through own actions or close observations of others' actions - the effects and success of different tactics. In action research there is a continual development, application and evaluation of knowledge and tactics' (ibid 2012:141).

Stringer (1996) argues that community-based action research is a 'search for meaning [that] provides a process or a context through which people can collectively clarify their problems and formulate new ways of envisioning their situations' (Stringer 1996:158), something that Trunk Širca and Shapiro (2007) consider as a 'juxtaposition of action research with constructivist thinking' (Trunk Širca and Shapiro 2007:102) as they argue that action research is a clear mirror to constructivist philosophy, and the same side of the coin, with the fact that 'action research fundamentally reflects constructivist thinking in its process and practice' (ibid 2007:105).

3.5.1 Defining Action Research

A number of researchers propose models for the action research process, with a large number of these models based on a cyclic form and containing a varying number of steps or processes.

Stringer (2007) details the steps as look, think and act, Lewin (cited in Elliot 1991) as fact find, plan, implement, evaluate, amend the plan before moving on to the second action step, evaluate. Piggot-Irvine (2006) - plan, act and reflect, through numerous action cycles. Hendricks (2009) - act, evaluate and reflect. The terms used show clear common elements, with all models beginning with a central topic or problem. Mills (2011) cited in Mertler (2019) summarises the processes as 'some observation or monitoring of current practice, followed by the collection and synthesis of information and data. Finally, some sort of action is taken, which then serves as the basis for the next stage of action research' (Mills 2011 cited in Mertler 2019:15). Figure 3.3 presents an example of an action – reflection cycle presented by McNiff and Whitehead (2003).

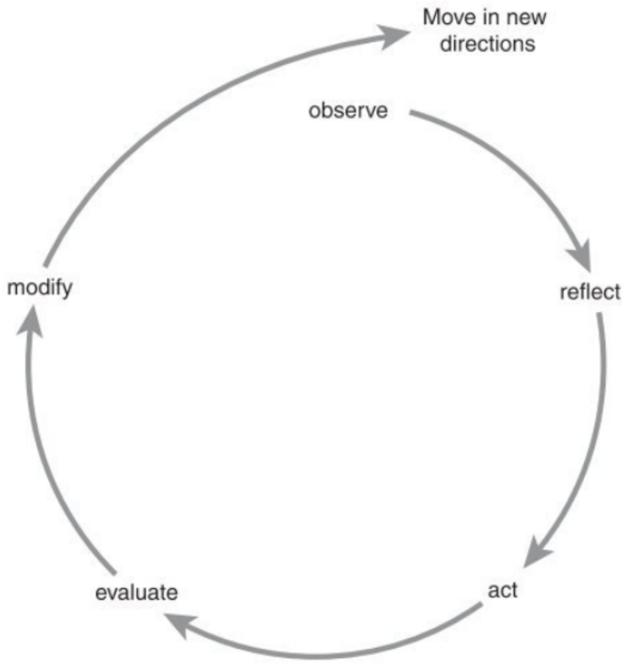

Figure 3.3 McNiff and Whitehead (2003) example of an action – reflection cycle.

Gray (2018) identifies three common features of action research within the cyclical models, highlighting that research subjects are often themselves researchers or involved in a democratic partnership with a researcher, that research is seen as an agent of change, and that data is generated from the direct experiences of research participants. Herr and Anderson (2015) raise the importance of the research being value-laden and collaborative, arguing that action research is best done in collaboration with others who have a stake in the problem under investigation. Kemmis and McTaggart (1987), when focussing action research through the lens of education, promote the importance of social justice to their definition of action research as a form of 'collective, self-reflective enquiry undertaken by participants in social situations in order to improve the rationality and justice of their own social or educational practices, as well as their understanding of these practices and the situations in which these practices are carried out' (ibid 1987:6). Creswell and Guetterman see action research designs as 'systemic procedures completed by individuals in an education setting to gather information and subsequently improve the ways in which particular educational settings operate' (Creswell and Guetterman 2021:639).

Whilst the positions put forward by Creswell, Guetteman, Kemmis and McTaggart clearly align action research to educational settings, it is equally important given that the nature of this research includes the design and development of new hardware and software tools, to consider action research through the lens of software engineering and new technology design. Staron (2019) acknowledges that empirical methods of research in software engineering have a long tradition, with much research in this area positioned more towards opposing objectivist epistemologies and positivist theoretical perspectives when compared to the constructionist and interpretivist research direction of this study. However, Reason and Bradbury (2001) acknowledge that there are inherent benefits of action research within the domain of information systems and information technologies, by emphasising the usefulness of the aspects of participation, and finding practical solutions found within action research as important when creating new practices and new products. Baskerville (2007) sees action research as an important example of modern research methods within the area of information systems, identifying it as 'empirical, yet interpretive, experimental yet multivariate, observational yet interventionist'. (Baskerville 2007 cited in Staron 2019:40). Staron indeed argues that 'these characteristics make it [action research] perfect for software engineering research' (ibid).

3.5.2 The Context of Action Research

With the assumptions already presented for the epistemology and theoretical perspectives grounding this research, there is the need to extend this consideration in order to explicitly acknowledge the assumptions and concerns when employing an action research methodology. Herr and Anderson (2015) see action research as a reflective process, but different to a reflective process that is isolated or undertaken systematically. They acknowledge that what constitutes evidence (or in traditional terms, data) is still being debated, but see the ideal result as being change, specifically change that occurs either within the setting where the research is carried out, or within the participants (as collaborative researchers) themselves. This focus on change connects deeply to the ideas presented within the overarching theoretical perspectives. Baskerville (1999) offers aligned thinking by identifying that the conducting of research within a complex setting, such as a social setting (schools, in the case of this research), and attempting to split lines of inquiry into variables or components, does not lead to useful knowledge about the whole setting; with social processes instead 'best studied by introducing changes to the processes and observing the effect of these changes' (ibid 1999:4). Baskerville does however offer a warning that a change-oriented approach leads to unavoidable effects – one of which is the nature of action research being rooted in the interpretivist domain, where the observer is part of the study, or acts as one of the study subjects. Here observer values, and all prior knowledge and experiences invariably intrude on the observation, and as the observer seeks to attempt to understand, all previously gained personal understanding invades the recording of the observation. Baskerville argues therefore that 'all inter-subjective meaningfulness of actions, and the social meaning of action shared between researcher-subject and other subject, must form part of the experimental data', that 'the structure of world perception as modified by evaluation and ideals has to be considered', and that 'meaningful investigation must consider the frame of reference and underlying social values of the subjects' (ibid 2019:4). For the purpose of this research, Baskerville's position relates to the fact that each context (school) is different and has a unique set of participants (pupils and teachers), and that wider connections to pupils 'world perception' should be considered and evaluated too. World perception in this case is related to change afforded by the developed technologies to support compositional work and reduce performance barriers, and also pupils' perceptions and importance placed on school music as a whole.

3.6 The Research Focus

The primary focus for this research was the creation of new technologies to support music education in schools, and the final product developed through the findings of this research forms part of this research submission. The focus of these technologies was to try to dismantle performance barriers to music composition, and in turn seek to better facilitate the transaction of musical ideas from an individual to a computer-mediated environment. In order to ascertain and understand the performance barriers encountered by students within the traditional model of composer – keyboard interface – computer; this action research studied pupils' approaches to composing using computers in music lessons within secondary school settings at Key stage 3. The results and findings from the various stages of this study informed the next phase of development and functionality of software and later hardware. Pupil's usage of the software and hardware technologies was observed at each phase of development, as were student's own perceptions of their success, ease, motivation and the challenges they felt they faced throughout the compositional process. This qualitative data contributed to the growing understanding, along with data from interviews with pupils, other music teachers, and field journals. The findings at each phase led to the refocus and honing of research questions that the technology-based developments sought to test, and this in turn fed into the design of a final developed product to support music composition. In the findings of this thesis, each phase of the technology development is analysed alongside the findings from pupil and teacher use, with the next phase of the developed software and hardware quantified.

I began this research whilst employed as a music teacher, teaching in a secondary school, and working as a music technology consultant in another. At baseline, I wished to seek to bring new possibilities to bear on my own teaching practice; and explore how such possibilities may help me to help my students in their creative compositional work and its performance. Through the lens of action research, I sought to 'collaboratively question practice, make changes and assess those changes' (Kemmis & McTaggart 2005), but also enact positive adjustments to the taught environment and access of facilities.

Lewin's model of action research as interpreted by Kemmis (1980, cited in Elliot 1991) provided the foundation for the plan of inquiry for this research. Kemmis' interpretation includes additional essential characteristics of reconnaissance, planning, first step monitoring and re-thinking. The further developments to this model presented by Elliot (1991) emphasise the importance of analysis and reconnaissance throughout the entire action research cycle, as well as the argument that the general overarching idea be allowed to shift. This warning against developing a fixed idea at the beginning of a cycle promotes reflexivity, and is important given the considerations presented by Baskersville with regards the researcher being a subject (a teacher) within the early stages of the research project, as I was. The plan for this research was closely aligned to Elliot's action research model, see Figure 3.4.

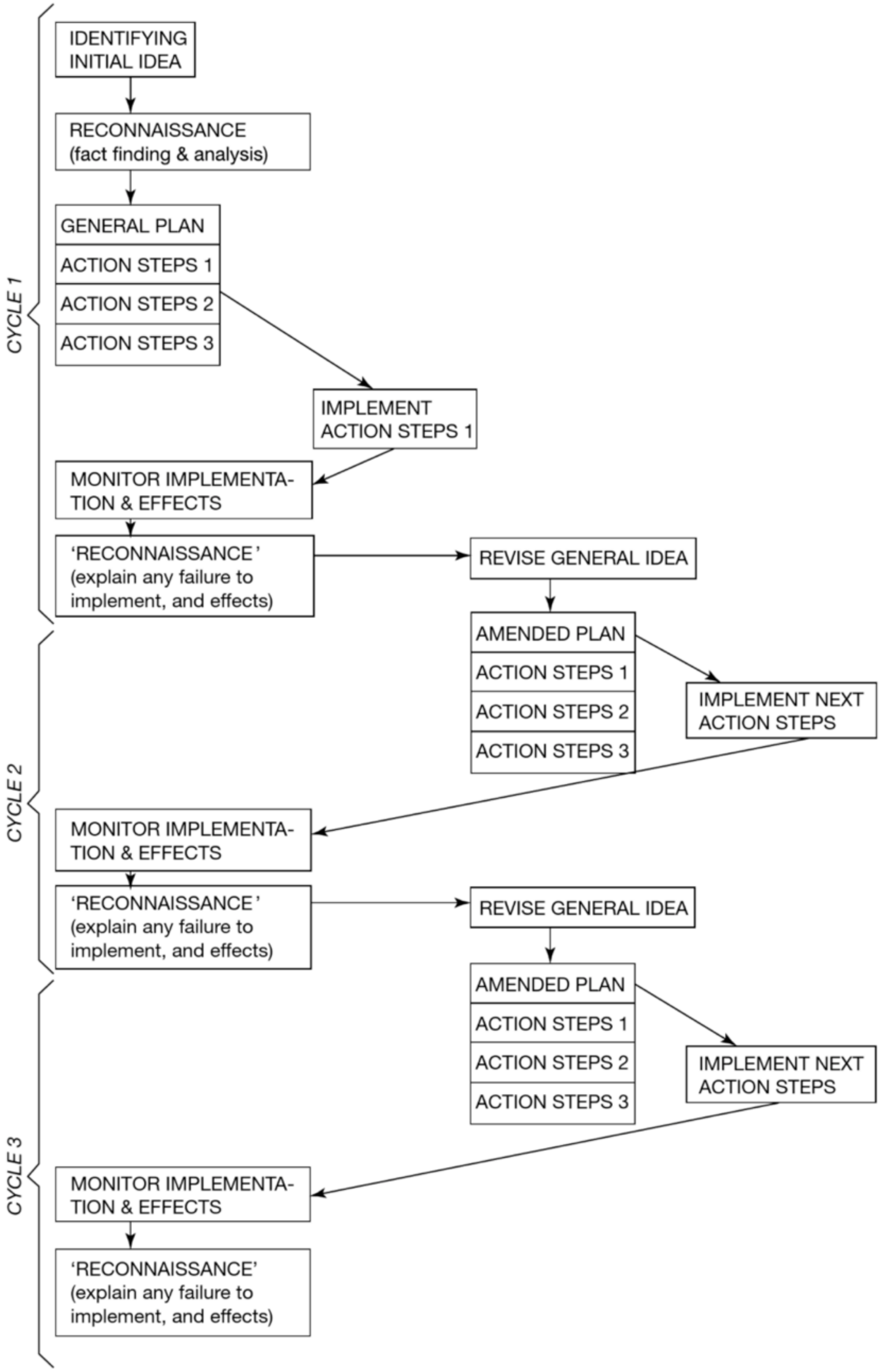

Figure 3.4. Elliot's (1991:71) action research model - seen as a developed revision of both Lewin's original model, and Kemmis' interpretation. This model formed the basis of this research project.

3.7 Data Collection Strategies

Cresswell and Guetterman (2021) present three main types of observational position within research, as summarised in table 3.2.

For the purpose of this study, I assumed the role of a participant observer, with such a role congruent with action research in educational settings, for teachers seeking to address schoolwide problems and improve practice (Allen and Calhoun 1998), and by doing so, naturally engaging in participatory action research (Cresswell and Guetterman (2021).

Type	Description	Advantages	Disadvantages
Participant Observer	Observer takes the role of 'insider observer' in the setting that they observe.	Excellent opportunities to see experiences from the views of participants. Affords depth and reliability. Ethical method if role is declared.	Can be difficult to take notes whilst participating. Risk of being unethical if role is not declared to the group.
Non-Participant Observer	Observer takes the role of an 'outsider' who sits on the periphery.	Requires less access to the research site.	Observer is removed from actual experiences, observations may not be as 'concrete'.
Changing Observational Roles	Researchers adapt their role to the situation. Become more involved as the research project develops.	Enables a rapport to be developed, which can lead to more opportunities to be involved within the setting.	Whilst good for those needing to classify an observational role, approach can take time to develop.

Table 3.2: Main types of observations (adapted from Cresswell and Guetterman, 2021 and Cresswell, 2003).

Whilst Marshall and Rossman (2016) see the ideal execution of such a role as blurring the distinctions between researcher and participants, creating a democratic inquiry, Bergmark (2020) presents an important ethical consideration within the realm of action research where such blurring takes place, arguing that where 'distinctions between researcher and the researched are blurred or removed altogether, questions are raised about anonymity, decision-making in the research process, ownership of research results, and the implication of those results'. (Ibid:332). As the design of the research was based on ongoing qualitative data collection and analysis from the development of new technologies and softwares that I created (so as to enable the repurposing of existing and available technologies for creative use within the music classroom), it is important to reiterate here that in order to enable anonymity, names used to reference specific people in this thesis have been changed.

My dual position as either a researcher and teacher, or as a researcher and consultant, in the data gathering phases of this research project, required the need for lengthy observation and contact periods over a sustained period of time, with both pupils and other music teaching staff. At the same time, my presence as a researcher needed to avoid compromising the integrity of the classroom as a place for learning. Thus, I positioned the research element of my dual position openly, sharing my interest in new technology development and individual compositional development for the pupils involved in the study. Reflexivity was also of paramount importance, so as to ensure that any meanings, judgements and practices that I held were not imposed on the other participants involved in the study. In addition, I kept detailed field notes primarily to document reflections from my perspective from the observations I undertook.

3.7.1. Interviews

The research questions posed in section 3.1 required gaining an understanding of pupils' perspectives. Without this data source, it would be impossible to fully know pupils' views and as such interviewing was a key method of data collection.

Within research literature, delineation is often made between three types of interview: structured, semi-structured and unstructured (the unstructured type can be further delineated as including non-directive, focused and informal conversation) (Gray 2018). Table 3.3 illustrates these differing types and presents their advantages and disadvantages.

Interview Type	Description	Advantages	Disadvantages
Structured Interview	Questions are pre-determined and standardized. Similar to the use of questionnaires.	Quick data capture, easy to analyse, respondent anonymity is easier to guarantee. Useful when wanting to make clear comparisons	Lack of flexibility. Questions developed in advance do not give the opportunity un-pick answers.
Semi-Structured Interview	Questions are usually pre-determined, but the order of questions asked may change, or some may be omitted depending on the direction that the interview takes.	Offers the opportunity to seek further detail from an answer given. Provides the interviewer with more flexibility.	Differing question sequences can reduce comparability of answers. Harder to ensure anonymity.
Unstructured Interview	Questions emerge and are not usually pre-planned.	Respondents are allowed to have the freedom to talk freely around the subject. The interviewer is mainly confined to checking on any points of doubt, and checking for accuracy of understanding.	Can be hard to analyse. Researcher tends to know the respondent, care is needed to avoid interviewer assumptions, can be harder to ensure anonymity.

Table 3.3 Main Types of Interview, adapted from Gray (2018) and Arksey and Knight (1999).

Gray (2018) acknowledges that the search for credibility is one of the main driving forces behind the design of interviews, in order to ensure that the findings can be trusted. There is also the need to consider how the findings from the interview study can be generalised to the wider population. Arksey and Knight (1999) see validity within the interview process as being strengthened by using techniques that help build rapport and trust, prompting respondents to illustrate and expand on their initial responses, ensuring that the length of the interview process is of sufficient length so as to enable the subject and discussion to be explored in depth, and that the interview draws questions from both literature and pilot work within the research study. These elements formed the basis of my interview design, with interviews following a semi-structured plan. Being aware of the need to critically set aside my own assumptions, the interviews conducted were guided by the need to gain insight into any changes of perspective the pupils had within their individual process of composing using the latest revision of the developed tools. Teacher interviews helped to further establish a rich understanding of context. These semi-structured interviews took place following the gathering of data from the observational and field note stages (gathered from the field work), with the semi-structured interviews enabling both pupils and teachers to collaborate with me as the researcher in the unfolding process of analysis of the next steps to take in the development of the tools and technologies.

3.8. Research Contexts

The research was carried out in three secondary school contexts, over the course of the full study.

School A was rated as 'Good' by Ofsted but had a very financially challenged music department. Two music classrooms were available, and music was taught to all students in Key Stage 3 for an hour a week. There were three students studying GCSE music in year 12 and four students studying in year 13. The annual budget for resource provision was less than £600. Classroom instrumental resources consisted of 33 entry-level (not MIDI compatible) electronic keyboards and one piano in each room. There was also a snare drum and two acoustic guitars, both missing strings. This was the sum total of instruments available for class music activities (composition and performance tasks). The keyboards were in various states of repair, with some missing keys, some only containing mini keys and not all made by the same manufacturer. Most keyboards had pen marks on them where notes had been written on using a white board pen in order to help students with locating where the notes were situated. No headphones were available, meaning that when the keyboards were in full use, the sound from all of the keyboards emanated into the classroom. Peripatetic music lessons were available on the piano and for voice and there was enough uptake to fill a half day of lessons per week for each instrument offered. There were no extra-curricular ensembles. There were no computers for student use, although the head of music would book a computer lab (a computer room in the ICT department) in the summer term to enable key stage 3 students to complete a biographical 'project' on the students' favourite bands or artists using available desktop publishing software and the internet.

School B was rated as 'Outstanding' by Ofsted. The music department consisted of two large teaching rooms and a high-quality recording studio with separate control and live rooms. One of the main teaching classrooms had keyboards around the room, whilst the other was music technology suite with 16 keyboards, each connected to an iMac computer. Both rooms had a teaching computer connected to a projector, and a connected keyboard; the management of the computer network in the music technology room was controlled by the music technology teacher. The keyboards were the same make and model across both teaching rooms, were MIDI compatible and contained a large number of in-built sounds. Music was taught to all students in Key Stage 3 for an hour a week. There were 36 students studying GCSE music, eight studying music A-level in year 12 and five students studying in year 13. There were also 10 students studying Music Technology A-level in year 12 and 6 studying this subject in year 13. The annual budget for resource provision was around £3000 a year as a baseline figure, but was also dependent on uptake rates at key stages 4 and 5. In addition to keyboards, there was a guitar and bass guitar and a range of amps and microphones in the recording studio, and these were maintained in good working order by the music technology teacher. There were well attended daily extracurricular ensembles that met during lunchtimes and a growing wind band that met before school on a Friday. A range of peripatetic lessons were offered daily, there was good uptake for these and a waiting list.

School C shared many similarities to school B, in that it was also rated as 'Outstanding' by Ofsted, had a flourishing extracurricular programme, very broad range of peripatetic lesson opportunities running every day of the week and had large numbers of students studying at music at GCSE. This school was however a secondary school where at key stage 3, students received 1 hour of music a week, but in year 9 had the option to take an additional arts-based module, and those that chose music for this module gained an additional hour a week of music in their timetable. There were three music teaching classrooms with the smallest containing 12 keyboards connected to 12 windows computers running Sibelius and Cubase software. The two other large classrooms contained a variety of acoustic instruments from ukuleles and acoustic guitars to tuned percussion. Practical music making focused on the use of these acoustic instruments and singing for performance and composition activities. Post 16 teaching was shared across a three-school consortium, with one school offering the music and music technology A-level, and the classes were made up of students studying from all of the schools in the consortium. Classes in year 12 were substantially larger than in year 13.

3.9. Validity

In many of the definitions of action research presented, the term 'to improve' features (Kemmis and McTaggart 1987, Allen and Calhoun 1998, Creswell and Guetterman 2021). Therefore, an important dimension connected to validity, is the need to identify whether planned intervention actually improves the situation. The subjective meaning of the term 'improve' does however open the potential for differing perceptions from stakeholders involved in a qualitative research process as to what constitutes 'improvement', and as such this requires a number of co-ordinated checks to be completed in order to present valid findings.

Lincoln and Guba (1985) pioneered the approach of linking validity to quantitative standards, with the terms: internal validity, external validity and reliability represented by the terms: credibility, transferability and dependability in qualitative research (Gray 2018). LeCompte and Preissle (1993) see internal validity as being 'addressed by using low-inference descriptors, multiple researchers, participant researchers, peer examination of data and mechanical means to record, store and retrieve data' (ibid 1993:338). Lincoln and Guba's research on credibility in naturalistic inquiry, and Onwuegbuzie and Leech's (2006) research into validity and qualitive research, formed the framework that was used to ensure credibility and internal validity within this study.

Credibility Check	Description	Implementation within this Research
Prolonged engagement in the field, with persistent observation	Conducting the study and field work for sufficient time so as to represent the 'voice' of the participants. Identify the characteristics, attitudes, traits most relevant to the investigation and focusing on these.	Action research cycles, building on the previous data collected. Mitigate against the Hawthorne effect (novelty effect) of using the developed tools and technologies.
Triangulation	Obtaining corroborating evidence from different methods, sources, theories.	Drawn from observations, and interviews.
Self-reflection	Narrative account of the process of the study.	Field notes, reflections, change of perspective and direction within developed technologies and tools.
Negative Case Analysis	Modification of emerging hypothesis, development of research questions.	Presentation of full picture, shortcomings of technology developments at each phase evaluated and analysed as well as positive elements to build on.
Member checking	Participants play a major role in assessing the credibility of account(s), eliminate the possibility for misrepresentation.	Findings discussed with participants so as to ensure the accuracy of interpretations.
Contrast / Comparison	Relating to literature, researcher experience and knowledge base.	Grouping following self-identification. Multi-site study with findings drawn from participants from multiple school settings.
Rich and 'Thick Description'	Maximise the ability to find meaning, enables readers to identify with the setting. Supports transferability (Guba). Can help with revealing bias.	Describing events and contexts in detail. Thick descriptions reported within the findings of this thesis.

Table 3.4 Credibility Checks used in this research. Adapted from Cohen et al (2018:249, 253), Onwuegbuzie and Leech (2006), Lincoln and Guba (1985).

3.10. Generalisability of findings

Whilst Mills and Butroyd (2014) acknowledge the debate in literature relating to the degree in which qualitative research can be generalised to larger populations, they do argue that 'findings from action research can be adapted to other settings, and this is where the power of action research lies, in its relevance to the audience of the research' (ibid 2004:102). Indeed, Stake (1995) suggests that naturalistic generalisations can be made by recognising both similarities and issues found in different contexts, and this position formed the basis for the decision to conduct the field work of this research project in different school settings. Music curriculum lessons, and the provision of music education had varying degrees of prominence within the identity of each school setting. However, these different settings provided the opportunity for this research to draw on the interactions from both pupils of similar age ranges across the various settings, and also from teachers who had made the decision to teach music as a career choice. Given that the findings directly informed the development direction of the new tools and technologies created as part of this research, findings drawn from various settings is conceivably beneficial to the reliability and validity of the project as a whole. Through the rich 'thick' description within the findings and discussion chapters of this thesis, support for naturalistic generalisations from this research study to further contexts, can be made.

3.11. Ethics

Ethics Committee approval at the University of Hertfordshire was gained as part of doctoral study registration, and this research project was undertaken following the British Educational Research Association (BERA) ethical guidelines for educational research, published in both 2004 and 2011. This document has since been further revised and the latest publication released in 2018.

The BERA guidelines highlight five areas of concern when conducting educational research: 'All educational research should be conducted within an ethic of respect for the person, knowledge, democratic values, the quality of educational research, and academic freedom' (BERA 2011:4).

With regards to the specific responsibilities required to be afforded to participants, voluntary informed consent was needed from all students and teachers involved. As this research project was concerned with minors, the plan for research, the research proposal and the ethical principles were presented to the senior leadership team of each school involved, and on this basis, voluntary informed consent from the school's perspective was sought. All participants (individuals, and the schools as a whole) were given the right to withdraw at any point of the study for any or no reason.

With regards to any potential 'detriment arising from participation in research' (BERA 2011:7), it was acknowledged that the pupil-facing elements of this study were carried out during the school day, and therefore there needed to be careful consideration to avoid disruption to both other school activities for pupils, or disruption to the planned delivery of the music curriculum. Collaboration and consultation with the head of department formed the consideration here, with timelines for engaging in the fieldwork and scheduling of interviews set so as to minimise disruption. Equally, as the fieldwork was conducted whilst pupils were working on their curriculum compositional projects and set tasks, disruption to the music curriculum was avoided.

There was also the requirement as articulated in point 16 of the BERA ethical guidelines, for compliance with Articles 3 and 12 of the United Nations Convention on the Rights of the Child. 'Article 3 requires that in all actions concerning children, the best interests of the child must be the primary consideration. Article 12 requires that children who are capable of forming their own views should be granted the right to express their views freely in all matters affecting them' (BERA 2011:6). Whilst all participants were made aware that in order to protect their identities, their names would be changed in the final report, with different names used to represent individual pupils, it was made clear that in order to support the requirement of Article 3 of United Nations Convention on the Rights of the Child, any disclosure made by participants of behaviour deemed illegal, unsafe or considered inconsistent with the best interests of the pupils, would be passed to the appropriate child protection officer at the school.

3.12. Initial Pilot Study (Action Cycle One)

In order to guard against the naturalistic classroom setting causing any unforeseen issues, and to ensure that the created software that I developed could indeed be installed on school computers, a pilot project was created in order to test both the suitability of the location for the research, and identify potential for further exploration within the initial research questions presented. This pilot project also served as an opportunity to test the position that I held that performance barriers existed for pupils with limited grounding or confidence in using the keyboard, and so enabled me to make a direct comparison. I sought to harness a commercially available game controller, and created software to enable a music computer workstation to respond to the controller being used. This software enabled the mapping of button presses on the controller to Musical Instrument Digital Interface (MIDI) data, which could then be interpreted by Digital Audio Workstation software (DAW software such as Logic, Cubase, GarageBand) running concurrently on the computer. This line of inquiry enabled a first opportunity to test if there were indeed any reductions to performance barriers when a game controller was used in comparison to a keyboard. The initial findings from this approach then formed the basis for further software and hardware development work to seek to further dismantle performance barriers, within the next cycle of the research.

The Playstation 2 Controller was selected as the 'digitally native' technology found outside of school given the popularity of the Playstation Console amongst pupils within the pilot study school (School B). This controller proved to be the most popular controller amongst the students. The symmetry of the button placement on the controller and the numbers of buttons available offered compatibility to traditional diatonic music theory, with the eight buttons on the face of the controller (shown as the eight identical round buttons on the face of the controller in figure 3.5) enabling the opportunity to host all of the notes within an octave for a scale. The notes from the C major scale were assigned to these buttons, one note on each button. The four buttons on the rear of the controller (known as shoulder buttons) were also mapped, with the two left shoulder buttons facilitating octave shifts (either up or down, giving a total span of three octaves), and the two right shoulder buttons facilitating accidentals – one button to sharpen a note, and one button to flatten a note. This meant that whilst a C major scale had been assigned as the default scale to the controller, the use of the right shoulder buttons in conjunction with the note buttons on the face of the controller provided the user with the possibility to trigger all of the notes from the chromatic scale. When a button was pressed on the controller, the corresponding notes would also show up on the keyboard and stave graphics on the software interface layer – this was to provide positive reinforcement of theoretical elements with regards to where notes are situated.

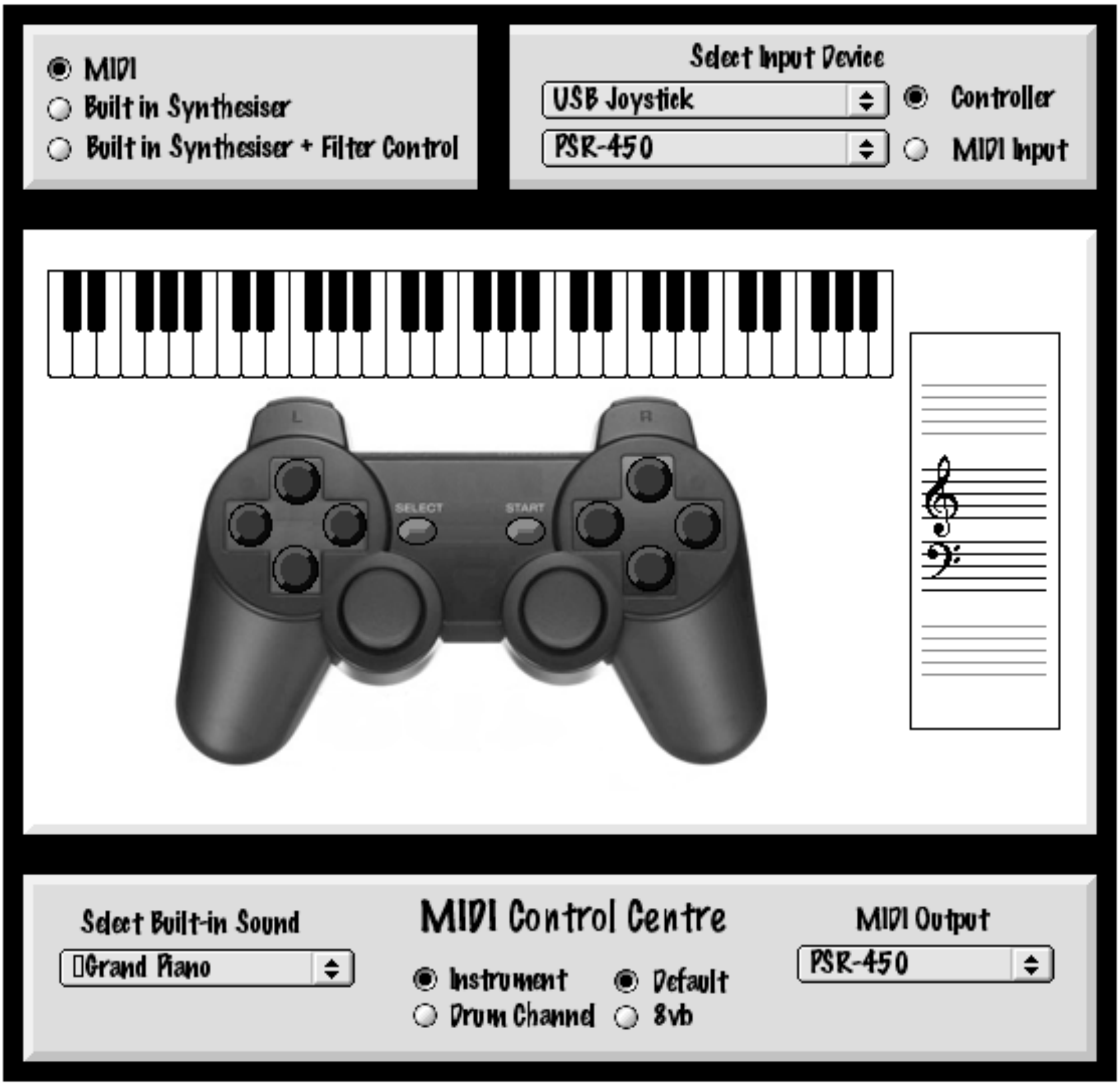

Figure 3.5 Software interface for the Initial Pilot Project.

The game controller and pilot software were first introduced and demonstrated towards the end of a music lesson. The rationale behind introducing the pilot project in this way was to emphasise the fact that digitally native technology, such as a game controller, affords the opportunity for pupils to bring their own controllers in from home, and this was needed so as to ensure that there were enough game controllers to go around in the pupils' next music lesson. The popularity of 'bring your own device' (BYOD) schemes was detailed with relation to portable computers and tablets in chapter two, with such an approach increasingly taken in schools so as to ensure adequate provision whilst also outsourcing the cost of technology. The benefits pertaining to the use of game controllers within an educational setting are that they are comparatively inexpensive (when compared to tablets and personal computers), and so Stager's (2011) concerns relating to affluence and disadvantage of BYOD schemes, were able to be mitigated against here. Given that there are numerous Playstation controller copies from third party manufacturers available, enough controllers were able to be purchased in order to ensure that there were enough controllers available for each pupil in the class to have access to one.

The first music lesson following the announcement of the project saw a heightened sense of 'buzz' as a large percentage of students brought their game controllers to their music class. The created bridging software had been already loaded onto every music workstation, and as students were continuing with previously started compositions, once the instruction for how to use their game controllers had been delivered, the pupils returned to progressing with their compositions. Aside from the offering of technical support, this pilot project was deliberately non-interventionist, so as to ascertain and observe natural decisions made by pupils regarding their perceptions of using the controller to support their composition progress.

3.12.1 Pilot Project Findings

Interestingly, this pilot project saw all pupils continue within their previously started compositions using the game controllers as their performance interface to start with, but this did not last long. A number of pupils made a clear decision to switch back to using keyboards to formulate and input their musical ideas very quickly. Interestingly, the pupils that did this straddled both camps - those who had previously self-identified as enjoying using keyboards in music lessons, and those who did not. For those that self-identified as not enjoying using keyboards, this raises an interesting question. Perhaps keyboards are indeed not the problem, with the main issue located in a much wider perspective on the value the pupils place on music education. This has deep connotations for this research, and these pupils were identified as needing careful questioning as the project developed in order to ascertain the answer.

The pilot project did reveal a number of technical problems that were clearly evidenced from the pupils requiring technical support. An all too common occurrence was stuck notes. Within the MIDI domain, a note on message triggers the start of a note, and a note off message (normally received when a key is released when using a keyboard) turns the note off. If a corresponding note off message is not received, then the sound producing circuitry found within a MIDI compatible hardware instrument, or a software instrument in the case of a DAW, continues to sound indefinitely. The use of the shoulder buttons to sharpen or flatten a note, or change its octave, meant that often, in changing a button configuration, the correct note off message was not received by the host DAW. Given that all available notes on a keyboard are presented as readily available, with a single key representing a single note, this is not usually a problem. When a small number of buttons represent a range of possible notes on a game controller, then this problem is heightened, and therefore needed addressing in the future technology developments.

The use of a game controller revealed that whilst it was now very easy to play a small set of notes – notes found within an octave of a C major scale, developing a new performance interface highlighted how versatile the piano keyboard actually is – the fact that multiple notes can be played at any one time, that there is a clear ordering of notes, and that there is no limitation to a single scale. Clearly all of these functions needed to be present in a developed interface in order to provide for 'sustainable progression', a term coined by Machover (1992) as a strategy for providing a fast-conceptual understanding with enough depth to reward a user's improvements in performance over time (Machover 1992). Whilst arguably all of these functions were present in this initial software version, I realised that I had failed to create anything new! If anything, the logical octave pattern found on the keyboard was now hidden, and while playing in the key of C major was straightforward on the Playstation controller interface, any note outside of this scale (or indeed a note from an octave higher or lower), now required multiple buttons to be pressed, instead of simply one key on the keyboard. For example, to achieve the note Bb below middle C, the user would need to press the button representing B on the controller, a right shoulder button to flatten the note (taking the B to Bb), and a left shoulder button to ensure that the Bb was in the lower octave (resulting in the Bb below middle C and not the Bb that features above middle C).

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4 Findings: Action Cycles Two and Three

My experience of teaching music in schools aligns with the findings of Savage (2010), specifically the use of keyboards as the most dominant method of musical instruction. In line with the pupil in Patterson (2000) who felt that their composing improved as their ability to play their instrument improved, there is arguably much common sense, certainly at face value, in focusing musical instruction through a single instrument. The skills gained can then support all three of the core practical elements of performing, improvisation and composition that have consistently been positioned and interrelated, in published national curricula spanning a number of years. Some of the schools that I have worked in or visited have indeed adopted this approach as the basis and rationale for the use of keyboards in every lesson (School B), with learning activities designed in order to form and then apply developing keyboard skills. By contrast, other schools appear to vary their approach, with less explicit connection made to learning the keyboard itself. Approaches in these cases include providing pupils with note strips that are placed above or below the keys to act as an aide-memoir of where the notes are, through to allowing pupils to write the names of notes on the actual keys with a whiteboard pen (both these examples occurred regularly in School A). Where these approaches occur however, notable problems were regularly observed. Pupils formed strong dependencies from their reliance on the note strips and would often be very unwilling to engage in keyboard activities without them. These note strips would also often become dislodged from their position, resulting in pupils not actually playing the notes they thought they were, but without the knowledge to realise the situation; this was much more of a problem in lessons where pupils were trying to learn basic melody lines for example. I also observed pupils writing the wrong notes on the keys, naturally resulting in similar scenarios.

For those pupils receiving instruction into the layout of the keyboard, it was clear that through regular reinforcement, pupils gradually began to grasp the logical octave pattern – the white keys of course only representing a very small proportion of the alphabet which all pupils when asked could easily recite without trouble. For those reliant on note cards or other means, significantly fewer pupils appeared to recognise any logical pattern at all. This could be to do with the types of keyboard melodies learnt – often not spanning much further than an octave. A common observation was that whilst pupils might play the correct notes, some notes would often be in the wrong octave because their note card perhaps did not stretch up to the next D for example, hence they would play the D in the lower octave, or where the note D was located on the note card.

The findings from the pilot project provided a foundation to build on from, for this action research. With regards to the research questions posed, there was a clear motivational gain from the prospect of using a digitally native product, this was evidenced in the buzz that was created from the initial introduction of the controller in front of the music class, and the fact that pupils who were able to, remembered to bring their own controllers in from home for their next music lesson. It was interesting to note that the prospect of using a PlayStation controller in the pilot project sparked informal discussion amongst pupils about whether alternative controllers from competing games consoles were 'better' controllers, and arguably connects to how pupils view their gaming interactions as influential within the forming of their own identities (Scholes et at 2021).

Blaine (2005) provides a useful introduction to the use of 'alternate controllers' – designs which Wanderley and Orio (2002) position as not following that of an existing instrument. This formed the basis of the next line of inquiry which focused on seeking to build on the limitations of the pilot project. Given that a conventional keyboard provides access to all notes, a question was formed in order to support the answer to the latter two research questions of this project. Whilst keyboards are built upon a logical octave-by-octave pattern, how important (or indeed logical) is such a pattern to the novice keyboard performer? If a user can define their own patterns (and layout of pitches) does this improve their perceived engagement with such an interface?

4.1.1 Action Cycle Two - Building on the Pilot Project

Collaborating with the pupils from School B on ways to enhance the pilot project offered an effective way to move this research forward, and such an approach aligns closely with the process of action research. The use of 'alternate controllers' put forward by Blaine (2005) presented the need to investigate the typical usage of game controller functionality for users. Semi-structured interviews with a group of pupils keen to engage with the next steps of this project's development provided an opportunity to understand how pupils typically used game controllers in gaming. Indeed, the clear advice presented by the pupil group was to 'make the application of the PlayStation Controller for music more akin to physical gaming'. This interview also revealed that within console game play, certain buttons are used more frequently than others, for example the X button was argued as the most predominantly used out of the four interaction buttons represented by □ Δ X O. It was also revealed that the two thumb sticks tended to be classed as very important within gaming, and that these had been largely overlooked within the pilot project.

The pilot project revealed that in its current format, the combinations of button / key presses needed to achieve certain notes was more akin to certain conventional instruments (such as a trumpet) rather than drawing influence from game play. Whilst the pupils acknowledged that the functionality of buttons was not necessarily an 'exact science' for every game, there was certain functionally that could be considered typical. The findings of this pupil discussion are summarised in figure 4.1.

Controller Element: A
Description: Directional Buttons (known as the D-Pad).
Typical uses as explained by pupils from School B: Can be used with the thumb sticks, used to move around, but it is more normal to use the thumb sticks to do this now. Often used for moving through (navigating through) menus.

Controller Element: B
Description: Option buttons (Start / Select / Pause)
Typical uses as explained by pupils from School B: Pause game, or bring up a menu to save, or adjust settings. These buttons are not typically used in game play.

Controller Element: C
Description: Square, Triangle, X, Circle (□ ∆ X O)
Typical uses as explained by pupils from School B: Main buttons for interaction – jump, pass a ball, fire weapons etc (a number of examples from specific games were given).

Controller Element: D
Description: Thumb sticks / Analog Sticks with buttons (also known as L3 for the left stick and R3 for the right stick).
Typical uses as explained by pupils from School B: Used to move around or look around, the perspective of what the game player sees, can be used to manipulate the camera in some games. Some games make use of the fact that these can be pressed as well. Adds further functionality.

Controller Element: E
Description: L1, R1 Shoulder buttons
Typical uses as explained by pupils from School B: Used in addition to the square, triangle, X and circle buttons – adds further interaction options.

Controller Element: F
Description: L2, R2 Trigger buttons
Typical uses as explained by pupils from School B: Commonly used in games where there is a need to fire weapons, often as part of 'taking aim'.

Figure 4.1 PlayStation Controller functionality summarised from the explanations given by pupils in testing school B.

Whilst I was interested harnessing such logic, to better align the controller for musical performance in a way more akin to physical gaming, I sought to also unpick Blaine's observations with the pupil group that 'the very notion of using a controller to "win" a game rather than being "played" as a musical instrument runs somewhat contrary to the notion of a musical interface designed for novel performance.' (Blaine 2005). The semi-structured interview also provided a good opportunity to discuss with pupils (from a blue-sky thinking perspective) the sort of functionality that should be present on a 'new' instrument, in order to make the controller feel more musical. This discussion also offered the opportunity to highlight the functionality and flexibility found on conventional musical instruments, including the keyboard, and offered the opportunity to try to understand what the perceived challenges were with the keyboard, that pupils faced.

The examples provided by the pupils in the pupil group regarding the use of the keyboard in music lessons were interesting, as their perspectives mostly all offered a point of comparison – right compared to wrong in terms of notes, a struggle to play 'in time', compared to not being able to, and from a compositional perspective a sense of feeling unable to create 'authentic music' compared to what they liked to listen to. The following are some of the individual statements from the pupils from School B where the pilot project had been carried out, that exemplify these positions:

> "I'm not very good at playing the keyboard. I find it hard to play the right notes when we have to play in class."
>
> "When we are learning melodies, if we are learning one that I know, or have heard of before, I find it hard to play the melody the way it should be. I know how it should sound but I find it difficult to make it sound the way it should, it's often really slow, and I find it frustrating, I just want to be able to play what I hear in my head."
>
> "When we are composing music, I always feel that my ideas are simple, compared to the music that I like listening to. I struggle to make music that I like."

What struck me with these perspectives, was the clear sense of awareness that the pupils had with the problems that they perceived they faced, and this offers a connection back to the motivational theory presented in chapter two relating to 'flow' and the work of Csikszentmihalyi (1992); that the ideal learning state is one that combines high levels of challenge with low levels of stress. Arguably in these perspectives, the required high levels of challenge were present, and the pupils were acutely aware in their own minds as to what would constitute improvement, but the route through to such improvement was complicated - finding the correct notes in a sea of all notes available, just one example of something contributing towards a sense of raising levels of stress, and arguably stunting progression.

Whilst it can be argued that wrong notes and correct rhythmical timing clearly connect to accuracy of performing existing repertoire, a number of professional musicians take a different and more pragmatic view when it comes to improvising or composing:

"*There's no such thing as a wrong note*."
(Art Tatum)

"*There are no wrong notes in jazz: only notes in the wrong places*."
(Miles Davis)

"*To live a creative life, we must lose our fear of being wrong*."
(Joseph Chilton Pearce)

"*There are no wrong notes, only wrong resolutions*" "*I think of all harmony as an expansion and a return to the tonic*."
(Bill Evans)

"*There are no wrong notes on the piano, just better choices*."
(Thelonious Monk)

(Quotes cited in Arca 2008)

Byas embellishes on these positions and suggests a way out – a knowledge or ability to know how to make it right and a confidence to keep going:

> There is no such thing as hitting a wrong note. It's just that when you hit that wrong note, you've got to know how to make it right … you just keep weaving and there's no way in the world you can get lost. You hit one. It's not right, you hit another … As long as you keep going you're all right, but don't stop, because if you stop you are in trouble. (Byas cited in Taylor 1993:52).

Whilst this is undoubtedly good advice; accuracy, timing and confidence as the antidote to 'wrong' notes is arguably of little help to a pupil still forming these skills in their own mind. The pupil comment cited in Patterson (2000) in chapter two regarding the sense that their composing improves as they get better at playing their instrument again chimes well here, and I was keen to draw on the perspectives presented by the pupil group with regards to wrong notes and timing. The challenge of performing correct notes, and performing in time with a sense of rhythmic accuracy appear to be the key performance attributes that act as barriers.

Whilst the way to achieve certain notes on the PlayStation controller in the pilot project, especially those that required the use of shoulder buttons to flatten, sharpen or change octave, resulted in button configurations that were not particularly common to gaming situations, the ease in which the C major scale could played, due to it being the default scale assigned to the D-pad and □ ∆ X O buttons, provided a good opportunity to focus a user's experience around only a small number of buttons.

On face value, a keyboard is much simpler to use; there are no elaborate combinations of key presses that are needed to trigger notes, all notes are equal in how they are triggered, and all notes are available and ready to be used at the performer's discretion. A game controller is at a clear disadvantage in terms of the number of buttons available for use. However, the findings from pupil observations and also the responses from the pupils in the semi-structured interview suggests that it is arguably the provision of many keys (spanning numerous octaves) that evokes fear on some level, causing panic, clouding a novice's ability to see the patterning behind the design. This is similar in a way to a novice approaching a mixing desk – the commonly perceived concept that because a device contains multiple faders, buttons and dials, that it must be complicated, when actually there is again a clear pattern, and once the parameters of one channel strip are understood, then the rest of the channel strips generally are also.

By making the eight buttons on the face of the controller (the D-pad and the □ ∆ X O buttons) able to be re-mapped, specific harmonic language and scales could technically be applied to these buttons by the user, and importantly offer the opportunity to scaffold learning through temporarily constraining the available harmonic language (removing perceived wrong notes) in order to support other areas of musical development such as timing. This also places the localising of the mapping of button triggers to notes in the hands of the user, and enables further flexibility to 'map' the controller in a way considered preferable to an individual, giving some scope to the user to map the controller in a similar way to how they might use the controller for gaming for example, if such an approach is preferable.

The release of the next generation of the PlayStation controller (version 3) brought further analogue control to each of the directional buttons (D-Pad) and all of the interactional buttons on the face and rear of the controller, enabling them to respond to varying degrees of pressure, as well as gyroscopic and accelerometer functionality, enabling the controller to report its movement within physical space. This additional analogue control afforded to the buttons as part of the next generation release provided the opportunity to harness this functionality, in order to support performance expression from the touch sensitivity of these buttons.

Action cycle two therefore focussed on:

1. Enabling users to assign the notes they wanted to use to the 8 buttons (D-pad and □ ∆ X O) on the face of the PlayStation controller, enabling the production of a custom scale of the user's choice, with each note from the created custom scale able to be placed on a button of their choice.

2. Enabling users to select a scale from a list of pre-sets, with all the notes from the scale then assigned to the eight buttons on the face of the controller. The pre-set options included all major and minor scales, all modes (with the user able to select the starting note of each mode – eg Dorian on G), and 'special scales' such as blues scales, diminished and whole-tone scales, again with the user choosing the start note. The software program would then work out the required intervallic relationships to provide the scale.

3. Seeking to support user's musical expression though the use of the PlayStation 3 controller's pressure sensitive buttons incorporated into the release of this controller.

4.1.2 Action Cycle Two – Software Realisation

Figures 4.2 to 4.7 show the revised software providing the user with six layers of functionality to be able to navigate through, although only one layer is visible on screen at a time. Navigation between the software layers was achieved through pressing the play button on the face of the controller. This button toggled between the play mode (where the controller was used to trigger notes) and a settings mode where parameters could be selected and changed, for example changing a note assigned to a button, or a scale pre-set. This approach sought to align further with traditional game controller use, where everything is controlled using the controller, and therefore removing the need to also use a mouse.

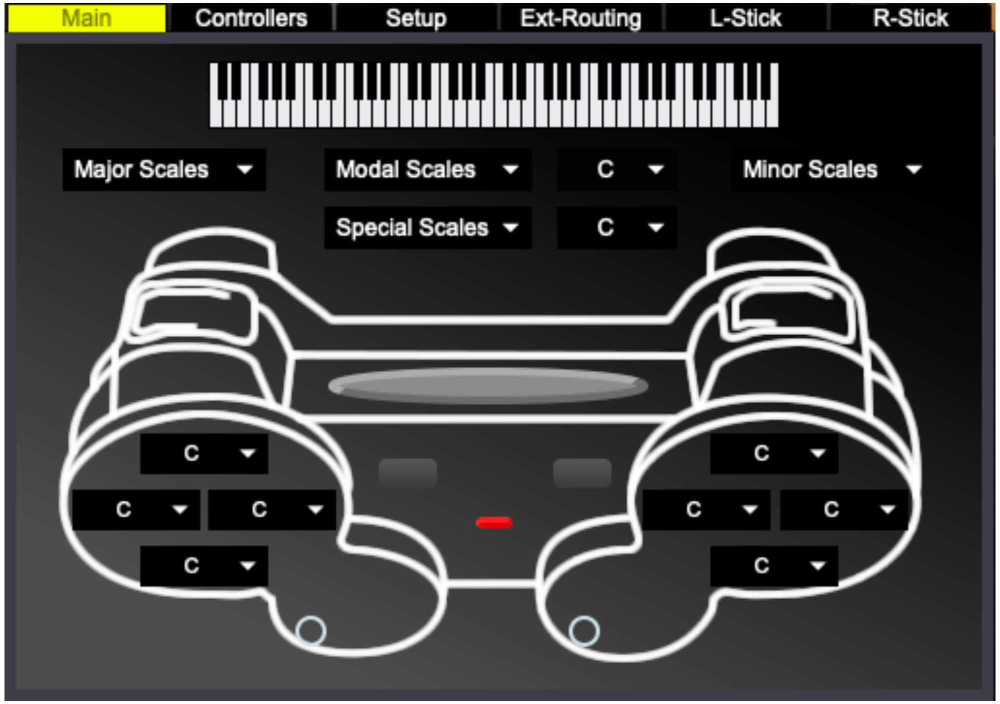

Figure: 4.2 – Action Cycle Two Software - Menu Label: Main

Drop-down menus above controller image provided scale pre-sets to choose from, and audition. Once a pre-set is selected, the D-pad and □ ∆ X O buttons display the notes from the chosen pre-set scale. Notes can also be set from the D-pad and □ ∆ X O buttons so as to enable the user to choose where notes were situated, or create custom scales. Pressing L1 and the note on the D-pad or □ ∆ X O raised the note by one octave. L2 lowered by one octave. R1 sharpened the note by one semitone, R2 flattened by one semitone.

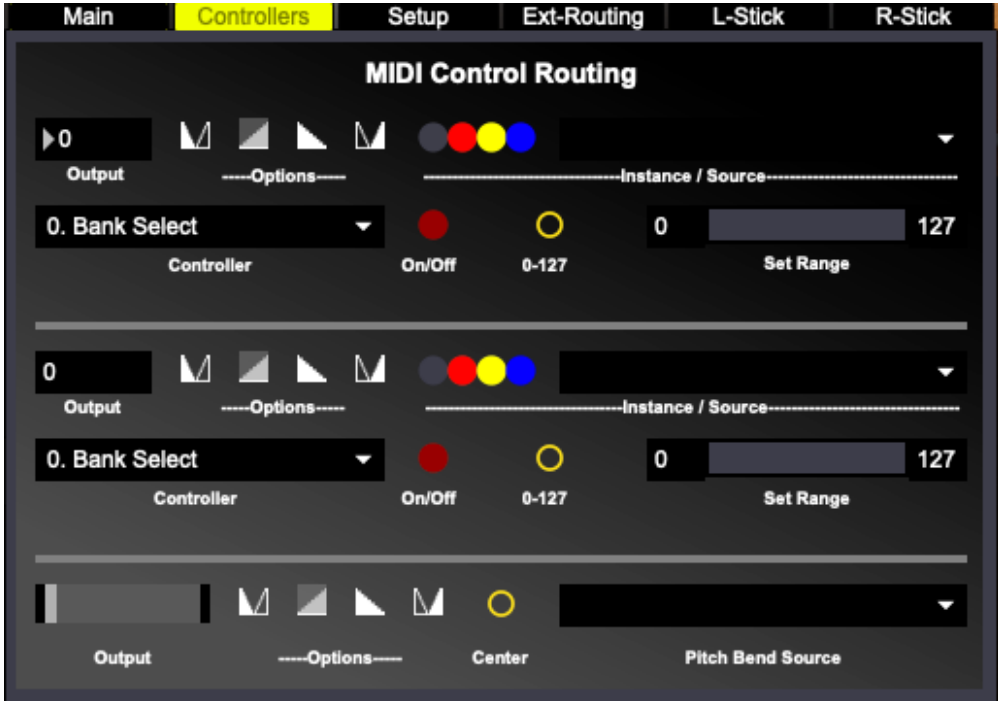

Figure 4.3 - Menu Label: Controllers

Enabled MIDI control change data (parameters to support musical expression) to be mapped to buttons (PS3 controller only) or the thumb sticks (all controllers). The user could make use of the full MIDI range (0-127) or constrain the controller data to a smaller range. Options for the thumb sticks enabled the mapping to be set within the range from the centre outwards (the thumb sticks by default rest in the middle) or be applied to the full range across the left to right, or top to bottom. The parameters at the bottom of this page set the control of pitch bend (which sends a two-byte message, compared to a standard Midi control change message, which sends only one).

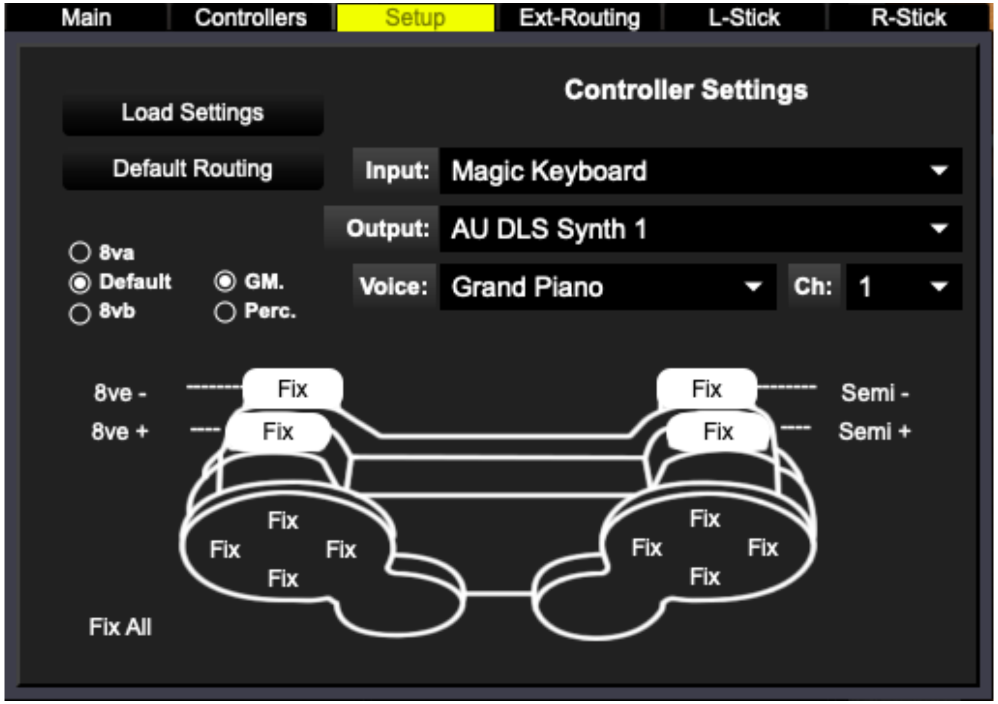

Figure 4.4 - Menu Label: Setup

Enabled the setting of the input controller and output routing (to the computer soundcard, digital workstation, or connected MIDI device). Set-up files are also loaded in here, which contain the controller mappings for each parameter. Default or External routing (see figure 4.5) is also specified here. 8va / 8vb options enable the user to select the tessitura of the controller, raising or lowering the default position by one octave, or mapping to percussion (using MIDI channel 10). 'Fix' on a per button basis, or applied to all buttons, enables controllers with pressure sensitive capable buttons (such as the PS3 controller) to output a fixed velocity.

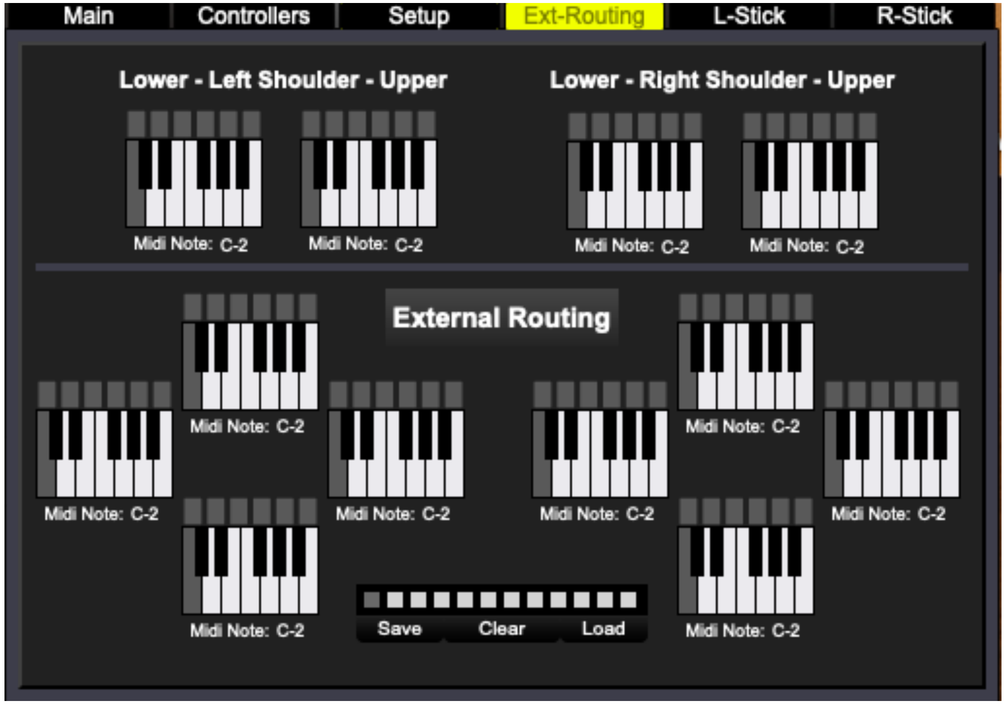

Figure 4.5 - Menu Label: Ext-Routing

The External Routing page, which enables all buttons on the face of the controller and the shoulder buttons to trigger a specific note. One example where this is useful is in the triggering of percussion, where individual drums and other percussive instruments are assigned to a single note within the MIDI specification. The boxes above the keyboards enable the specifying of the octave, with the keyboard diagram providing the relevant note in that octave. Pre-sets can also be created, saved and recalled using the blocks above the save, clear and load buttons.

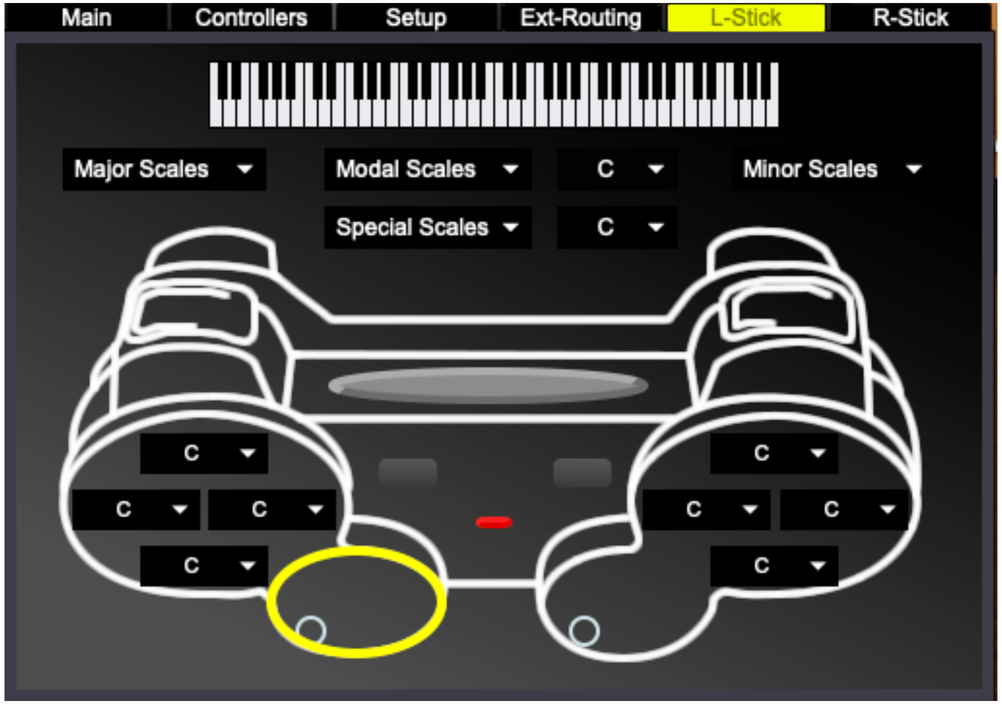

Figure 4.6 - Menu Label: L-Stick

Triggered by pressing down on the left thumb stick. This provides the opportunity for another scale pre-set or custom scale to be auditioned and applied to the D-pad and □ Δ X O buttons, and then recalled by pressing the left thumb stick down again. This enables the user to be able to use and move between differing scales.

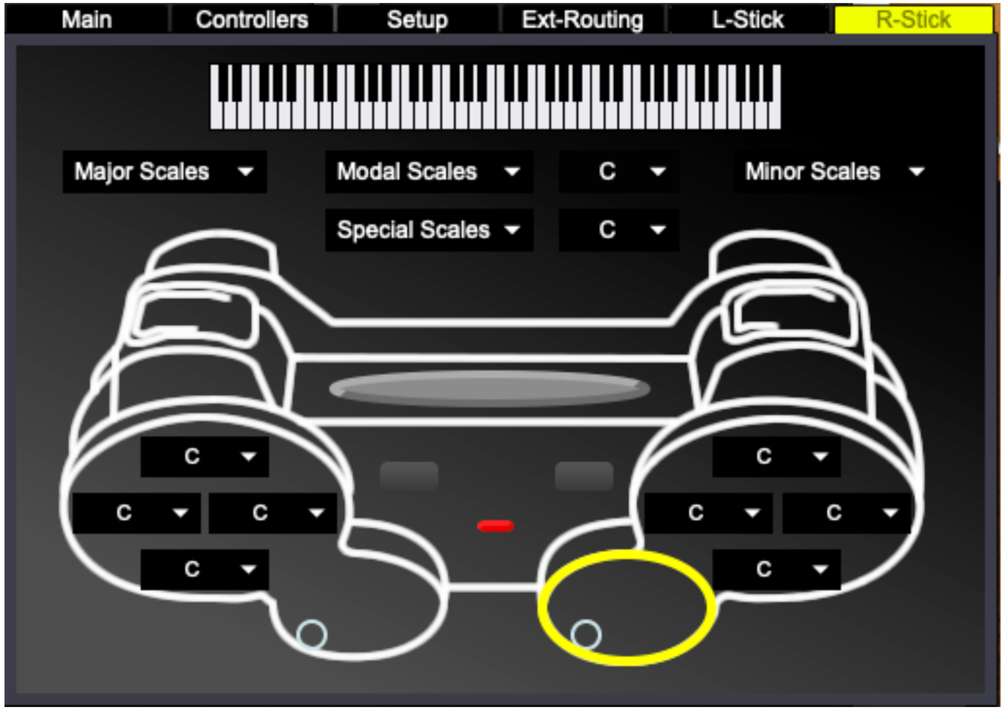

Figure 4.7 - Menu Label: R-Stick

Triggered by pressing down on the right thumb stick. This provides the opportunity for another scale pre-set or custom scale to be auditioned and applied to the D-pad and □ Δ X O buttons, and then recalled by pressing the right thumb stick down again. This enables the user to be able to use and move between differing scales.

4.1.3 Action Cycle Two – Approach to Development

This action cycle was tested across two schools with a total of 66 pupils from key stage 3 involved. One class was from testing school B, the same school where the original pilot project had taken place, but a different class to those pupils involved in the pilot project, and another class from testing school A. As part of introducing the controller and software, I explained that the controller was not being developed as a replacement for the keyboard but was simply an alternative tool for composition and performance. However, I was keen to also include pupils who were competent on the keyboard in the testing process so as to observe whether the ability to define the placement of notes could be of benefit to them also, or if it was simply an un-necessary distraction.

Pupils again had access to a controller each, but this time the controllers that they brought in from home were a mixture of the newer version 3 controller (that benefitted from the additional analogue and pressure sensitive capabilities applied to each button as well as gyroscope and accelerometer functions), the older version 2 controller (in which the two thumb sticks were the only analogue controls available, providing up and down and left and right movement, but no pressure sensitivity), and various third-party versions of both controllers (which had a varied amounts of additional control, often somewhere between the capabilities afforded between the branded PlayStation 2 and 3 controllers). There is no standardised framework for controller functionality communications across manufacturers, and this lack of a framework leads to complications when attempting to integrate controllers designed for a specific console platform with Windows or Mac based machines, and the various operating systems that exist with these platforms. There are arguably two options underpinning the development process at the start; one is to develop software for a specific controller, an approach akin to the games industry, where there is a single controller that is developed for a console, or to seek to develop software to enable a range of controllers to be used. There are a number of advantages and disadvantages to both options, as presented in table 4.1:

	Advantages	Disadvantages
Develop software to respond to a specific game controller.	• Enables the set-up process to be built in to or automated within the created software. • End user is not required to engage in a set-up procedure. • Functionality of controller is consistent and the same for all. • Reduces the potential for technical problems by limiting the number of technologies in use.	• If employing a BYOD scheme then using a specific controller potentially limits the number of pupils who can engage. • A Limited number of pupils who can engage leads to potentially unethical barriers to entry being created, eg cost of ownership/ affordability not viable, leading to pupils feeling discriminated against. • Potential high cost of a class set if not adopting a BYOD approach - a challenge on tight department budgets. • If the next release of console / controller not supported, leads to software slowly becoming obsolete over time.
Develop software to respond to any / a range of game controllers.	• Enables a broad range of controllers to be used. • Offers more scope for future proofing regarding later versions of the controller. • Cheaper controllers may be able to be sourced to supplement the numbers of controllers available (listed as an advantage for cost purposes).	• Functionality of the controller is likely to vary across the range of controllers used. • Potential for unethical barriers to entry to be created if controllers have differing levels of functionality – cost of ownership / affordability not viable, leading to pupils feeling discriminated against. • User needs to be involved in a set-up process so the software can learn and map the data from the controller. • More potential for technical problems due to using controllers from a variety of manufacturers, or from the extra complexity introduced through the need for a set-up process.

Table 4.1: Comparative advantages and disadvantages of developing software for a specific game controller, or range of game controllers.

For this action cycle, developing the software to respond to any compatible controller offered the most scope to generate broad findings, including perspectives from teachers regarding the extra complexity through the user element of the controller set-up process, and this was the route taken.

A necessary set-up procedure (completed via a created set-up utility) was therefore required before the very first use in order to set parameters from the controller to parameters within the developed software. This was in order for the created software to learn the data received from each button press or thumb stick movement, and to save a preferences file so that the learned data could be simply recalled at the next time of use. In the pilot project, the set-up procedure had been a very quick process, and required the simple pressing of buttons in a specific order given the simpler capabilities of the controllers used (there was no button based analogue control, therefore button presses reported only note-on and note-off data). The process within this action cycle took much longer due to the need to also capture the analogue data on a per button basis from the PlayStation 3 controller, and the fact that the analogue data across all of the other branded controllers was not within a consistent range. The constant stream of gyroscope data that outputs from the PlayStation 3 controller also meant that the simpler button press regime used in the pilot project could not be used, therefore each button address, and its corresponding data range, needed to be entered into the set-up utility manually.

4.1.4. Action Cycle Two – Initial observational findings from the set-up procedure

Though the use of controllers from differing manufacturers supported the BYOD approach, with substantially more controllers brought in from home than if one particular Playstation controller had been specified; it was very clear from the first observations that such flexibility with using a variety of game controllers from various brands, brought additional layers of technical complexity not usually found in the traditional music classroom. Whilst the set-up process needed to only be completed once, and then saved to enable it to be recalled for next time, it still took a number of minutes to get to the point where the whole class was ready to engage in music making. This use of valuable music lesson minutes taken to complete technical set-up tasks is arguably problematic, especially when considered against Ofsted's subject report focusing on quality and inequality in music education which revealed 'in too many cases there was not enough music in music lessons' (OFSTED 2012:4), and that 'students in less effective schools performed poorly because the main focus of teaching was on mastering the functional aspects of the technology, rather than seeking a musical response through the technology.' (ibid 36).

I was acutely aware in this initial introduction that I was there as an additional adult to support both the pupils with completing their controller set-up processes, and the music teacher in the room. None of the testing schools in this study had access to a music technician, and therefore outside of this research, additional adult support for completing the setting up process would likely not be available. I was concerned that the need to go through such a set-up process might be considered an insurmountable challenge by teachers, due to the time investment needed to set the controller up, and potential wider concerns that teachers might have, such as the potential for poor behaviour from pupils, whilst they were engaging in the initial setup process. This resonates well with the positions presented in chapter two by Wise (2016); Mills and Murray

(2000); Pitts and Kwami (2002) that teachers' pedagogical approaches are concerned with developing successful operation of software before creative work takes place, and from Uptis and Brook (2017) that without extensive support, new technological innovations were unlikely to be used to support student learning. Csikszentmihalyi's (1992) flow model also relates here: Clearly it is important when attempting to break barriers for pupils in order to support their learning through using a digitally native technology, that technical barriers for teachers are not built in their place. This highlights the need to counterbalance attempts to harness digitally native technologies that might lead to a positive experience for pupils, with a similar positive experience for teachers, or at the very least, extensive support so as to be able to deliver the positive experience for pupils.

4.1.5. Action Cycle Two – Initial observational findings from pupil use – the first session using game controllers

As was the case with the pilot project, there was the same sense of 'buzz' from pupils at the prospect of using game controllers in music lessons at their first introduction in both testing schools. However, whilst it was encouraging to see the idea of using a game controller continuing to spark initial interest, it was important to understand through initial observations, how the pupils used the controller, and through interviews the perceived impact on musical performance and compositional engagement, especially regarding the user's ability to define parameters to support bespoke approaches to learning.

The initial observations of pupils using game controllers with the revised software developed as part of action cycle two, revealed that pupils found recalling a pre-set scale very straightforward, and moved through the pre-set scales in order to audition a harmonic language that they felt sounded 'right' for the composing task that they had been set by their teacher. However, observations revealed that the pupils tended to stay in the confines of the first controller page, thereby confining themselves to the 8 notes from the loaded pre-set scale that they had selected, with only the additional ability to change octave or sharpen or flatten each note using the L and R shoulder and trigger buttons. Interestingly, no pupils in their first music lesson using the controller naturally experimented with the functionality to switch to a different scale or harmonic language through the pressing of either one of the thumb sticks in order to experiment with a broader palette of notes and scales to compose from. This was also the case for the controller settings page, where aside from recalling the controller settings and setting the output destination so as to hear audible output from the computer sound card, no natural steps were taken by the pupils to define expression, or effect parameters, in order to heighten the sense of musicality of playback. Those pupils that were using the PlayStation 3 controller were able to make use of the pressure sensitivity of the D-pad and □ Δ X O buttons, but those using controllers that did not have this functionality, were not able to. However, the pupils using the older controllers also did not attempt to add in expression control such as assigning pitch bend to one of the thumb sticks through the controller settings software page, meaning that all triggered notes were the same in terms of articulation, velocity and timbre. The external routing functionality, provided in the software layer to map a specific note from any octave to a controller button was also not used initially by pupils in their first lesson, but this page is particularly useful for triggering percussion, where a specific unpitched drum or percussive instrument is triggered, and the compositional task that had been set by the teacher focussed around the building of a melody line.

This was the first-time that the pupils were using the game controller and software, and was therefore a new experience. Further exploration of the functionality of the game controllers and software might naturally come to bear in future music lessons, however with such a large amount of the software and controller functionality naturally unused by pupils in this initial observation, this posed some interesting questions: Was the reason for pupils remaining within the confines of a single controller page on the software due to a lack of confidence to explore further? In essence, a deliberate decision made to remain within the relative safety of being able to play using a single scale with no notes outside of that scale (or 'wrong notes') able to be triggered accidentally? The concepts of scaffolding presented by Bruner (1984) in chapter two, building on the work of Vygotsky (1978) relates to the creation of support to enable pupils to do something that they find too difficult to attempt without such support. Didau however makes a compelling statement: 'we should never use scaffolding unless we have a plan for removing it' (Didau 2016:327), and suggests providing only the 'barest minimum of support to enable children to produce the very best work of which they are capable and then take away that support as quickly as possible' (ibid:327). This would therefore require monitoring in future observations so as to ensure that a comfort zone was not being created, stunting creative development, and actually limiting progression through pupils creating more formulaic compositions that were limited to a single scale. It was important to make sure that the game controller and software did not just offer a technological equivalent to the note strips, or the act of writing the notes on keyboard keys with a pen, and that it did not result in the forming a similar dependency for pupils.

In line with the original pilot project, pupils' informal conversations focussed around concepts connected to gaming, rather than on the compositional task in hand. This, coupled with the observations of the initial use, particularly the software functionality that was naturally unused by pupils in their first session, presents an interesting position when attempting to harness benefits from digital native technologies that pupils are accustomed to in a specific context (in this case gaming), to a different context. Prensky's (2001) positioning of a 'digital native', outlined in chapter two as a pupil who is naturally digitally literate, and proficient with using technologies, is arguably therefore too simplistic. The use of a game controller as a performance interface did not simply unlock the challenges pupils found with performing or composing in their music lessons, neither did it provide (in the first instance in any case) an adequate harnessing of gaming expertise that could be applied to performing music with the controller. Much research focusses around the design fundamentals and formal elements of game design (Salen and Zimmerman 2003, Macklin and Sharp 2016, Schell 2019), where a created context is designed to be encountered by the player of the game, from which meaning emerges (Salen and Zimmerman 2003). This was using a game controller, but not to play a game, and arguably presents a dichotomy of the two experiences, with no additional game-based context surrounding the use of the controller within the music classroom, or premeditated musical content to 'play with', so as to enable pupils to create original ideas from scratch. Smith et al (2020) provide an interesting criticism of Prensky's 'digital native', and offer an approach to take this action research forward, placing focus on effective use of technologies and developing an ongoing process:

> 'Problems can arise, perhaps even unintentionally, when we uncritically adopt the digital native stereotype – encouraging us to believe that, when technology is involved, learners will "just get it".'
>
> 'Whereas digital native advocates maintain that younger students already possess the knowledge and abilities needed for understanding and using technologies, the defining elements of digital literacies instead emphasise the importance of learning to effectively use technologies as an ongoing process.' (Smith et al 2020:3).

4.1.6. Action Cycle Two – Scheme of Work: The Blues - Testing School B

A year 8 topic on the blues in testing school B provided opportunities to listen to authentic blues music, and then discuss stylistic features of the blues with pupils in order to draw out responses for ways to integrate authentic stylistic elements into performing an improvisation. 'Note bending', and 'pitch bending notes up to the next note' were amongst the responses from the pupils during a listening and discussion exercise, and this, alongside a discussion on instrumentation, led to the teacher modelling the ideas put forward by the pupils, and using the game controller and software to demonstrate. When embarking on their blues improvisation task, all pupils used the blues scale pre-set, however the modelling of stylistic performance characteristics by the teacher, such as the bending of notes, resulted in pupils integrating this into their improvised performance. It was however interesting to note the differing approaches taken by pupils to map pitch bend to their controller. The most common approach taken by pupils was to apply pitch bend control to the vertical motion of one of the thumb sticks. The thumb sticks naturally rest in a centre position, therefore such an approach allowed pupils to pitch bend up and down in similar fashion to that of the pitch bend wheel found on a keyboard. Other pupils applied a similar approach, but used the horizontal motion of the thumb stick. Interestingly, some pupils using PlayStation 3 controllers experimented with assigning pitch bend to the pressure sensitive buttons on the face of the controller, effectively seeking to vary the amount of bend applied based the pressure applied to a held down note button, in a similar way to the use of aftertouch within the MIDI standard. This flexible approach enabling the bespoke positioning of parameters and functionality was precisely what I had hoped to see occur, and was the was the first example of pupils working in this way.

Individual pupil responses provided interesting feedback on the ability to map pre-set scales to the D-pad and □ ∆ X O buttons:

> I found the 'C Blues' scale preset the best because I couldn't play any wrong notes. Sometimes when I play the keyboard I forget where the notes are but this was not a problem on the Playstation controller. I thought my improvisation was good – I was relaxed and didn't have to worry about getting my notes wrong.
>
> (Pupil from testing School B).

This pupil's comment provides a direct relation back to the earlier interview session where pupils discussed the challenges they perceived with keyboards, and specifically their use of the terms ‘right’ and ‘wrong’ notes. Arguably by removing notes that do not feature in the blues scale, this pupil could work on developing their improvising by focusing on timing, use of rhythm, motific construction, and other aspects of their performance. All of these are key skills in improvisation and composition, but through temporarily removing some of the possibilities for error, opportunities exist to support development and skills in other areas. In this pupil’s case, the ability to constrain and map notes to buttons on the controller aligns well with Csikszentmihalyi’s theory of an ideal learning state – maintaining high levels of challenge but reducing the levels of stress. Whilst a pupil with more musical expertise might find this limiting, for this pupil there were clear benefits resulting in the development of skills in improvisation, and a growth in confidence that could be harnessed, transferred, and built upon, in future musical tasks.

In the music lessons that followed, it was interesting to note that the process of defining and mapping notes to the D-pad and □ Δ X O buttons appeared to provide a useful reinforcement exercise for pupils, especially those who had indicated that they found performing on keyboards challenging. As pre-set scales were required to be recalled, or custom scales required to be created and mapped prior to the Playstation controller being used as an interface, this physical action appeared to help cement the position of notes on the controller into the short-term memory of the user. With music lessons in testing school B only forming one hour of a key stage 3 pupils’ weekly timetable, this supported the consolidation and revision of previous learning from the previous week’s music lesson, in order to progress further.

Outside of scheduled music lessons, the teacher from testing school B reported a desire from some pupils to continue using the Playstation controllers in order to make music over lunchtimes. It was clear that there was a group of pupils who felt that performing and composing music had become more accessible, and that this had in turn seen an uplift in motivation and self-desire to improve.

> With the blues backing track on our school network, some pupils asked to borrow the [PlayStation] controllers at lunchtime. They loaded up the track and continued to improvise over it. As the controller worked with Cubase, some other students then began making their own backings from scratch, using the controller to do this.
>
> (Teacher comment from Testing School B).

4.1.7. Action Cycle Two – Scheme of Work: Popular Music – Testing School A

A year 9 topic on popular music enabled the game controllers and software to be trialed in another school setting. The first part of this particular scheme of work attempted to harness pupils' abilities to recognize a selection of popular melodies, the idea being that this recognition would therefore support a self-awareness of note and rhythmical accuracy. Pupils then embarked on learning to play popular melody lines from traditional notation, with the melodies differentiated by complexity. This activity would then help support a compositional approach towards creating a popular melody line, whilst also drawing in further listening and discussion opportunities surrounding popular hooks, riffs and motifs. In previous years, this whole activity was completed on keyboards, but this year the teacher had booked the centrally bookable ICT suite and the controller software had been loaded onto the computers in there. As there were no computers in the music room for student use, this was the first time that computers had been used in music lessons for creating music. The computers in the ICT suite had no additional music software installed (software such as digital audio workstations, or sound sets), but the controller software could play the built-in general midi sounds on the in-built computer sound card, and this therefore provided the sound output for the pupils embarking on learning and performing the differentiated popular melodies element of this scheme of work. All pupils had access to a computer and a game controller each.

The first lesson in the ICT suite was a very different music lesson to what would be considered 'normal'. With keyboards but no headphones as the sole resource for usual class music making, classroom music lessons in testing school A were usually loud - with the teacher describing this first lesson as 'eerily quiet'. Whilst there is an argument that 'music lessons should be filled with singing and the playing of instruments' (Arts Council England 2016:6), there was some very interesting behavior that was observed within this first lesson. As all pupils had their own computer, game controller and some desk space, it was very interesting to observe an almost score study session taking place, with pupils working through the notes of their chosen popular melody, but with a number of differing approaches taken. Some pupils went through each note in the notation and applied each note to a button on the face of the controller, and pressing the thumb sticks to access additional layers of the buttons on the face of the controller to apply notes to. Some pupils arguably took a more enhanced approach, and found out the key of the melody line they had chosen. Interestingly, some pupils made use of the fact that they could search the internet to do this, before selecting the corresponding scale preset to work from. Many of these pupils then used the extra layers that were available through pressing the thumb sticks to assign and access the notes that were not found within the key scale. Other pupils realised that the same result could be achieved through pressing the right-sided shoulder and trigger buttons to raise or flatten by a semitone.

The variety in the approaches taken to achieve a musical response in this first session offered further evidence that the ability for pupils to define or experiment with a bespoke approach to learning can be of benefit. Whilst there was clearly the need for further prolonged engagement with the game controller and software, in order to ensure credibility, and mitigate against any hawthorne effect (this was the first time that the pupils were using the game controllers and using computers in school music lessons to create music), I felt at this stage, from a digital literacy perspective, there were opportunities forming for pupils to share their rationale behind their approaches to using the game controllers and software with each other, and opportunities for teacher-pupil exploration and discussion around seeking out musical solutions, providing ways to integrate and apply music theory in order to hone the natural approaches taken by pupils.

The music teacher's response from testing school A arguably exemplified the findings of Pitts et al (2002), concluding that the limitations of hardware / software adversely affected their desire to use ICT for music composition.

> The major strength of the game controller and software for me was the fact that I could make music technology portable. We were up and running quickly [in the ICT suite] – it would have been a logistical nightmare to have taken all the keyboards up to the suite'
>
> (Teacher comment from testing School A).

Taking the keyboards up to the ICT suite would indeed have caused significant logistical challenges. The keyboards in the music room were not MIDI compatible, and therefore could not be connected to the computers in any case.

4.2. Action Cycle Three – Chord Integration and Ensemble Opportunities

The teacher comment from testing school A, regarding the music lesson being 'eerily quiet' resonates with the findings of other connected research, namely: An over-reliance on individual work on the computer restricts social interaction (Wicks 2008), and that headphones can contribute to an isolated musical experience (Hodges 2001).

In my own teaching experiences, I tended to see music technologies, or electrically powered devices such as keyboards, as supporting individual work, and more conventional (acoustic) instruments as supporting ensemble work, although I do recognise that keyboards are commonly also used in bands. However, as identified in chapter two, commercial attempts to blur this distinction at a controller level, have previously been made through products such as *Rock Band* and *Guitar Hero* to specifically target the scope of the band ensemble through the creation of controllers modelled on rock band instruments. The developers behind these products had clearly seen the power of social interaction, and ensemble creation as a way to enhance user adoption, and sense of 'band reality' in their more music focussed gaming products. For this action cycle, I was keen to explore possibilities to support ensemble provision using the game controllers. This required the software layer to be modified in two ways.

The first modification was to provide a chord module, modelled on guitar chord voicing, to enable chords, instead of notes, to be assigned to the □ ∆ X O buttons on the face of the Playstation controller.

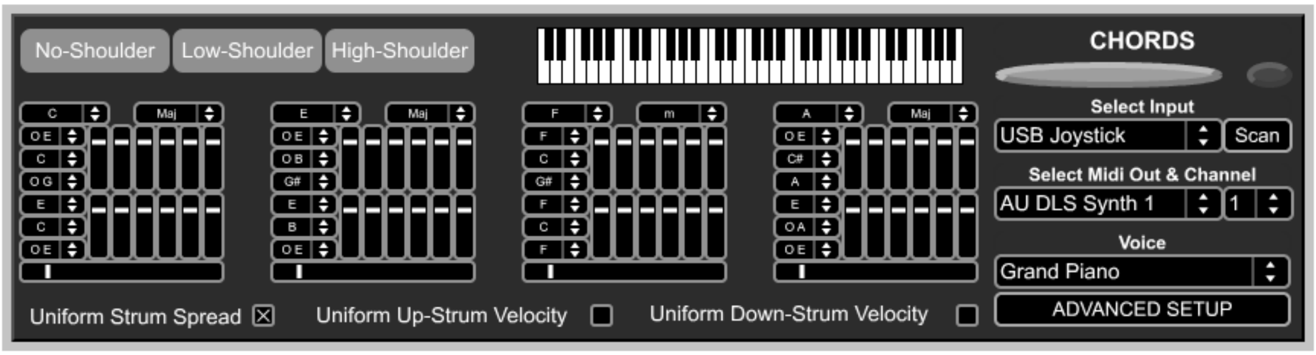

Figure 4.8 – Action Cycle Three - The created software layer for chord use.

Pupils could design custom chords and assign these to the buttons, or select from a range of pre-set chord voicings: maj, sus4, 6 6/9, maj7, maj9, m, m6, m7, m9, m11, m13, m7b5, dim7, 7, 7sus4, 7b5, 7#5, 9, 9sus4, 9b5, 9#5, 13, for any root note. The L1 and L2 shoulder buttons (at the rear of the controller) allowed for the chord to be triggered as an up-strum or down-strum, and the thumb stick position enabled control over the speed of the strum. The R1 and

R2 shoulder button provided additional pages to enable additional chords to be defined and set up, enhancing the number of chords available for triggering.

The second modification to the software was the creation of a multiplayer / band mode, where a single application could host multiple instances of the new chord layer and existing software layers from action cycle two. Multiple controllers were able to connect to a single computer via a USB hub, with each band member still able to use their own controller to build up their own custom scales and chords, or recall pre-sets independently. This represented a key difference to the common keyboard-computer set up found within the music classroom which does not easily promote ensemble interaction - pupils can work in pairs or small groups, but frequently need access to the same, single connected keyboard. With each controller also assigned a different MIDI channel, recordings of performances and compositions were able to be captured onto separate tracks in a host sequencer, where standard editing and other DAW-based procedures such as quantizing could then be applied if necessary.

Across the testing schools, there were a number of very interesting behaviours observed within this action cycle. The creation of an ensemble or 'band' suddenly promoted detailed and focussed conversation between pupils / members of 'the band' around music, and away from being more centred around games or gaming, as had been the case in the pilot project. Where music rooms were previously 'quiet' due to music being heard privately through headphones, pupils were now actively commenting on each other's creative work. They were listening to each other, working out the best way that the bass line would fit with the drums, they were debating whether a chord sequence actually went with the bass part, they were working out where section or textural changes were needed to ensure what they were making was not too repetitive. They were also creating melodies that would interlock with the backing parts, as well as suggesting a range of other things that could be tried out. Interestingly, they were also discussing perceived best ways of assigning notes and harmonic language to the controllers themselves. Josh, a pupil from testing school B made a very interesting comment when I asked the pupils to reflect on the process undertaken in their group compositional performances: 'It was cool, like playing a multiplayer computer game' he said. The use of game controllers within school music lessons was transitioning from novelty to more common place, and I felt it was through this action cycle, and specifically the conversations that ensued from the multiplayer element that were really starting to push the project forward. The tentative approaches to using the controllers and software observed at the beginning of action cycle two had subsided, and pupils were in the main attempting to take ownership, and striving to break down learning into manageable steps, buoyed on further through opportunities for collaboration and conversation.

Choosing which notes were mapped to the buttons on the controller seemed to serve as a positive subconscious memory re-enforcer, and I felt that this was improving the learning experience for pupils who had previously relied on note strips for locating notes on the keyboard. Equally, it was clear that one of the continued strengths of the project was the opportunity for pupils to 'audition' harmonic language through the experimentation with pre-set scales, and this was further enhanced with the new chord layer. This appeared especially significant when pupils had been set a compositional task to evoke specific moods in testing school A. Observations revealed that by trying out or 'auditioning' chords and scales, pupils were able to evaluate them against their own pre-defined conceptions before deciding whether or not to draw from them in their mood compositions by assigning the chords or notes to buttons on the Playstation controller.

Aligned to the concept of pupils taking greater ownership, and being able to define their own individual approach to note and parameter positioning on the controller, it was interesting to see examples of pupils broadening the scope further to include other instruments in their learning process. Indeed, the addition of chord possibilities actually led to an observation of a compelling sequence of pupil-led learning. Andrew, from testing school B who received weekly keyboard lessons, built up a jazz chord sequence, using the controller and software, and a selection of complex chord pre-sets. Andrew was developing as a keyboard player, but given his current level of keyboard skill, experimenting and auditioning the chords on the keyboard alone would not have been possible. What was most interesting however, was observing Andrew writing down the notes that built up each chord in the sequence he had created using the controller in order to transfer these to the keyboard. In this case, the ability to audition provided the opportunity to explore harmonic language, a language that Andrew was then motivated to engage with further on the keyboard – and at this point the PlayStation controller was not needed, satisfying Didau's (2016) position that scaffolding should support and then be removed. Here the controller and software had been of benefit by acting as a type of 'sketch-pad'. Interestingly Andrew's approach aligns very well to the approach that Salaman (1997) saw as an example of best practice for the use of technology, and keyboards in particular:

> The best use of keyboards that I have seen took place in a girls' grammar school with a thriving music department. Here, the keyboards and a couple of computers were set away from the main activity area of the large classroom. Wearing headphones, pupils used them as 'sketch books', trying out harmonies, exploring the sequencing facility to create counterpoint, and generally moving back and forth between this 'laboratory' and the world of acoustic instruments, which most of them preferred. The musical purposes of the lesson were always clear and the electronics served only to enhance their knowledge and understanding of music. The final compositions were often assured and expressive (Salaman 1997:149)

Another example involved a pupil (Jack) providing a chord accompaniment (using the Playstation Controller) for another pupil (Dan) playing the melody of a popular song on the keyboard. By removing the obstacle of having to locate the notes for each chord on the keyboard, Jack's rhythmical accuracy improved, aiding him in working towards maintaining his own part with an awareness of how different parts fit together. With an awareness of the different parts, and greater control of timing, Jack then moved on to learning the chords on the keyboard – the Playstation Controller 'scaffolding' the experience for him and resulting in greater confidence and a sense of mastery.

4.3. Reconnecting with the Initial Research Questions

The initial research questions presented in chapter three focussed around whether the use of a digitally native product, in this case a game controller, could lead to enhancements in pupil engagement and motivation, and whether there were any benefits over using a keyboard for pupils with limited controller use and / or limited motivation for keyboard activities. The use of the game controller did indeed generate an initial buzz amongst pupils, and certainly the prospect of using a game controller in their lessons generated interest. However, it was clear that the removal of the context of its normal use (console gaming), created a situation where the pupils were using a 'digitally native' device, but in a very different context to normal use. The switching of informal conversation from the task in hand, to talking about concepts connected to gaming arguably highlights that pupils were not in a state of 'flow' as defined by Csikszentmihalyi (1992), or in an ideal learning state. In line with Smith et al (2020), the concept of a 'digital native' was too simplistic; the use of the controller did not offer a magical solution to solving the problems that pupils found with using keyboards.

Action cycles two and three highlight the greater success surrounding the benefits of using the controllers and software in a digital literacy approach, and the use of technology as an ongoing and supporting process, and this targets the latter two research questions specifically. The ability to temporarily constrain parameters did in a number of cases, appear to offer supportive scaffolding in order to develop connected musical skills, such as the awareness of timing, accuracy, and sense of ensemble. The result was the perception of a reduction in stress, with a sense of the challenge being brought more within reach; with the evidence of this drawn from an observed heightened sense of 'on-task' engagement, compared to music lessons that just made use of keyboards.

The case of Andrew, from testing school B offers the opportunity to reflect on the ideas of Machover (1992) and the need for offering 'sustainable progression'. Whilst it was compelling to see Andrew's use of the controller and software, and successful scaffolding enabling him to develop his jazz sequence, Andrew's development needs were specialist given the fact that he was embarking on keyboard lessons in addition to school music lessons. Whilst the scope of this project was not to seek to replace a preferred instrument, it was clear that in the case of Andrew, and other future pupils with similar specialist needs, the controller offered too little depth to reward a user's improvements in performance over time, and in these cases, the limitations of the controller's design would quickly be outgrown. This was evidenced by the fact that Andrew used the controller and software to aid in his discovery and trial of new compositional ideas, but with the core intention that the findings would then be related back and engaged with on his preferred instrument.

Whilst the game controller and software supported scaffolded musical experiences, there was a clear and arguably inevitable trade-off: Just as the game controller and software could do things that keyboards could not, there were a number of examples where the keyboard could indeed trump the controller and software. One example of this was within the chord module developed as part of action cycle three. Here it was possible users to define custom chords, or select from a range of pre-set chords for any root note, as well as defining whether these were strummed upwards or downwards, and with some control over the speed of the strummed chord. However, it was not possible to access the individual notes, or change the arpeggiation; therefore, the user was not able to play notes from the selected chord in a customised order. My concern was that the lack of 'sustainable progression', risked the controller and software being considered at best a tool, and at worst a gimmick, by those pupils who had already developed, or were in the process of developing, specialist musical skills.

4.4. Wider Implications from Action Cycle Two and Three

Whilst the documenting of the action cycles highlights progress along a positive trajectory, there were nonetheless wider implications introduced from each action cycle. The BYOD approach to using controllers in the initial pilot project worked from both a cost perspective, and the fact that functionality of each controller was the same. This commonality in controller functionality for all pupils mirrored that of the typical music classroom, where the provision of resource is usually consistently applied across the whole class. The various controllers brought in by pupils, and the varying functionality that these controllers offered within action cycles two and three, highlighted a clear problem when attempting to integrate a consumer technology that has a regular product refresh cycle within an educational setting.

Stager's (2011) equality concerns clearly align here; and there are clear ethical issues if certain pupils within a class are able to access the opportunity to perform, experiment, or create with greater levels of musical expression, compared to those pupils who are only able to access the older or more limited technologies. Indeed, previous iterations of the National Curriculum for Music at Key Stage 3 have positioned performing with accuracy and expression, using the inter-related dimensions of music expressively and with increasing sophistication (DFE 2013:02) as a core element of what should be taught. Whilst the current published National Curriculum and framework for curriculum pedagogy and assessment for music (Faultey and Daubney 2019) only directly connects the term 'expression' to singing, there does still continue to be significant reference relating to musical awareness, musical thinking and 'acting musically', of which performing with expression is arguably a clear component.

The release of the fourth generation of the PlayStation console (PlayStation 4) brought a new and updated corresponding game controller, with additional functionality including a touchpad, light bar, built in speaker and headphone socket introduced. In addition to the ethical issues surrounding pupils' access to controllers with differing functionality (now further heightened due to differing functionality over multiple generations of controller), this fourth-generation release highlighted an emerging development problem: in order to harness the functionality of the new controllers, the software layer would need to be redeveloped again. Given that there had already been a necessary change to the initial set up process and software layer following the release of the third generation (PS3) controller compared to that of the preceding second generation (PS2) controller, Chen's (2017) findings regarding teacher concerns around adopting new technologies, equipment set-up and technical support resonated here. However, not taking steps to integrate the latest release of controllers would have a significant impact on sustainability and future scope, and would likely over time lead to less and less pupils bringing in and using their own game controller devices within lessons. The gradual increased reliance on older controllers or 'legacy equipment' would soon compound Swanwick's (1999) position of school music as a 'quaint musical subculture' rather than abate it, with the positive trajectory of what had been achieved also gradually reducing.

Whilst I attempted to keep pace with this new controller release and began redeveloping the software layer in order to integrate it, it became apparent that the only way to enable the controller to work on windows-based machines was via the installation of an additional externally developed piece of bridging software that had been created to 'trick' the windows computer into thinking that the controller was something else / a different input device. The new controller was also less able to be mapped to other computer platforms given that it had been designed in a much more closed way by the manufacturer. There would always likely be a period of time before the latest version of a controller could be incorporated in schools: The time needed to react to the latest console release, to then develop the new software, to undergo appropriate bug testing and architecture testing so as to ensure that the new software release would work across a number of platforms and operating systems for example. These are indeed obstacles that need to be overcome in order to integrate a technology into a setting in which the technology has not specifically been developed for by its manufacturer. This arguably limits the potential for popular technologies found outside of school from being able to integrate into the music classroom as long term and sustainable solutions to support learning. The reliance on an additional piece of unverified third-party software would also likely concern school IT departments, and potentially block the release onto school networks, effectively making the future scope of this project in its current form, unviable.

Music lessons continued to use the PS2 and PS3 controllers, and the varying third-party controllers that had been modelled on these products, but it was interesting to note the change in pupil behaviour to using these technologies that were now considered, since the release of the newer PS4 controllers, 'old'. Informal conversations between pupils saw a return to topics surrounding gaming, as had been the case in in the initial pilot project and action cycle two. Pupils able to bring in the very latest PS4 controller appeared perplexed, almost let down, that their brand-new controller was 'not compatible'. It was very clear that the initial buzz of using game controllers in music lessons, previously considered new, exciting and even 'cutting edge', was now starting to feel outdated. The following chapter discusses several themes which emerge from these findings, and through this discussion the next action cycle of this research is informed.

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5 Discussion: Action Cycles One, Two and Three

The initial research questions are framed around seeking to understand both the 'benefits' to using digitally native technology, but also the impact on 'motivation'. It is important to note that it was not possible to simply plug in the controller and be able to 'play'. Part of the created software layer included the necessary process of converting the output data from the controller into data a computer would understand. The positive gains (benefits) detailed in the findings presented so far in the previous chapter of this thesis are arguably actually ascribable to the possibilities afforded through the created software layer, rather than through the actual controller itself; the multiple button presses from the initial pilot project to trigger a note, compared to the ability to map a note to a specific button in action cycle two are good examples of this point. The physical game controller layout remained broadly the same across all action cycles, and the later releases of the controller broadly continue to do so also. It was the potential afforded via the software layer that changed over time through responding to the findings of each action cycle. The 'digitally native' (Prensky 2001) device on its own was very limited in the scope it could offer for practical music making and as such supporting the growth of digital literacy (Smith et al 2020) through facilitating an understanding of the developed software layer was important. However, the findings do show that the prospect of using physical game controllers in music lessons did have a clear impact on initial motivation to engage. In the music classroom, the initial 'buzz' that was created at the prospect of using game controllers was palpable, but it was not until the development of the band element within action cycle three, supported by opportunities for social interaction, that the longest sustained motivation to remain 'on task' without pupils switching their focus to game related conversation occurred.

On the theme of motivation, Gilbert (2004) acknowledges a model widely attributed to training and skills development, drawing specifically from Noel Burch and Gordon Training International from the 1970s, that learning as a four-step process: unconscious incompetence (step 1), conscious incompetence (step 2), conscious competence (step 3) and unconscious competence (step 4). Gilbert argues that in order to progress through step 2 (conscious incompetence) and also step 3 (conscious competence), there needs to be the motivation to do so. It is plausible, that step 2 is where barriers actually begin to form. There needs to be the sense that progression is possible, that a result is achievable, and that there is (ideally) an intrinsic reason to progress to the next step. The pupil in Baxter (2004) who cited keyboards as 'boring' due to their overuse, cannot see the intrinsic reason; the pupils from school B at the beginning of action cycle two in this research when discussing using keyboards in their music lessons, cannot see that a result is achievable. If steps are not taken to remove these formed barriers here, then progression to step 3 and beyond is placed in significant jeopardy; barriers are strengthened and arguably become further interconnected and reinforced in a perpetual cycle: The perceived barriers to what is possible and achievable becomes the barrier to performing, becomes the performance barrier to composing, becomes something considered not possible, not achievable…

In step 3 - conscious competence, there is the need for the pupil to think hard about tasks that they are engaging with in order to accomplish them, and herein is the challenge faced by novice keyboard users seeking to realise their creative potential via keyboard device. Pupils must be diligent in their creative thoughts and then diligent again as they attempt to channel their ideas via the keyboard; the motivation to do this also needs to be both present and high. There was evidence through the action cycles, that the use of game controllers were having a motivational impact, not just motivating pupils through the prospect of something different, but evidence of deeper motivation to progress to the next step in the learning process. The pupils in school B choosing to continue to make music using the PlayStation controllers over their lunchtimes were arguably now, in their own minds, making the transition to Gilbert's (2004) phase 3 of conscious competence, through their self-desire to improve, and this was very pleasing to see taking place.

Providing scaffolding options, and providing opportunities for pupils to develop their own bespoke approaches to mapping notes, scales and chords to the controller layout, were two clear positive gains from the completed action cycles, and these gains supported the creation of a flexible framework that pupils could explore to gain overall confidence with performing, along with the auditioning of ideas. The social interaction opportunities through the band element introduced in action cycle 3 also brought a change in how musical concepts could be modelled. Dickey provides a succinct explanation of typical modelling practice within the music classroom: 'alternations of teacher demonstrations and student imitations' (Dickey 1992:29), and highlights that this technique is useful when seeking to demonstrate a number of elements of music performance, relating to rhythm patterns, pitches, style, and articulation. The teacher-pupil modelling and pupil-pupil modelling from both action cycles 2 and 3 however moved much further beyond the imitative 'here is how it should sound, now you try' approach, and enabled a much deeper discussion of the actual approach, facilitating two-way communication between the teacher or modeller and pupil. Here the teacher or modeller could see how a pupil was approaching setting up their controller, could gain an understanding of the rationale behind how the pupil was approaching the task, and could then input with their expertise to guide, or modify the pupil's approach in order to support them in performing with more discerning control.

Whilst performance barriers were reducing, or gradually being dismantled for pupils with novice keyboard skills, it was clear however that other types of barriers were forming in their place. The BYOD approach enabled pupils to use their own game controllers within their music lessons, and ensured increased access without the need for whole class sets of controllers to be purchased. Whilst this does indeed represent a benefit to the school and school budget, and thus allows funding to be better targeted to other areas of need, a barrier to access was created due to the varying controller functionality that existed between the controllers that pupils had access to. In the case of controllers with or without button pressure sensitivity, some pupils were able to perform expressively, with control over a note's triggered velocity, whereas those using controllers without this functionality could not. This is interesting given the core success of the use of game controllers within this project was the ability for pupils to remove parameters, or simplify what was available through constraining harmonic language, removing notes and placing of the positioning of notes on the controller where they wanted, through the software layer. Pragmatically then, perhaps there is the argument as to whether it really matters if performing with expression is not possible for a selection of pupils, and that this could be argued simply another parameter removed in order to support with scaffolding. The counter-argument however lies in the ability to make a conscious choice: The ability for the user to consciously define how best to scaffold their own experience, and this becomes very different in scope if access to the control of elements of music are removed from being in the hands of the user.

When functionality is not available to all, it creates a barrier that reduces the potential for pupils to engage musically and progress. The use of differing controllers with differing functionality raises concerns over equality, (Stager 2011), but also places family affluence and other socioeconomic factors at a more visible level within the classroom - some pupils clearly had access to the latest controller, others did not. In addition to the equality barrier introduced, the potential for a personal controller to be lost or stolen either inside or outside of the music classroom also brings the potential for disruptive behaviour to exist. By contrast, the typical provision of class music resources through a set of class instruments, or the provision of keyboards with the same model number, ensures the same potential experience is afforded to every pupil. Whilst pupils will perform and compose with varying degrees of expression depending on their mastery of music, the important factor is that the potential to perform with expression is available for all. Moving away from the BYOD approach and towards the provision of a class set of controllers would help to ensure that parity of functionality is regained to all pupils, but the problems amass further down the line with later releases of controllers leading to previous versions becoming considered 'old', obsolete, and no longer cutting edge. The keyboard as an interface, by comparison, has already successfully existed over a number of centuries.

From the position of pupils with specialist musical skills, and particularly those able to play the keyboard, the case of Andrew highlighted that the physical game controller was too limited as a performance interface in comparison. Although the software layer did provide scaffolding to support the development of Andrew's jazz chord sequence through enabling the experimentation and auditioning of musical ideas, Andrew had no intention of using the game controller interface to perform the result; the limitations of the game controller interface were a barrier for Andrew. The research questions focus primarily on novice keyboard players, and pupils with limited motivation for keyboard activities, but the lens of the specialist musician, and the processes that they have already gone thorough to become 'specialist' helps to promote important considerations surrounding the development of learning mastery and progression design. The potential afforded through using two hands, eight fingers and two thumbs on a piano keyboard, and having access to all notes at once, compared to primarily the dominance of two thumbs for the controls on the face of the game controller, supported by two index fingers and two middle fingers for the controls on the on the rear, represents a very different anthropometric design. This lack of similarity between the keyboard interface and the game controller interface also means that there is no enabling of developed expertise on one to feed into the other. Effectively this reduces the competent keyboard player to a novice games controller performer, and in the same way does not offer a progression route from games controller to keyboard, or indeed other musical instrument. Hunt and Kirk argue that 'a conventional acoustic musical instrument is an inanimate object which relies on the innate processing power and creativity of the human player in order to bring it to life' (Hunt and Kirk 1994). Interestingly though, Hunt's later findings on Human Computer Interaction research provides a direct contrast where he argues the focus is on 'the ease of use, resulting in the belief that interfaces which are not fully operable within a very short period of time are inappropriate'. (Hunt 2000: 89). A device which is easier to operate within a short time frame does not however necessarily offer scope for developing growing mastery, and Hunt's statements when considered with O'Neill's findings that better conservatoire students accumulate over 10,000 hours of formal practice by the age of 21 (O'Neill cited in Jorgensen 2002) exemplifies the dichotomy that can exist between learning a traditional instrument, and using a device like a game controller to enable human-computer interaction.

The Key Stage 3 pupils from the testing schools in this research project all had one hour a week of curriculum time devoted to class music. Over the course of a standard 39-week school year, this equates to 0.39% of O'Neill's 10,000 hours figure, and this highlights the difficulty of finding (or creating) single a performance interface that is both suitable for the novice, but that also provides opportunities for competent musicians to support their practice. The case of Andrew highlights that even though he was a competent musician, and motivated to immerse himself in music, he still faced barriers to composing. Andrew is very unlikely to be alone here, indeed informal conversations with the teachers from the testing schools revealed areas within music that they felt more confident with, describing themselves more as a performer than a composer, or a traditional musician over a technologist. Machover's (1992) concept of 'sustained progression', as a strategy for providing a fast-conceptual understanding with enough depth to reward a user's improvements in performance over time resonates here, and provides the solid grounding for future work. However, the development of an interface to support those with limited motivation for keyboard activities, or experience with playing the keyboard, should not exclude those who are already well on their way with their own musical development. Future interface design should seek to bridge this gap in order to support musical learning, experimentation, and crucially provide opportunities for progression.

In addition to the potential other barriers for pupils, there were signs that the use of the game controller in class music lessons could erect barriers for music teachers too. The findings of Wise (2016); Mills and Murray (2000); Pitts and Kwami (2002); Uptis and Brook (2017) presented in chapter two highlight the concerns and worries many teachers have when seeking to integrate technology into their pedagogy. The fact that the game controllers were not able to just 'plug and play' arguably risked the creation of a barrier of entry for teachers and other staff, and especially for those who considered themselves as not confident with using technology. The necessary calibration process required in order to enable a range of controllers to work, and the likely requirement to modify the process with each future controller / console release in order to harness the latest functionality, passes additional technical complexities on to music teachers and school IT departments, and certainly so in comparison to using keyboards. Again, moving away from the BYOD approach and towards school provision of a class set of a particular controller could mitigate against this, but as newer controllers are released, schools would need to decide whether they upgrade and adopt (at significant cost) or remain as they were, risking the consideration by pupils of it becoming 'old' technology. Somekh's (2008) position, that teachers' use of ICT for teaching and learning depends on the interlocking cultural, social and organisational contexts in which they live and work; their beliefs, attitudes, confidence and competence, also chimes here, and opens debate as to whether teachers would accept, outside of the testing schools in this research, a 'radical' new interface not based on conventional instrument design. Indeed, Cox et al argue that there is 'a genuine fear amongst many teachers about ICT, and scepticism of its value to their pupils' (Cox et al 1999).

The cyclic nature of the process of action research enabled the integration of game controllers within music lessons to be honed through the series of investigative cycles; the results and findings formed the basis for the next cycle, in order to further build upon. The release of the PlayStation 4 controller, the challenges with accessing its functionally, the need for additional unverified third-party software, the likely need to develop another approach to calibrate the controller for use within the music classroom, meant the need to change approach in order to continue the trajectory of this research. The completed action cycles so far all had a common theme – that harnessing a game controller to support music education was a reactive process: reacting to the functionality that the console manufacturer had decided should be present on their proprietary controller. It was the created software layer that enabled the opportunity to map parameters to the specific interface controls on the controller, but there was no possibility to change the controller itself, to add, remove or change the physical position of the buttons, to change the ergonomics of the design, or input into the design of future games controllers to further support their integration into the music classroom.

Elliot's (1991) model of action research used for this research, emphasises the importance of reflexivity, and promotes the argument that the general overarching idea be allowed to shift. It is through this lens that the next part of this action research process is presented. Harnessing a popular technology did provide opportunities to support the dismantling of performance barriers for certain pupils, but the created alternative 'trade-off' barriers that formed in their place were not able to be overcome through the physical game controller interface alone. Moving the next action cycle towards the development of a new physical controller interface, built from first principles, would likely enable the continuation of the positive trajectory of this research, whilst also better supporting the mitigation of the alternative 'trade-off' barriers that formed through the use of the game controllers.

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6 Findings: Action Cycle Four – A Developed Flexible Guitar Interface

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There were several emerging themes from the preceding action cycles that I felt could be better targeted through the development of a bespoke controller. Moving away from the BYOD approach would support both better parity of provision in terms of controller functionality, and eliminate BYOD controller variations, and thus support the development of playing technique and performing with expression, for all users. Equally in action cycle three, whilst the band functionality provided the possibility to harness social interaction opportunities, I felt that the potential to only strum up or strum down a selected chord, and the inability within the chord module to trigger an individual note from within a selected chord, or 'finger pick' notes so as to arpeggiate the notes in any order, was detrimental to providing scope for sustainable progression.

As the game controller usage within school music lessons progressed into the latter action cycles, observing the ways in which pupils applied a customised approach to mapping musical parameters to their game controller, and the conversations that ensued between pupils and teachers as to 'why' they had adopted such an approach, I felt provided a valuable and effective insight into how pupils were approaching their tasks. I wanted to further develop the concept of flexibility, but move it beyond just the software layer. Whilst the game controllers in the preceding action cycles remained a fixed entity, there was scope to explore a more flexible approach through being able to interchange components at a hardware level.

At the height of both Guitar Hero and Rock Band's popularity, there was broadly supportive adoption of these products within the music classroom and school environment. A selection of research identifies a range of opportunities that these products offered: Musical experiences that resonate with perceptions of embodied performance, and recreational listening (Biamonte 2010); the enabled study of culturally authentic material directly from recordings (Hein cited in Schrier 2014); supporting transition from primary to secondary education (Jindal-Snape et al 2011) amongst other areas. The rapid demise in popularity due to 'lack of game changing innovation' as argued by Stuart (2011) in chapter two, presented an opportunity to consider whether the initial success of the guitar controller form factor could be developed further and potentially re-modelled to integrate interchangeability as the development needs of the user changed. Machover indeed points to a reason for the initial success, and provides a reason for why success was not able to be sustained:

> The good news about Guitar Hero and Rock Band is that they clearly demonstrate the public's willingness to dive in and immerse themselves in music-making, given the right environment. The bad news is that neither platform is truly musical, nor do they encourage learning, expression or creativity. (Machover 2008).

The original Guitar Hero guitar controller was very simple in its design. A plastic guitar form-factor contained a single two-way momentary switch with a central off position forming a strum bar, and a spring-loaded leaver connected to a potentiometer formed a whammy bar; these acted as the human interface elements built into the plastic guitar body. On a separate plastic guitar neck, five buttons were positioned side by side towards a non-functional but indicatively modelled headstock. Later versions saw some changes to this design: in order to closer simulate the feeling of forming chord shapes, there was a move to six buttons on the neck in the Guitar Hero Live version of the guitar controller, with these six buttons positioned in two rows of three, again near the non-functional but indicative headstock. The two parts to the Guitar Hero guitar (the plastic guitar body and the plastic guitar neck) reduced the size of the packaging of the product, and required the user to slide and click the neck into place on the guitar body before first use. There was no scope however to interchange either the guitar body or the guitar neck with another guitar body or neck that offered additional or different functionality as a player's skill level increased, and I saw this as an opportunity to develop this as a possibility for the next cycle of this action research – specifically interface flexibility to support the scaffolding of dismantling performance barriers. This indeed aligns with the arguments of Medvinsky and the ideal that music technologies should provide multiple pathways in order to support the development of musicianship skills.

> Technology integration is the most effective when it provides a transparent scaffold within a musical learning experience. The technology provides a differentiated experience from learner to learner, such that music learners can have their voices and choices in deciding which technology best suits their needs and how to use it to support their musicianship. However, it is important not to concentrate too much on the technology itself. The music must remain the focus of the learners' experience, with the technology becoming a vehicle for their musicianship. Technology simply provides musicians with multiple pathways to express, problem-solve, and show their understanding of learning goals, thus fostering divergent thinking. (Medvinsky 2017:467)

6.1. Conceptual Design: The Guitar Body

Figure 6.1. Action Cycle Four – The developed guitar hardware – Guitar Body. The lower image shows the pick guard removed to facilitate the insertion and connection of an insert block and neck.

I modelled the guitar body on the same dimensions as the body of the original Guitar Hero guitar controller and the guitar body itself formed a USB hub. In the middle of the guitar body was a large cut-away section in order to facilitate a series of specifically designed interface blocks to be interchanged within this section. An interface block would connect and slot into this cut away section and could be later removed and replaced by a different block. The guitar body itself contained a tilt sensor to report how the guitar was being held, two dial potentiometers, a dual XY thumb stick in order to provide functionality similar to a whammy bar, and removeable touch sensitive bar positioned to act as a palm mute. This functionality, along with the connected interface block, could be mapped to control specific parameters within the accompanying software layer, in a similar way to the how the software had worked in the previous action cycles.

Conceptual Design: Guitar Body Insert 1: String Block

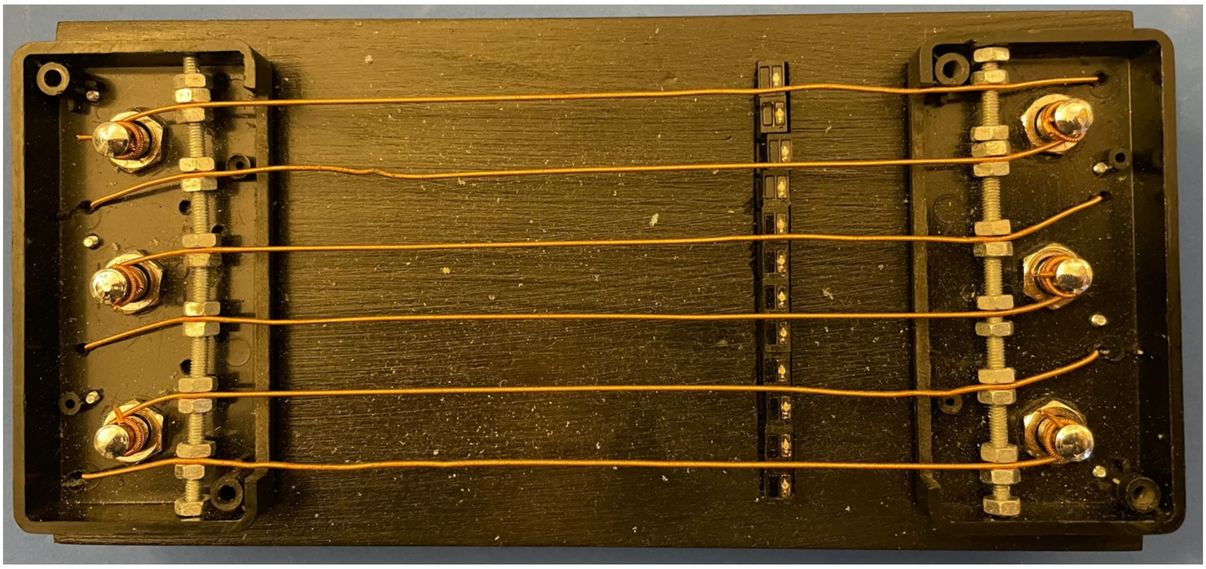

Figure 6.2. Action Cycle Four – The developed guitar hardware – String Block.

The string block was modelled on the strum section of an electric guitar, and consisted of six steel strings. The strings were required to be taut, and could be tightened via a series of machine heads underneath the string block, the strings however were not tuned to any specific frequency or note. Two phototransistors, placed either side of a resting string on the face of the block, acted as the 'pickups'. As a string was played, it would move to cover the infrared light of the emitting diode element of the transceiver and the infrared light would then reflect back on to the photo darlington element of the transceiver. This enabled the capturing of up and down strumming, and sought to offer a direct improvement over the chord module from the preceding action cycle where only up or down strumming was possible. Here, a chord could be assigned and the individual notes from the chord then 'picked' or triggered at the user's discretion.

Conceptual Design: Guitar Body Insert 2: Grid Block

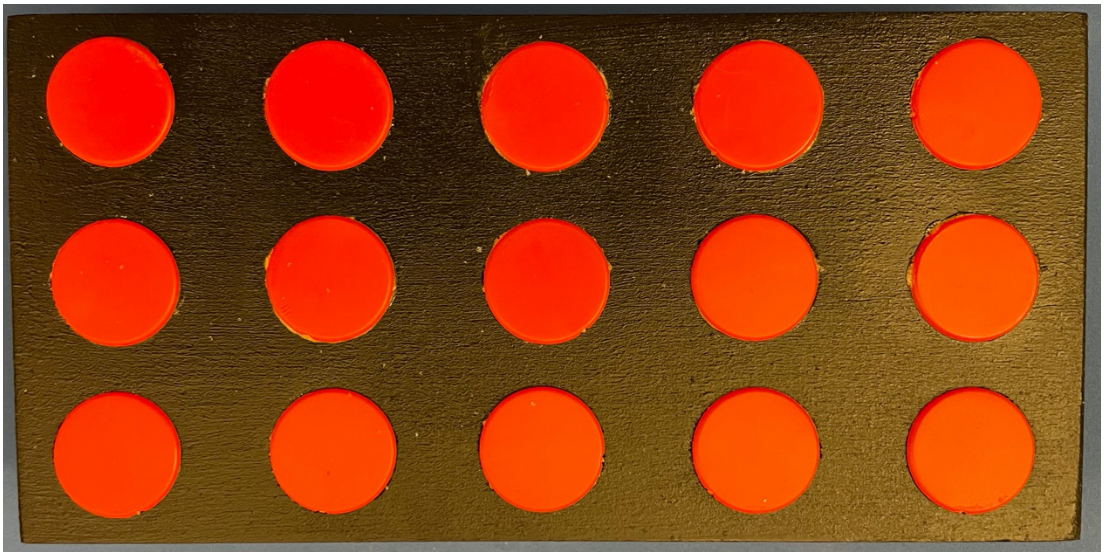

Figure 6.3. Action Cycle Four – The developed guitar hardware – Grid Block.

The grid block provided 15 buttons. In a similar fashion to the preceding action cycles, these buttons could be individually assigned and mapped via the software layer to enable the triggering of notes, samples or other parameters.

Conceptual Design: Guitar Body Insert 3: Range Block

Figure 6.4. Action Cycle Four – The developed guitar hardware – Range Block.

The range block sought to include the capture of gross motor movements. On one side of the block was an infrared range sensor enabling the tracking of the position of a hand above it within the range of 30cm. On the other side of the block was an ultrasonic range sensor which enabled the same tracking of a hand but over a much greater distance. This analogue controller could be assigned and mapped via the software layer to enable control change information to be applied, through the control of parameters including but not limited to expression, volume, and modulation.

Conceptual Design: Guitar Neck 1: Novice Neck

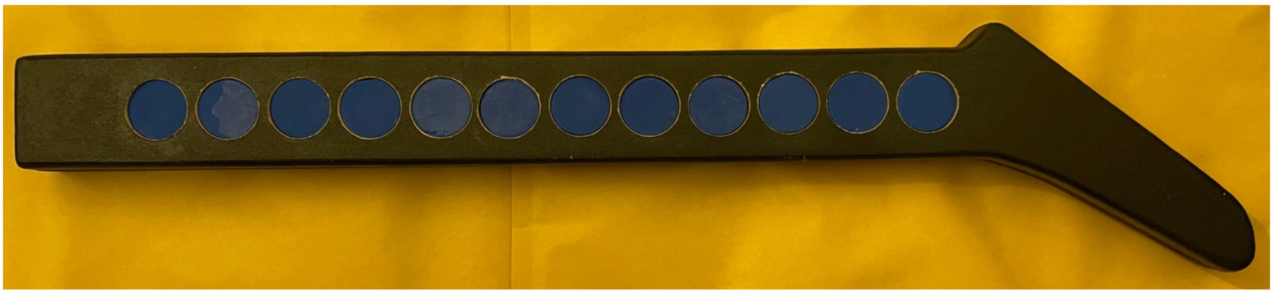

Figure 6.5. Action Cycle Four – The developed guitar hardware – Novice Neck.

The guitar necks were modelled on the same dimensions as the original Guitar Hero guitar neck. The novice neck consisted of twelve inline buttons. These buttons were mappable in the software layer.

Conceptual Design: Guitar Neck 2: Advanced Guitar Neck

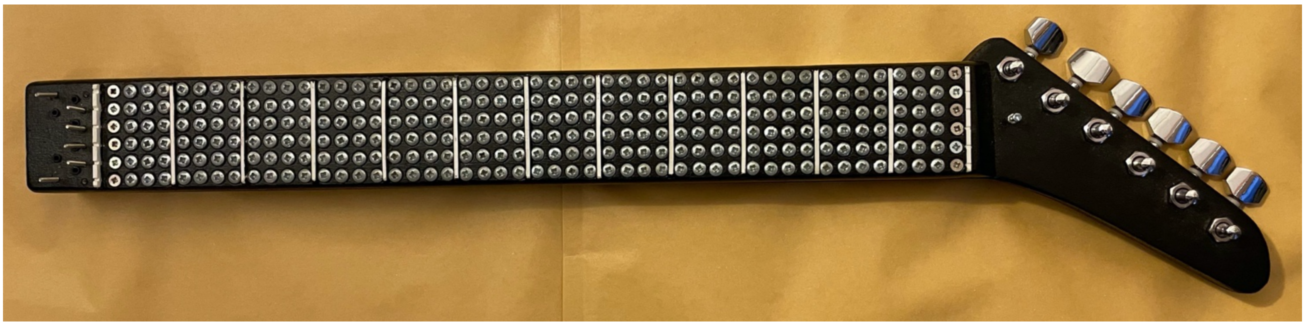

Figure 6.6. Action Cycle Four – The developed guitar hardware – Advanced Neck (note the stings have been removed in this image).

The advanced guitar neck was modelled on a conventional electric guitar neck, although matching the dimensions of the guitar hero version. It consisted of six guitar strings and a number of metal contacts built into the fingerboard. These connected through to a resistive layer. As the guitar strings were pressed down onto the fingerboard, the voltage along the restive strip varied in order to provide the software layer with information of where a string had been pressed, and it was this that enabled the position along a string to be mapped within the software layer. A touch sensitive bar inlaid into the length of the neck could also be mapped, with the original concept to provide the potential for an additional trigger, for example perhaps assigned / mapped to enable emulation of a guitar harmonic.

The user of the flexible guitar interface could therefore choose how to construct their guitar, by selecting the interface block that would sit in the body of the guitar, and also through choosing which neck to connect. The software layer enabled the user to then map musical parameters to the created guitar interface with three options: to either select only, select and trigger, or trigger a musical parameter based on something else that had been selected. For example, on the novice neck, a user could assign a chord to one of the buttons. In select and trigger mode, pressing the relevant button on the neck would select and play the assigned chord. However, in select only mode, pressing the relevant button on the neck would only select the assigned chord - the triggering could then instead be completed by another interface element. For example, if the string block was assigned to trigger the chord selected by pressing the relevant button on the neck, the individual notes of the chord could be triggered by the different strings on the string block, enabling the various notes in the chord to be triggered at the user's discretion. Figure 6.7 demonstrates a configuration using the string block as an insert in the guitar body, along with the novice neck.

Figure 6.7. Example guitar combination, using the string block and novice neck.

6.2. Findings from the testing of the developed flexible guitar interface

Sixth form pupils from testing school C were involved in trialling the developed flexible guitar controller, and were introduced to the controller in a music technology lesson that focussed on new and emerging technologies. A class discussion followed on how these technologies might support the production and creation of music. The flexible guitar controller was included amongst a selection of three other controllers: An 8x8 grid controller, a DAW controller (with functionality consisting of a single fader, transport panel, a range of selection buttons and a continuous scrub wheel), and a 25-key keyboard containing (in addition to the keyboard itself) a small selection of dials, small faders and square pads.

An initial discussion of the differences and potential uses between the four controllers sparked some very interesting comments from the pupils. The first was that the flexible guitar interface was the only one that was 'not a square box', although another pupil quite rightly identified that the inserts for the guitar body were indeed square boxes. The DAW controller was seen as not a compositional tool, but rather a 'tool to stop you needing to use the mouse', and consensus was that this would be a tool to use once there was some content already in the DAW (ie the composition or track had been started) and that this tool would then be useful to help with mixing for example. Interestingly the 25-key keyboard was seen as the best 'all-rounder' with the pupils commenting that the various sections of the controller could be used for different tasks – the keyboard for coming up with musical ideas, the square pads for playing in drums, and then the small sliders and dials to help with mixing and controlling effects. As part of the lesson, dialogue centred on the pupils considering and discussing how they might set up the controllers in order to aid in their compositional workflow. This was particularly valuable data to collect, for all of the controllers presented in the lesson, as it enabled the opportunity to investigate whether pupils' conceptual approaches could be physically applied, and whether their application aligned with pupils' conceptual expectations. Regarding the flexible guitar controller, there were four differing approaches taken to physically constructing the guitar interface. The pupil's names in the approaches below have been changed:

6.3.1. Pupil Approach 1 – The Grid Block insert and the Novice Neck.

This combination had the most support amongst the pupils in the class in terms of the chosen combination of the available guitar interface components. However, the approaches to assigning musical parameters to components varied quite substantially. One pupil, Harry, identified that he would configure the grid block to assign the common notes from chords - root notes to the top row on the grid controller, and thirds and fifths on the second and third rows respectively. Under this format, the 15 buttons would provide 'slots' for 5 chords, with each column of three buttons forming the first, third and fifth of a chord. The novice neck would be used to effectively create selectable chord banks for the grid block insert, and through pressing a button on the novice neck a different 'bank' or selection of chords would be applied to the grid block insert for triggering. Another pupil, Phoebe, took a different approach and instead identified that she would assign all of the buttons across the grid block and the novice neck to specific parameters 'for ease', and use solely the trigger mode, rather than have certain buttons select and other buttons trigger as in the case of Harry's approach.

Researcher: How do you feel the approach that you took to building your controller worked for you when it came to creating music?

Harry: I felt I was able to set up quickly. I actually ended up with quite a large number of notes that I could pick from, but I found the root, third and fifth approach that I took quite limiting. It made me realise that even though the root, third and fifth notes are pretty common within chords, you need other notes to make things interesting.

Researcher: Based on what you say here Harry, would you look to change the approach you took.

Harry: Yes, I think I would, although I'm not sure how. I guess if I think about it, I had too many roots, thirds and fifths available, and I lost track on which chords I had connected to the [novice] neck. Rather than having five chords available on the grid block, I could turn things around and have only three, then I could get two more notes per chord, and have five notes per chord instead of only the three.

Researcher: Did you make any observations between using the flexible controller that you build compared to using a keyboard that you would normally use?

Harry: My guitar felt 'cooler'. I guess I could have had any note that I wanted though with a keyboard though. When I'm composing in a DAW, I often slow things right down or use step input so I can play in one note at a time, this did feel more 'real' though, more 'natural'.

For Phoebe:

Researcher: How do you feel the approach that you took to building your controller worked for you when it came to creating music?

Phoebe: I liked it that I could just trigger the notes that I wanted, the number of buttons that I had available meant that I could have lots of notes available if I wanted, but I actually didn't use all of the buttons, it made me focus around using a smaller set of notes to make the melody and bass lines I was working on.

Researcher: Did you make any observations between using the flexible controller that you built compared to using a keyboard that you would normally use?

Phoebe: Compared to keyboard it felt more natural, I could get my idea in quicker, it was nice not to have so many notes, I could work on my idea, and then add in an extra note if I needed, but I liked working on an idea, to try and make it catchy with only a few notes.

6.3.2. Pupil Approach 2 – The String Block and the Novice Neck

Dan, identified his approach to combining these components through the process of assigning chords to the buttons on the novice neck for selection only, and then using the string block to strum and pick the individual notes from the selected chords in the order that he wanted.

Researcher: How do you feel the approach that you took to building your controller worked for you when it came to creating music?

Dan: This was good, I think it worked really well – a bit like Guitar Hero but better. I could play the notes I wanted in the order I wanted, as well as strum chords. I'd have loved to have used this when I was like in year 9, it would have been much more fun.

Researcher: Did you make any observations between using the flexible controller that you build compared to using a keyboard that you would normally use?

Dan: I'd like to keep trying the guitar controller I think. I like the way that there are dials and other controllers that I can use to change the sound, or get the kind of sound that I want kind of on the fly, I think this helps me then with coming up with ideas if I can get the kind of sound I want first.

6.3.3. Pupil Approach 3 – The String Block insert and the Advanced Neck

Jamie, who was a talented guitarist, chose to combine the components together to create an interface that closely modelled an electric guitar, aligning the pitches achievable on the advanced neck to that of a conventional guitar. Pressing a string down within a fret would select the relevant note, and the action of strumming or picking via the string block insert would trigger the selected notes and chords.

Researcher: How do you feel the approach that you took to building your controller worked for you when it came to creating music?

Jamie: I was a bit disappointed to be honest. It looks like a guitar, but it's not a guitar, it's quite a bit smaller, and the neck weighs quite a bit more that the body of the guitar. With the string block, it's weird that the strings are all the same thickness, I also found it a bit annoying that I could hear the strings on the string block making a ‘twangy’ sound as I played, it’s also difficult to get these strings tuned exactly the same as each other. Shall I go on?

Researcher: Yes, please do.

Jamie: Actually, that’s probably about it. Sorry for being harsh. I think it’s quite a good idea though and it’s good to see something being done for guitarists. I’d quite like a MIDI guitar, they look really good.

Researcher: Did you make any other observations between using the flexible controller that you built, compared to using a keyboard that you would normally use?

Jamie: I think my problem was that in my head I thought it was a guitar. I know a keyboard is not a guitar, so I guess I’ve just got used to having to use a keyboard to compose on a computer. It’s always been that way, I perform on my guitar but have to compose on a keyboard. I’d probably use the string block insert though with the other neck. It’s not great having to use a keyboard to do guitar strums, they don’t sound real. I reckon that the string block could help me program guitar strums better.

6.3.4. Pupil Approach 4 – A creative, alternative approach

Interestingly, one pupil Ben, identified the guitar body, interface blocks and guitar necks were all USB devices, and asked whether he could connect them all together via a USB hub. As this was indeed possible, he then positioned his focus on three of the devices, the range block insert, and grid block insert and also the advanced guitar neck, using the grid block to trigger samples, and the range block and strings on the advanced neck to control effect parameters within a digital audio workstation.

Researcher: How do you feel the approach that you took to building your controller worked for you when it came to creating music?

Ben: My uncle has an Akai APC that I've played with before. I think grid controllers are great, and I liked how I could affect my samples with the range block and strings on the neck of the guitar. The long length of the guitar neck was great as there was a long distance, to be able to control a parameter over, like the filter cut-off, it was great to have such a long range to be able to work with.

Researcher: You chose not to form the various components into a guitar, can you tell me a little more about what you did have in mind for what you wanted to achieve?

Ben: No that's right. The grid for me is the most important bit – I want that in the middle of my desk, the range controller under my left hand and the neck above the grid controller in easy reach. I'm not a guitarist, I didn't want to make a guitar, that wouldn't work for me.

Researcher: Did you make any other observations between using the flexible controller that you built, compared to using a keyboard that you would normally use?

Ben: Hands down, if I could, I'd use a grid controller over a keyboard all day long.

6.4 Reflections on the Approaches Taken

Reflecting on the points made here by the pupils, and the approaches they took to constructing their flexible controller, there are some interesting points to take forward. In the case of Harry, there was clear ownership starting to take place with Harry referring to the controller that he had constructed as 'my guitar'. There was also clear demonstrable development in both Harry's original approach, with regards to the mapping of the root, third and fifth notes from chords, and the later consideration applied to the ways to adjust this in order to provide further scope for flexibility, memory recall and awareness of how notes outside of the triad shape are important in creating music. The theme of temporarily constraining harmonic language and also the physical number of buttons or keys available as explored through the use of the game controllers in the preceding action cycles, receives further support through this action cycle with the positions put forward by Phoebe and Dan. For Phoebe it was the relative economy of being able to explore the possibilities afforded through a small selection of notes and buttons, but the flexibility to add to these if and when needed, and indeed the willingness to do so, arguably indicating quite an advanced approach of working on ideas, and seeking to squeeze out the full potential of these. For Dan, it was through the flexibility to work with a focal harmonic language through a selection of chords, and the ability to be able to select the individual notes from the chord voicings to use in his music creation. Dan's approach represents an encouraging extension to the overarching temporary constraining of functionality theme, and the chord module explored in action cycle three in particular.

Dan also identifies that for him, timbre has an impact on stimulating his ideas, and that easy access to be able to shape the instrumental tone, and putting this control in the hands of the performer and / or composer offers the potential to support creative music production. This concept is arguably unsurprising, especially given the popularity of a number of music genres that rely heavily on sample and synthesis manipulation. Interestingly though, certain conventional instruments place scope to modify timbre 'on the fly' at arguably a more prominent level – the pickup controls, tone and output volume dials on a conventional electric guitar being one example. Whilst dedicated controller keyboards often integrate a series of dials and faders (as in the case of the 25-key keyboard that the pupils from testing school C coined as the 'best all-rounder'), many conventional and traditional keyboards do not; this was indeed also the case the with the game controllers used in the previous action cycles of this research. With the game controllers it was difficult to disassociate the functional ability to control timbre with the ability to trigger notes due to the varying degrees of controller functionality, and the fixed game controller design. On the game controllers, the XY thumb sticks were predominantly reserved for MIDI control change and the affecting of timbre; but these thumb sticks were spring loaded, and therefore any adjustments were either momentary, or were required to be 'held' by the performer. The dials on the developed guitar body offered simple dials that could be used in either a 'set and forget' approach, or adjusted when required.

In chapter two I presented the common scenario that I regularly witnessed in the music classroom – the guitarist often seen working out phrases and ideas on a guitar, (their preferred instrument), only to then have to convert the application of these ideas via a keyboard interface. The case of Jamie in this action cycle aligns to this position, interestingly however, Jamie appears to have reconciled in his own mind, that if he wants to compose using a computer then he must do this via a keyboard. For Jamie, the created guitar that he built up, using the string block insert and advanced neck enabled the possibility to create something that looked very close to the instrument that Jamie wanted to be able to use in order to compose, but a controller that looks like a guitar, without actually being one, arguably led to further dissatisfaction for Jamie; effectively this was a guitar imposter! It is important to note that the rationale at the beginning of this action cycle was not to create a guitar, but instead build on from and harness the popularity of the Guitar Hero guitar format. There is however arguably a logical extension to seek to integrate guitar-type elements into a guitar form-factor product as was the case with the string block insert and the advanced guitar neck.

Jamie's reference to MIDI guitars is interesting, these usually work through the use of a pick-up per string to capture the string's vibration and then convert the frequency of the vibration to the closest MIDI note. MIDI guitars are also very expensive, and certainly in the school music departments that I have worked in, are financially out of reach in the department budget. The string block insert and advanced guitar neck work in a very different way to that of a Midi guitar, but the problems that Jamie pointed to (the problems of the distribution of weight between the neck and the guitar body and the fact that the strings were the same width) are all by-products of the alternative way used in the string block insert to capture performance information from the user. The reality of using photo transceivers meant that the strings needed to be the same thickness in order for a strummed or plucked string to break the beam of infrared light and reflect it back onto the photo darlington. Using conventional guitar strings with their varying degrees of thickness, would therefore alter the uniformity of the response received by the transceivers – thinner strings would cause less light to be reflected back onto the photo Darlington receiver. It is useful at this point to consider *why* the transceivers were used instead of a traditional pick-up or hexaphonic pick-up as with the Midi guitar. The answer lies within the problem of 'modularising' performance interface blocks and seeking to maintain traditional instrument elements. A traditional guitar uses tuned strings over the full distance of the guitar neck and guitar body, but in order to provide differing guitar necks and differing guitar body inserts that could be interchanged by the user to enable the creation of a user-defined interface, the ability to accurately tune guitar strings in the manner that they would be on a guitar, is disrupted. The developed string block sought to enable the capture of the action of strumming and plucking individual strings – this was its primary function, and technically seeks to compartmentalise a single aspect of playing a guitar. Other options were explored in order to attempt to do this, for example applying capacitive touch sensing to the string; but touching a string is different to plucking a string, and there is no scope in this scenario to also capture the pressure applied through the picking or strumming action as there was with the use of the infrared transceiver route taken. These challenges arguably demonstrate support for the concept of traditional instrument design as perfection outlined by Bijsterveld and Schulp (2004), and further highlights the challenge of seeking to address the dichotomy of an interface that is suitable for pupils at all levels, from those starting out, through to established, gifted and talented musicians. As was the case with Andrew in action cycle three, Jamie's 'specialist' needs, and the format of Jamie's constructed guitar controller, did not present him with a musical experience that matched his expectations.

Ben's approach is an interesting one when considered through the lens of the components that he used. He chose to construct an interface in order to form something that he wanted to use, rather than relate to existing instrument design, and he saw potential in using the strings on the advanced guitar neck to form long position sensors to control effect parameters. Ben's and Jamie's differing approaches show on one side, a pupil (Jamie) wanting the controller to be more like their preferred instrument, and on the other side, a pupil (Ben) who is not bound by conventional instrument design. Ben's approach also succeeds in creating a performance interface that harnesses further functional potential by deliberately removing any connection to existing instrument design through utilising the block inserts without placing them in the guitar body. Whilst this again highlights the challenges of creating a single interface to dismantle performance barriers for all, it also raises an important point, and counteracts Bijsterveld and Schulp's (2004), position of traditional instrument design as perfection: Guitar necks and guitar strings are likely not the ideal way to achieve the desired end result for pupils like Ben given that many pupils experience pain when learning to play the guitar due to the indenting of the skin on the hard guitar strings. Fundamental to much traditional instrument design is also the reliance on consumables, as was the case with these incorporated traditional elements into the flexible guitar controller, the requirement for guitar strings being one example. Ben is taking a creative and pragmatic approach to constructing a device that does what he wants it to do, but this is achievable without the need to create callouses on fingers first, or require the replacement of worn out consumable elements such as guitar strings. Indeed, the occurrence of either (finger callouses or broken guitar strings) could easily be considered further examples of performance barriers.

My additional observations of this action cycle related to access. Despite the shortcomings of the BYOD approach of the previous action cycles, and the lack of provision parity afforded by such an approach, it was clear that this action cycle lacked the richness of the previous action cycles, where large numbers of pupils (full classes) were able to engage with their own, personal game controllers from home. In this action cycle, only one flexible guitar controller was available, and thus only one pupil could use it at any one time. This scenario also arguably presented a regress from the positive findings of pupils using their controllers in groups to form ensembles, the beneficial conversations that pupils had to discuss their approaches taken to mapping the musical parameters to their game controllers, and their rationales for following such an approach. My feelings on this particular action cycle were that it very much represented a shift back to facilitating an experience for an individual, as opposed to an ensemble or group. However, the approaches taken by Dan and Ben in particular show positive evidence of the extension of functionality offered compared to the simplicity of the Guitar Hero guitar controller, and also positive evidence, building on the preceding action cycles through extending the concept of flexibility from the software layer to the hardware layer. The approaches taken by Harry and Phoebe present further evidence of beneficial short-term constraining of functionality in order to support the scaffolding of individual approaches to creating music, and in the case of Harry, the potential that this affords for a pupil to reflect on their initial approach before making informed adjustments to hone their approach. The case of Jamie represents useful findings when seeking to integrate conventional musical instrument elements into a developed design, and highlights the potential challenges that can be faced when utilising alternative ways to capture performance compared to established methods. Whilst these alternative methods may provide opportunities to reduce cost, or may indeed be required if the conventional approach is not viable (as in the case in this action cycle, and the reduced string length due to the modularised design), there is arguably a clear argument to seek to relate, rather than emulate, these traditional design elements into the next stage of this research.

The following chapter goes on to explore several themes which emerge from these findings and the discussion and findings from the preceding action cycles, and seeks to connect and consider them through the lens of the development of a new hardware and software product, built from the scratch, to seek to further support the flow and effective transfer of compositional ideas into compositional reality, using technology.

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7 Discussion: An informed proposal for the next action research cycle (cycle five)

Whilst this research project originally set out with the intention of seeking to find alternatives for pupils with limited grounding in keyboard performance, the findings of this research also showed that for pupils such as Andrew from action cycle three, there were elements within the developed technologies, particularly within the software layer, that could also provide support for musical experimentation, for those pupils who were well on their way with their own music development. Thus far, this action research has drawn its inspiration through the use of controllers specifically developed through the lens of computer gaming. The initial pilot project and the first three action cycles incorporated PlayStation game controllers, and other third-party versions of these controllers, however for both novice and more established keyboardists, the game controllers as a physical interface were found to have insufficient sophistication required in order to support the potential for sustainable and continued progression. When considered under the overarching aim of this research project – the dismantling of performance barriers to music composition, the limited potential for sustainable progression resulted in the re-forming of performance barriers at a later development stage, even if there had been a reduction to performance barriers in the initial stages.

Arguably a move away from using computer game controllers, devices which are well ingrained and integrated into popular culture, risks a negative impact on relevance for pupils. In order to inform the next action cycle of this research and continued investigation into this area, it is useful to further examine the evidence that 'clever' technologies (introduced in chapter two) have on shaping technology culture, the ways that novices interact with such technology, the area(s) these technologies open up, and by extension, connections that can be made to music composition in the classroom.

This research considers at its core, the model of the composer – keyboard interface – computer, and specifically the exploration and development of alternative devices to the keyboard interface in the middle of this model. Interestingly, a common position within the traditional 'composer – keyboard – computer' model is that the auditioning and forming of musical ideas is placed within the domain of the composer's interaction with the keyboard. The computer element of the model is largely excluded from the audition and experimentation process, and the creation and formation of ideas, until the ideas that have been formulated on the keyboard are ready to be captured and sequenced. Green's (1988) much quoted statement presented in chapter two relating to pupils' cultural expectations and cultural dissonance, arguably relates with this model, although now, over 20 years on from Green's original statement, the consideration of cultural dissonance runs much deeper than just metallophones and tambourines being poor substitutes for electric guitars and drum kits. Cultural dissonance has grown further through pupils' interactions with evolving technology, and the differences between the type of technology interactions found within in and out of school contexts.

Karray et al argue that 'it is economically and technologically crucial to make Human-Computer-Interaction (HCI) designs that provide easier, more pleasurable and satisfying experiences for users. To realise this goal, the interfaces are getting more natural to use every day.' (Karray et al 2008:141). The potential afforded through the growth in computer technologies, and the strive to make HCI interaction easier, more pleasurable, and a more satisfying experience, connects to the dismantling of barriers under investigation within this research. Where such barriers are reduced, connections are then made that in turn shape the development of culture, particularly so in informal contexts, as the potential to engage in areas becomes easier and more convenient.

The development of the camera phone is a good example, and a product that has led to an explosion of photos being taken, largely driven by convenience with phones available 'on person' (in pockets), reducing the need for a separate camera, and also providing the easy ability to discard any photos taken that are not deemed 'good enough' to be kept. For the user, camera phones enable the decision to keep or discard a photo to be made *after* the event of the photograph being taken, and this represents a significant cultural change to standard cameras where the requirement of camera film placed a typical limit of 27 possible exposures, before a new film was required. This case, in contrast, required the decision on whether a moment should be photographed (and therefore kept) to me made *prior* to the photo being taken, and such decisions were often further compounded through additional factors requiring consideration - the requirement to pay for all 27 photos to be developed, no possibility to pick and choose from a selection of the photos taken, the monetary cost of a new film etc. It is this difference in the point of the process by which a decision by the user is required to take place, that is the important factor here, and arguably the element that contributes to the creation of cultural dissonance within schools. Numerous technologies found outside of school seek to support and provide scope (particularly for novices) for wider immersion and reduce self-perceived risks of engagement through the technical intelligence of the technology to 'coax' ideas out of the sub-conscious and into the conscious, and therefore enabling evidence based and context rich decision making.

When viewed through the same lens, GarageBand (considered in chapter two – an example of one of the first 'drag & drop', and loop-based DAWs) is also an interesting prospect, and similar with 'technical intelligence' built in. Apple (2021a) position 'Incredible music in the key of easy' and 'create with or *without* an instrument' as headlines relating to their product. There is clear and explicit intent here to enable the potential for successful music creation to be possible without the intermediary of an instrument, and as such the composer – keyboard – computer model comes under challenge through this decision to reduce the necessity of the keyboard within the composing process, therefore bypassing this problematic middle instrument element, and enabling instead the direct interaction between the composer and computer. Karray et al's concept of interfaces being 'more natural to use' is poignant as it relates to the position put forward in chapter two that the keyboard puts non-keyboard instrumentalists (and indeed non-instrumentalists) at a disadvantage. For these two groups, a keyboard could certainly be argued as an 'unnatural' device. The marketing of the current version of GarageBand clearly positions the software as 'enabling the creation of music projects', to record, to add loops, to 'arrange regions containing recordings, loops and imported files' (Apple 2021b). There is no explicit reference made to the playing in of musical ideas, instead reference is made to the potential to *learn* how to play the keyboard through included lessons, and not actually as something to aid in the creation of musical projects.

These examples demonstrate the broader interest from technology manufacturers to seek to provide explicit guidance through the 'intelligence' of their products in order support novices through the provision of a framework, in order to enable and promote user immersion and engagement. The informal route of 'bedroom production' as the new apprenticeship model discussed in chapter two relates again here, with the targeting of the novice market, and the creation of products that are both easy to use, yet importantly enable users to craft professional results. This shaping of culture surrounding our technology usage, alongside the findings in this research, suggests that the composer – keyboard – computer model found in schools is becoming increasingly ill-aligned to informal and socially-guided cultural trends. Indeed, this ill-alignment is made further explicit when the statements from the pupils in chapter four on page 64 – all novice musicians with limited grounding in keyboard skills, are considered through this lens. These pupils eloquently documented the problems that they faced and were highly self-aware of what they felt they were unable to do. However, the current processes that they must go through, through their interactions with the keyboard, demonstrate clear parallels to the approaches outside of their technological cultural sphere – the requirement to imagine musical ideas, formulate and then play them on an 'alien' device, likely isolated from the desired end context. It is unsurprising that these pupils are anxious to commit to the capturing of their ideas, and it is plausible that there is an implicit heightened sense from a self-perception perspective, that for an idea to be captured, it should be worthy of being captured, which risks the creation of a perpetual cycle relating to being unable to realise or perform the musical idea within one's head. These pupils are experiencing cultural dissonance as their likely engagement with technological and cultural trends in other areas of their lives, promote the potential to make decisions at later stages of engaged processes, based on tangible evidence, and via relevant 'non-alien' intermediaries.

Conversely, Bowers cited in Hynes (2021) urges caution against seeking technology cultural homogenisation as the solution:

> The mode of consciousness [inherent in digital technology] makes a virtue of ignoring the forms of intergenerational knowledge and skills essential to the world's diversity of cultural commons that enable people to live less consumer-driven lives'. (Bowers cited in Hynes 2021:39).

The priority is arguably therefore to exist in the middle ground; to develop an interface that offers the potential to extend sufficient challenge at timely points, a scaffoldable device that can be modified to align and support pupils from a position of (self-)perceived expertise. Action cycle four drew influence from the Guitar Hero guitar controller, and sought to explore ways in which this controller form-factor could be developed and extended. This point saw the move towards investigating the impact and potential of a construction-based approach, in order to seek to better support bespoke and individual user-needs. From an interface perspective, the findings from action cycle four highlighted that it whilst it can be beneficial to relate to elements of conventional instrument design, seeking to attempt to directly emulate conventional instrument design was problematic. The findings presented in chapter six, solidified the position put forward in chapter five, that the focal element of the interface should support musical learning, experimentation, and crucially provide opportunities for progression. The rigidity of the interface models from action cycles one to four did not provide enough flexibility in order to achieve this sufficiently; there is now a need to move away from established instrument form-factors and existing technologies primarily designed for supporting interaction in alternative areas. In order to move forwards, there needs to be the potential to cultivate and maintain intrinsic relevance, rather than through alignment to an extrinsic game layer.

7.1. Key Design Themes

I sought to ground the focus of the key design ideals around the following areas, exploring development avenues in order to:

- **Ideal 1:** Seek to provide **flexibility and customisation at the physical interface level**, so as to enable user to dismantle performance barriers through developing their own performance interface that is applicable to their needs.

- **Ideal 2:** Seek to **harness the existing musical expertise of teachers**, reducing potential technology entry barriers for teachers (Wise (2016); Mills and Murray (2000); Pitts and Kwami (2002); Uptis et al (2017)).

- **Ideal 3:** Offer opportunities to **promote sustainable progression** (Machover 1992), and the promotion of balance between challenge, frustration and boredom (Levitin 2002) though exploring the possibility for the interface to either grow with the user, or provide a link to other opportunities, including those of traditional instrument learning.

- **Ideal 4:** Explore design opportunities that can **support affordable adoption into schools** and other learning contexts.

Each of these above ideals are now discussed in turn. However, at the point of this thesis submission, this next action cycle has not been able to be tested in schools due to the Covid-19 global pandemic that has caused much disruption to face-to-face education. The discussion here therefore seeks to connect the findings presented in the preceding action cycles, to support the informing of the interface design and functionality of the new physical interface. This next action cycle will form the basis of further ongoing research into this area post the submission of this thesis. A prototype of this new interface and software will however be presented at the viva examination.

7.2. Ideal 1: Flexibility and customisation at the physical interface level

> Lego is the ultimate toy … because it doesn't have any rules. What Lego allows you to do is to dip into a big bucket of mess and pull out these bricks and slowly make something that is uniquely yours (Dyckhoff cited in Pirrie 2017).

Dyckhoff's quote, directly referencing the brick construction toy of Lego, and relating specifically the concept of being to create something that is 'uniquely yours', presents important support for this first ideal relating to both flexibility and customisation at the physical interface level. The flexibility in action cycle four to construct a guitar from a series of blocks, or in the case of Ben, using the blocks to construct an interface without any connection to a guitar model, provided continued evidence that flexibility and customisation at a hardware level can be beneficial, and this builds on the benefits of the flexibility afforded through the software layer that was presented in the first three action cycles.

I was keen to investigate whether I could develop a device that was formed from a series building blocks, the rationale being that that these building blocks could then be connected together by pupils in order to enable the formation of their own instrument, 'unique' to them. The concept of pupils being able to build (or construct) their own interface directly connects back to the constructionist epistemology presented by Crotty (1998) and Gray (2017) in chapter three, and is further brought to the fore through the constructionist views on effective learning presented by Papert and Harel (1991): The building of knowledge structures, and that 'learning [is] particularly effective when it takes place in the context of a rich and concrete activity, which the learner experiences while constructing a meaningful product' (Harel 1991). I hoped that through pupils engaging in the active construction of their performance interface, that this would further support the visualisation of the approaches that pupils were taking to perform musical ideas, enable further alternatives for the transfer of compositional ideas though technology, and further support opportunities for the scaffolding of their learning. This indeed aligns with the interests of Papert, as put forward by Ackermann:

> Papert is interested in how learners engage in a conversation with their own or other people's artefacts, and how these conversations boost self-directed learning, and ultimately facilitate the construction of new knowledge. He stresses the importance of tools, media, and context in human development. Integrating both perspectives illuminates the processes by which individuals come to make sense of their experience, gradually optimizing their interactions with the world. (Ackermann 2001)

Papert's views provide a supportive framework for this project's research practice and investigation and support the process of designing pupil-centred opportunities in order to provide them with formative analytics: Pupils questioning their own practices and drawing their own analogies and conclusions in order to inform their approaches moving forward has thus far been seen through the action cycle three and action cycle four in particular.

Support for flexible interfaces, engaging pupils in creating projects that are 'uniquely theirs', and harnessing and facilitating pupils to respond and adjust their learning within cultural and social contexts, can be found in a number of recent national and international initiatives: The provision of a BBC micro:bit pocket sized computer for all pupils aged between 11-12 in the United Kingdom, sought to encourage creativity and programming, and in turn offer a lower barrier of entry to computer science. Sentence et al (2007) specifically identify this product as 'proving opportunities to create something that has a practical purpose, [this] seems to motivate students and in turn affords students a more meaningful learning experience' (ibid 2007). In addition, the Scratch coding community for children very much promotes working and exploring though a continuous spiral: 'Typically, a student will start with an idea, create a working prototype, experiment with it, debug it when things go wrong, get feedback from others, then revise and redesign it.' (Scratch n.d). Moving the next cycle of this research to enabling pupils to create their own music controller interfaces is therefore timely, given the existing appetite for flexibility, experimentation, working, re-working and social feedback found in the initiatives of the micro:bit, and the Scratch coding community, alongside the broader concept of seeking to explore creativity as improvisation and creativity as innovation (Hallam and Ingold 2007).

7.2.1. Interface Design

The blocks that I designed are based on multiples of 51mm. I designed two block sizes, one at 51x102cm and a larger version at 51x153mm. Each block has a base, a top, and four sides, two sides of which (one long side and one short side) contain a protruding dovetail, and the other two sides contain a recessed dovetail. The sides are designed in order to facilitate the physical connection of the blocks together through the recessed dovetail of one block sliding over the protruding dovetail of another block. The base provides the electrical and data connections, with each block connecting together through forming a bus network. The blocks can be connected in order to form an interface that that can grow in any direction. A 51x102mm block contains a PICMicro PIC18F4455 microchip, and this microchip handles the USB communications to the connected computer, acts as the master/host node for the network, and also contains a circular buffer which enables efficient first in first out (FIFO) data byte storage. All of the other blocks that connect are client blocks, but with a defined address. These blocks contain PIC18F46K22 microchips as this particular chip enables the interfacing of a large number of analog I/O ports and pins. Any change in state on one of these blocks (through the user triggering a parameter) triggers the sending of the block's address to the circular buffer on the host, and this in turn causes the host to read the data from the relevant client block. This all happens very quickly, with minimal latency, so as to not impact the performance of the user. On the top of the blocks there are a series of magnetic strips and spring-loaded contact pins. These permit a variety of configurations of top keys that then sit on the connected base blocks. These keys connect to their base block via the spring-loaded contact pins, with the magnetic strips holding them in place. I created three sizes of top keys: Two long and narrow keys, one being very narrow at 5.5x99mm and a slightly wider version measuring 14x99mm. There is then a shorter but wider key, measuring 22.5x48mm. These keys provide linear position sensing along their length and pressure sensitivity across their full body. For the base block measuring 51x102mm, a maximum of six of the long but very narrow keys can be accommodated, or three of the less narrow but long keys – these can also be placed in a mix and match design. A total of four of the wider but shorter keys could be accommodated in the same base block space. The longer base block (51x153mm) enables an extra two of the shorter but wider 22.5x48mm keys to be accommodated. Figures 7.1 to 7.4 outline a variety of configurations of the product, and how the top layer keys are connected to the base layer.

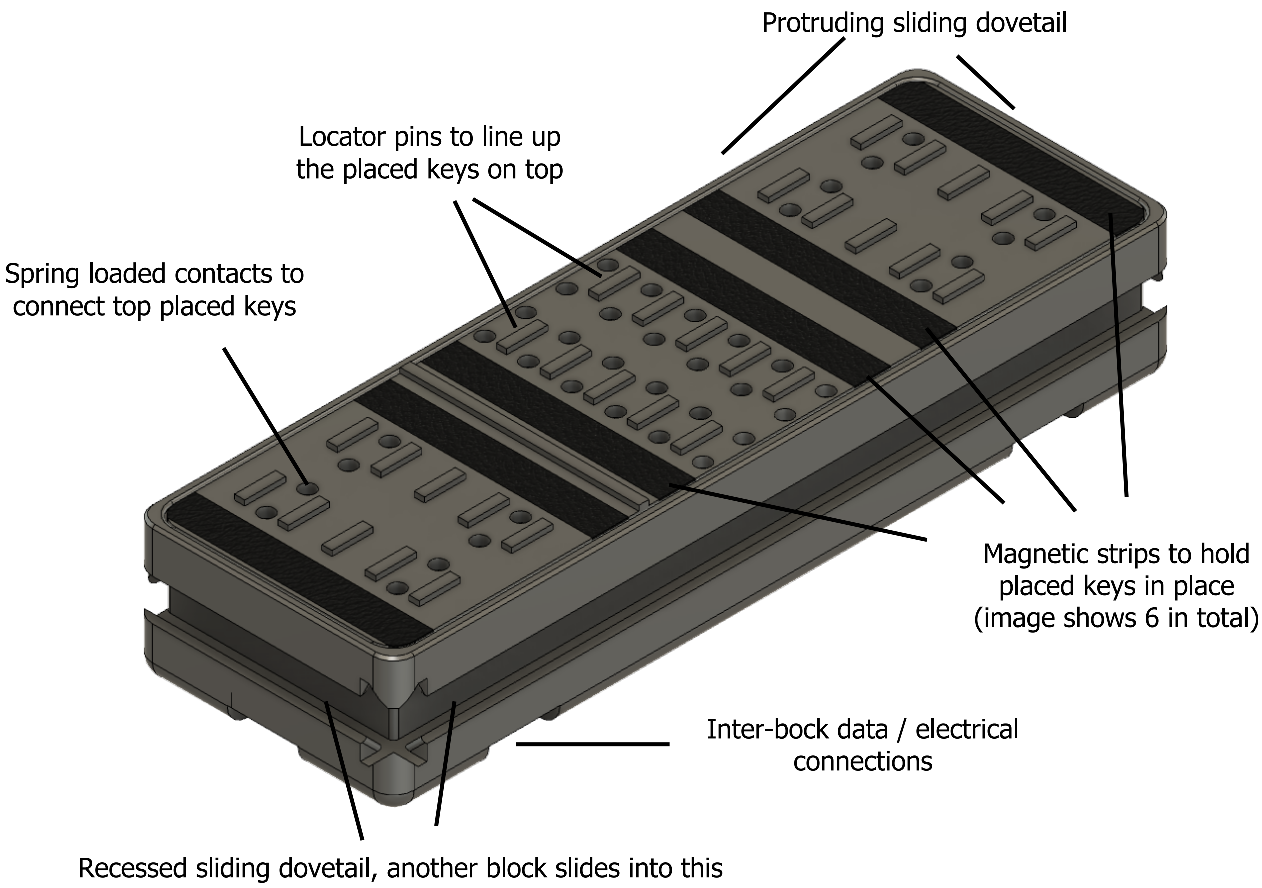
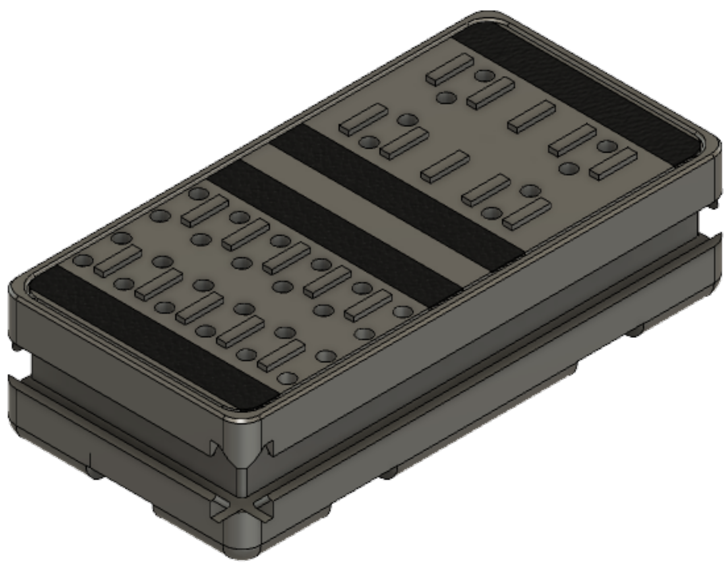


Figure 7.1. – Two examples of the blank interface base blocks. The top image represents the longer base block (measuring 51mm x 153mm). This block is one third longer than the smaller block shown below which measures 51mm x 102mm. The same labelled elements from the block above are also present on the smaller block below.



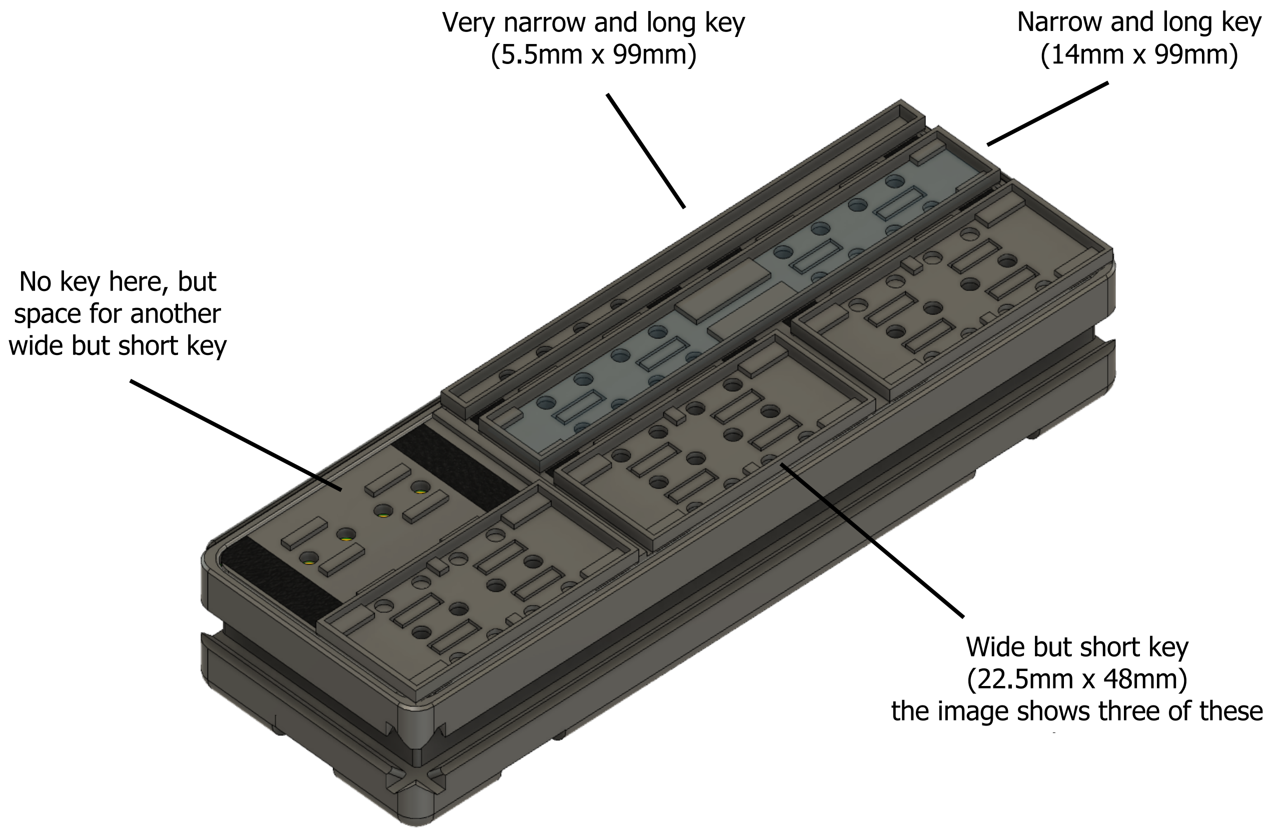


Figure 7.2. – An example of a variety of keys placed on the longer of the two base blocks. This image shows how the rectangular locator pins on the base block mate to the top keys. The circular holes in these keys permit the contact pins from the base block to touch the circuit board contained within the key, to permit data transfer.

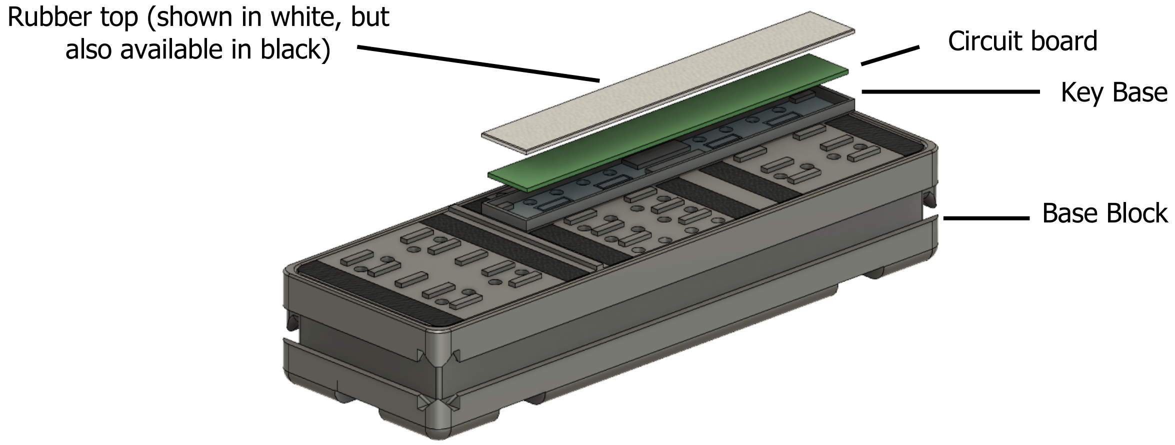


Figure 7.3. – An example of the longer of the two base blocks, with the layers of a top key shown. Here the bottom layer represents the base of the key. The green layer represents the circuit board, and the top white layer represents a soft rubberised layer that is touched by the user. The green circuit board layer reports touch position along the key as well as pressure of touch.

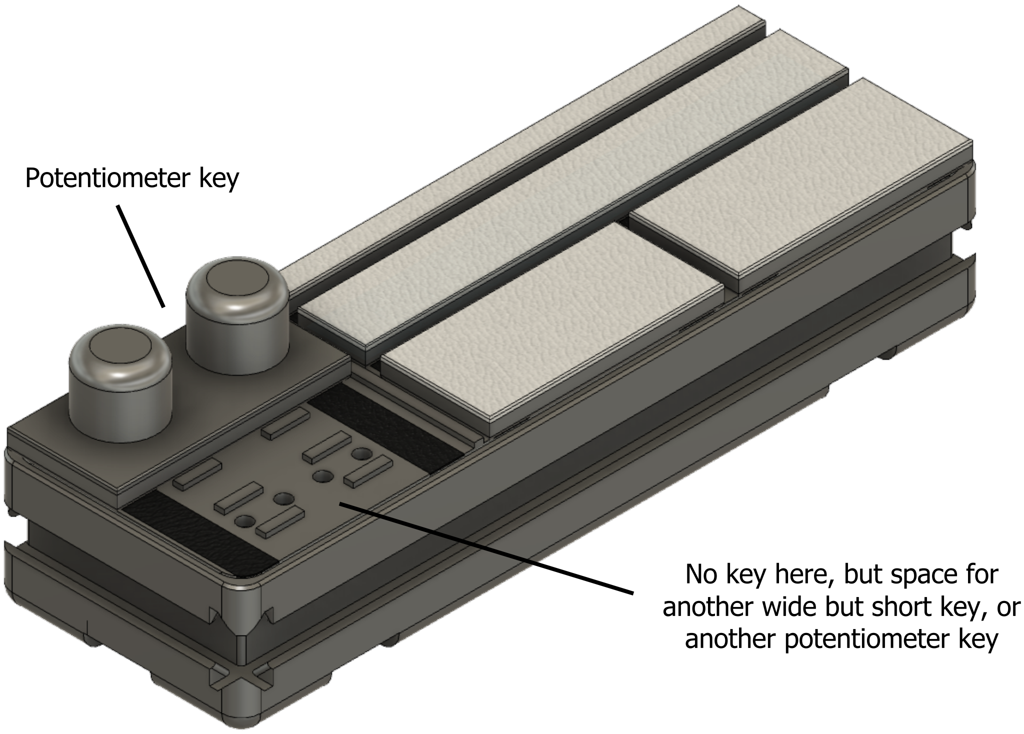


Figure 7.4. – A selection of top keys applied to one of the longer base blocks. The image shows the three sizes of top key (two of the wide but short keys are shown), and also includes a potentiometer key, which uses the same footprint as a wide but short key (22.5mm x 48mm).

7.3. Ideal 2: Harness the existing musical expertise of teachers

Research already documented within the case for this research in chapter two, acknowledges a range of barriers both encountered and perceived by teachers when seeking to adopt technology into their pedagogy. Indeed, wrapped up within this are often individual teacher perspectives, grounded in perceived confidence, as well as their cultural backgrounds and foundations. When considering music education through the lens of authenticity, and the perception of music inside verses outside of school, a selection of research (again outlined in case for this research) presents teachers themselves as the 'heart of the problem' due to being products of the Western classical tradition (Hargreaves et al 2003, Wise et al 2011). This conception arguably takes an older, more formalised view of teaching, and misses the fact that many positive opportunities present themselves when pupils are active partners in the learning process, specifically when there is dynamic interaction between teachers and pupils, or indeed pupils and pupils. Whilst teachers and pupils are arguably grounded in differing foundation paradigms, based in part due to the different experiences gained, as a teacher and as acknowledged in chapter two, I have always found value, been intrigued by, and learnt much from the extent of pupils' knowledge about *their* music, and the strong musical identities that they hold. Active learning and dynamic interaction is a key feature of the initiatives mentioned previously: the BBC micro:bit and Scratch coding community. It is also evident in the action cycles of this research, specifically the two-way dialogue drawn through being able to visualise the approaches taken by pupils to setting up their controllers, conversations surrounding the rationales behind their decisions, and the discussions that took place to support and guide approaches to work with more discerning control.

It is through this lens of active learning and promoting dynamic interaction that I wanted to find a way to harness the musical expertise of teachers. Indeed, there is little point in reducing barriers for pupils at the expense of creating barriers for teachers. Reflecting on my own approach to musical composition, I arguably have one foot in the western classical tradition camp: I play the piano, and it is via the piano keyboard that I develop my compositional ideas. For me using anything other than a keyboard interface would likely act as a barrier to my compositional output. This is arguably an interesting position as this research has focussed on seeking to find alternatives to the keyboard interface. However, drawing in the cases of the music specialists in the form of Andrew in action cycle three, Jamie in action cycle four, along with the interlocking cultural, social and organisational contexts of teachers use of ICT presented by Somekh (2008), and teachers' scepticism of the value of ICT as argued by Cox et al (1999); there are compelling reasons to seek to develop an interface that can work for these groups in addition to those new to music. Arguably a truly flexible developed device should enable both novices and experts to both engage in active learning and dynamic discussions relating to visualising each other's approaches to music composition. Interestingly, this approach aligns with Wise et al's (2011) embellished stance, originally put forward by Hargreaves et al (2003), that in order to allow students the freedom to express their creativity, music teachers must create relevant scaffolding structures in order to support with knowledge, skills and appropriate resources for what the pupils are doing. At baseline, if I can build a device that works for me, and a pupil can build a device that works for them, then we are both able to have a conversation and learn from each other's rationales and approaches.

The dimensions of the developed blocks and keys enable the opportunity to relate (as opposed to emulate) conventional instrument designs through combining and connecting a series of bases and keys together. Figure 7.5 highlights an example configuration that draws some relationship to an existing instrument (a piano keyboard). This approach arguably connects into the concept of skeuomorphic design – a design concept that features heavily in software user-interface design, where an object in software is modelled on a real-world object. Common examples of skeuomorphism include the disk icon for saving work, and the image of a recycle bin or 'trash can' as the place to drag a file (or folder – another skeuomorphic image) that is no longer needed. This type of design seeks to promote an intuitive approach to software interfaces, as users are able to relate and reference back to a real-life counterpart, and thus is often considered a useful design concept in order to support the creation of learning curves. Skeuomorphic design in music software is very prevalent, especially in the design of plugins that are based on physical hardware. In many cases, the software version seeks to graphically emulate its hardware equivalent, even though there is technically no reason to do so. There are however compelling reasons for why skeuomorphic design in the twenty-first century, is also considered less appropriate:

> Skeuomorphism helped a generation through the learning curve of coming to grips with a digital era. But, it also began to hold us back. We became familiar with the concepts and they entered the language and our day-to-day lives, but skeuomorphic design led to huge amounts of clutter on the desktop. They brought too many useless details to our computers which we no longer needed. There's a whole generation out there now that has never known a world without computing. The visual metaphor is not necessary anymore. (Göttling 2020).

There are arguably parallels that can be drawn between this argument and the keyboard. On the one side the keyboard is a highly relatable and recognisable interface, and especially so for those with roots in the Western classical tradition. On the other side there are arguably pupils where the music keyboard represents nothing more than a device found within the 'sub-culture' (Swanwick 1999) that is school music. Placing the opportunity to create a skeuomorphic inspired or non-skeuomorphic inspired controller in the hands of the user, represents the potential to align to the different cultural paradigms that exist between teachers and pupils. Indeed, this was already in some form emulated by the approach taken by Ben in action cycle four, who saw no reason to construct something that related to, or emulated, a guitar; Ben instead saw it as an opportunity to go his own way. Figures 7.5 and 7.6 represent indicative controllers that could be constructed with reference to this theme.

Figure 7.5 – A skeuomorphic design example. This construction demonstrates a connection back to a traditional keyboard. The sizing of the blocks used also represent a close map to the sizing of a keyboard. This example shows one octave but could be extended through the use of more blocks. In this example, the interface is constructed from four of the longer base bocks, with eight wide but short keys (here in white) representing the white notes of a keyboard beginning on the note C. The black narrow but long keys here represent the black notes on a keyboard and are positioned in the same place on this interface as where they fall on a keyboard interface.

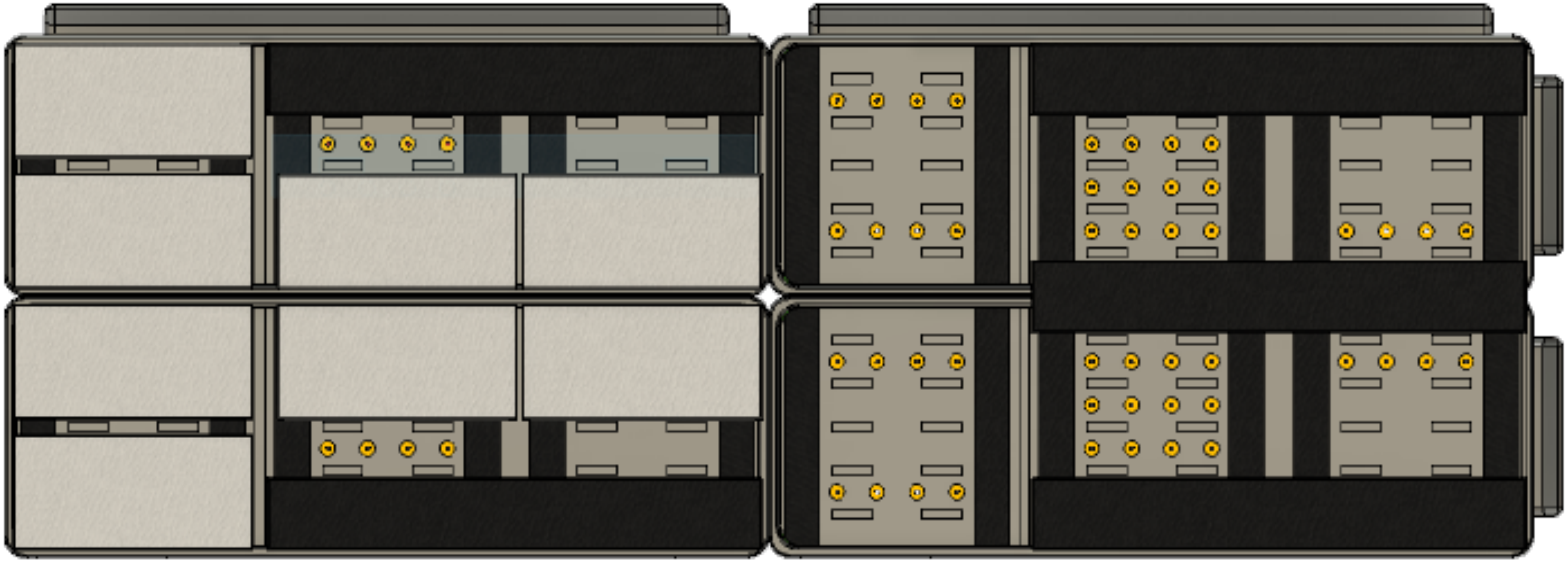


Figure 7.6 – A non-skeuomorphic design example. This example uses the same number of base blocks and top keys as figure 7.5, but they are arranged in a very different way. Note, this image is shown horizontally, but the creator (user) who has decided on the construction of this interface may choose to orientate this in a vertical position. Within the software layer, the user is able to determine the functionality of each key.

7.4. Ideal 3: Promote opportunities for sustainable progression. Seek to balance challenge, frustration and boredom though exploring the possibility for the interface to grow with the user. Explore potential links, including those of traditional instrument learning.

As a precursor to this ideal, it is important to also discuss the 'computer' element of the 'Composer – Keyboard – Computer' model. Typically, the computer element relates to the Digital Audio Workstation (DAW) software for the recording of, sequencing, editing and layering of compositional ideas into compositions.

7.4.1. Link 1: The Digital Audio Workstation (DAW)

> Whilst the appearance of their interfaces may vary, many DAWs share common elements, such as the main sequencer interface (often referred to as the "arrange" page), the mixer, the "piano roll" for MIDI editing (a rather archaic interface which refers back to the era of the Player Piano), a waveform display (modelled on the oscilloscope) and the traditional score. (Marrington 2017).

Marrington's summary of the common DAW elements is particularly interesting given that each of the elements listed is a digital emulation of something that previously existed in either the analogue domain (mixers and oscilloscopes) or the low (even no)-tech domain (piano rolls, traditional notation scores). Indeed, whilst a number of DAWs provide all of these elements, certain DAWs promote the focus of a particular element over the others; the Sibelius software for example uses the traditional score as the user interface for the MIDI engine underneath, and this is a good example of where technology in music has enabled the potential to do tasks on a computer that were previously undertaken using non-computer means (a pencil and manuscript paper, or costly manual music typesetting). With DAWs therefore providing digital emulations of previous technologies, and a connected keyboard providing a physical user interface that draws on an 18th century design, Savage (2007b) argues a harsh reality:

> The linking of a computer with a piano type keyboard, hinders a reconceptualization, pre-empting discussion and argument about new ways forward. The interposition of an 18th century piece of technology (i.e. the equal tempered keyboard) mediates at a fundamental level the type of musical activity in which students can engage. Unfortunately, it also reinforces traditional concepts of success or failure within such activity. The opportunity for using a computer as a musical instrument has been lost. (Savage 2007b:145).

When this is considered alongside the music technology innovations of innovators such as Imogen Heap, and her gloves developed in order to revolutionise the way music is made through movement, Joseph Malloch's Prosthetic spine, developed as a digital instrument in order to capture and 'musicalize' the movement of dancers, or 'Cyborg Artist', Neil Harbisson, who is able to compose music just through looking at things via an antenna implanted into the back of his skull; it is clear that technologies found in music are highly complex, but the technologies found in the music classroom and music education, are very much rooted in the past. Indeed, one of the emerging themes of this research; affording the opportunity for personal control, has yielded numerous explorations, over the last few decades in commercial music in particular, to seek better ways in which to draw in music audiences, and encourage individuals to be part of the overarching musical experience. Through attempts made to enhance our consumption of music, artists and bands originally released 'bonus content' in the linear form of videos and lyric sheets in order to provide their audiences with extra content, but these have since been replaced by much more innovative opportunities that enable the user (or consumer) to remix, gamify or virtually immerse themselves with the content, in order to support the construction of their own personal experience. Pupils in school will have certainly seen their consumption of music pushed through models such as these, but there has been very little change to how pupils interact with music and music technologies in the classroom.

There is interesting research that positions the Digital Audio Workstation itself as having a hand in the shaping of music education, and in turn shaping the type of compositions that are created. The functionality that is afforded to users via bundled built-in effects, loops and virtual instruments that can be played via a connected controller interface arguably positions the DAW in this way, rather than it just being a tool that is used to capture and layer compositional ideas:

> A particular effect of linear sequencer interfaces is to encourage 'accumulative' forms of composition, in which the constituent parts of the music are gradually introduced one layer at a time until the piece appears as a complete entity in front of the user. (Marrington 2017)
>
> They [DAWs] subliminally direct the actions of users, in both musical and non-musical ways (Jennings 2007:78).
>
> Beneath the veneer of the DAW graphical user interface, there is a layer of music education woven into the code of the software that makes the 'ready-made' experience possible. Programmers make assumptions and covertly steer users by limiting options. (Bell 2015).

Bell's position that the programmers developing DAW software covertly steer users by limiting the available options is an interesting position, and connects to the first ideal that I present within this discussion regarding the desire to seek to provide flexibility and customisation in order to enable pupils to build interfaces that are applicable to their needs. Whilst the flexible developed interface does constrain and enable the user to limit options on the interface itself, the flexible interface enables the user to remove constraints when ready. My research positions the argument that the constraining or limiting of parameters should only be temporary in order for sustainable progression to be enabled, as when the availability of options or functionality are permanently removed, or placed out of reach to the composer, it represents a barrier to engage or progress with the development of musical ideas. This indeed also chimes with the earlier discussion presented in chapter five relating to the affordances of certain game controllers compared to others, and the harnessing of expression. Indeed, Marrington argues that 'the DAW's impact, whether it constrains or liberates creativity, is entirely dependent upon the specific nature of the literacy that the student brings to it' (Marrington 2011). This further provides support for this research project and further cements the need for the performance interface to better converge and connect the composer and the computer in order to support the development and practical application of the literacy that pupils are able to bring to the process.

Despite these positions on the Digital Audio Workstation, it is widely acknowledged that the emergence of the DAW has represented a major transformation in enabling people to produce, create and compose music; removing the requirement of needing a physical studio, in turn enabling 'bedroom production' and opening up many opportunities for informal engagement with music technologies. Fagnoni and Morelas (2019) position Ableton Live as the current most popular DAW based on their own findings within their own research and the findings of another, much larger study, drawing in over 30,000 respondents. Their findings are particularly interesting as the design and functionality of Ableton Live arguably represents a step-change to the common model of a DAW, and the typically common DAW features presented by Marrington (2017). Prior's (2008) cultural evaluation of Ableton Live, emphasises its clear difference from the other software emulations of the hardware recording studio, presenting the software instead as one that 'encourages creativity and play' (ibid 2008:912). Originally designed as a performance tool by two electronic musicians who were frustrated at the lack of software dedicated to live improvisation (ibid 923), the findings of Fagnoni and Morelas (2019) presented in figure 7.7 show strong migration from other DAWs to Ableton Live. These findings indeed also provide support for this research project as they highlight that there is a strong appetite amongst users to actively seek a DAW that encourages the possibility to experiment and creatively 'play'. These are themes that are very much presented through this research and across all of the previous action cycles, particularly the desire to encourage the trialling of ideas, auditioning harmonic language, and following the trial and experimentation process, the mapping of these ideas to the physical controller interface in order to perform them.

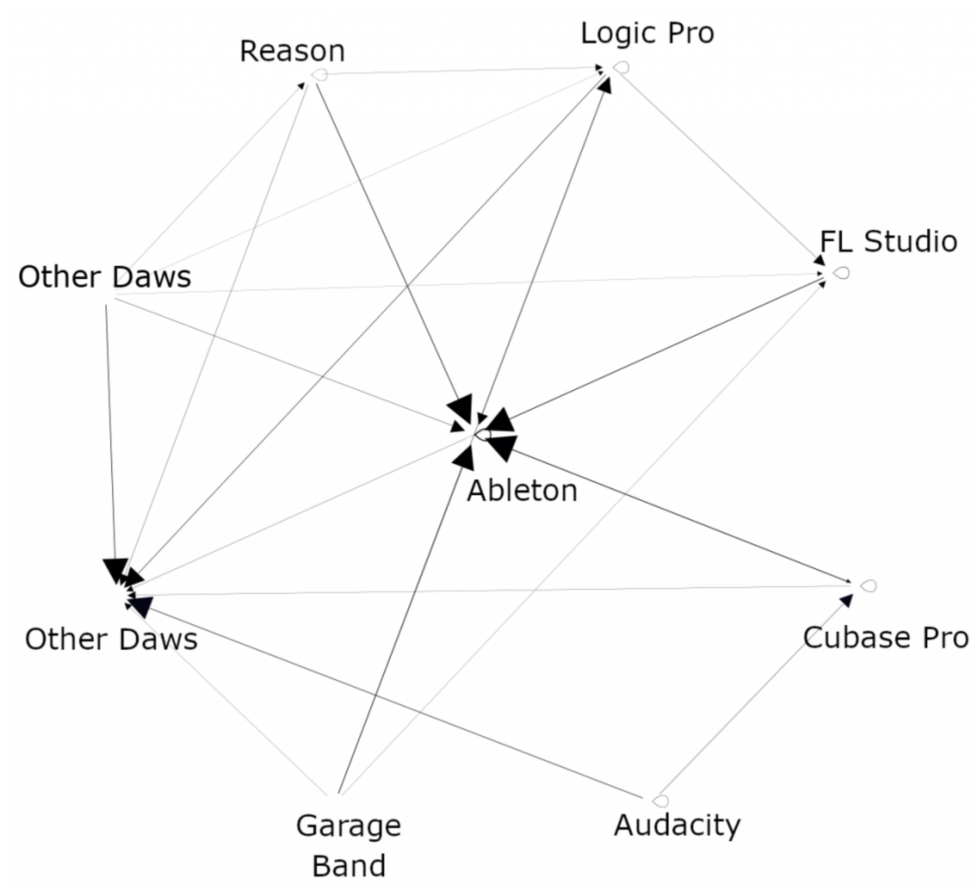


Figure 7.7. Fagnoni and Morelas (2019) findings revealing the migration between main DAW used. Arrows show direction of migration, and can therefore be both ways. The size of the arrow here represents the volume of users switching DAWs.

7.4.2. Link 2: iPads and Tablets – A reactive change to the traditional composer – keyboard – computer model?

In chapter two, I stated that the use of tablet computers in schools had led to growing research focussing on 'tablet pedagogies.' Indeed, the research by Geer et al (2017) identified 'promising signs' that tablet use was bringing about a pedagogic shift to support 'enhanced' learning.

Indeed, at baseline, the use of the iPads and tablets, represents an adjustment to the composer – interface – computer model, as it effectively merges the interface and computer elements of this model together. There is however arguably a deeper reaction to the traditional model taking place here, and potentially due in part at least to the previous inflexibilities of the older but established model of an 18th century interface (keyboard) connected to the emulation of technology grounded in 'older' studio traditions (DAW). The proliferation of so many music related apps, in a way affords the opportunity to cater for and importantly challenge all pupils, relevant to their specific needs, through the relevant app that they use. This in turn provides the potential for a highly accessible music making environment, with iPads and tablets demonstrating their ability to be modified, not physically, but through the many different available apps that they can run.

Sustainable progression within this iPad and tablet model is therefore charted via a path through a broad range of apps, rather than through the more traditional and often school-based models, such as the model employed by testing school B where learning activities are designed in order to form and then apply keyboard skills. Indeed, there are a range of DAW emulations, and tablet specific DAWs that offer from the range of typical functionalities found in computer-based DAWs, but in contrast to desktop and laptop technologies, there are also a vast number of apps that are designed to explore a single specific area relating to music, or act as a tool to enable 'something', usually with the expected user expertise level clearly targeted. Navigation through the apps in order to develop musical literacy through the plethora of apps available is often informal, drawing on social constructs for recommendations, or through spending time through trialling in order to ascertain if the app does something that is perceived useful, or results in being able to do something that is desired. This informal approach again further highlights the dichotomy between music inside and outside of school, and the informal verses formal school-based approach to learning. As indicated in chapter two, authors and editors of music technology focused blogs, websites and publications do indeed often suggest perceived 'good apps', but the apps identified are often presented in isolation from each other, rather than highlighting how learning can be constructed along a meaningful path in order to develop progression; where the learning of a skill in one app can be developed further or applied in another. As in chapter five, Hunt's (2000) position that interfaces which are not fully operable within a very short period of time are 'inappropriate', again chimes here. Through this lens, it is plausible that the more informal, socially guided, 'try then keep or discard' approach of the tablet model is driving the change in informal contexts to remove encountered problems that hinder flow (Csikszentmihalyi 1992), or perceived user challenges, such as the need to be able to play a physical interface like a keyboard. Indeed, numerous keyboard apps are available if the user wants them, but the tablet model enables the physical interface to be afforded much less importance than the composer – keyboard – computer model does. Arguably then, the warnings presented by Jennings (2007), Bell (2015) and Marrington (2017) regarding the technology used encouraging certain forms of composition, or programmers (as opposed to teachers) subliminally directing actions and steering users are further heightened here.

There is an argument that rather than seeking to enhance the composer – keyboard – computer model, which is the core focus of this research, that instead adopting the tablet model would help to reduce the differential gap between informal out of school contexts and the more formal context of school music education. However, the availability of tablets for all pupils in schools is still on an emerging trajectory, and as such there are similar challenges that exist with this model that existed with the game controllers in action cycles one to three. A BYOD approach leads to a range of different tablets running different platforms requiring different technical support requirements, and resulting in a different set of apps that are available, and therefore connects into the ethical and equality issues discussed previously. Conversely, the provision of class sets represents significant costs for schools or music departments. Tablets also bring with them additional challenges including in-app purchases, lower processing power to run multiple apps at the same time, and less storage space compared to their desktop or laptop equivalent. Additionally, whilst the potential to harness pressure sensitivity from tablet screens is emerging, it is still a long way from being a common functionality across all tablet types, and whilst networking technology is widely built into tablets, the user is constrained by the physical tablet size. The flexibility of the tablet to host a broad variety of apps in order to create an accessible music environment does however provide further evidence that there is user appetite for flexibility, and it is hoped that through the building of this into the flexible performance interface as part of this action cycle, the various strengths of the tablet model can be harnessed whilst also enabling the enhanced utilisation of existing technologies in schools.

7.4.3. Link 3: Connections to traditional methods of learning music and instruments

> 'The ability to remove notes from barred instruments makes note accuracy more accessible, freeing students to focus on more sophisticated musical elements related to balance, blend, and dynamics.' (Taylor 2012).

Taylor's observations relate clearly to the Orff approach to musical learning and teaching, and in particular Orff instruments like the glockenspiel and xylophone. The concept of temporarily removing parameters (in the form of note bars), effectively temporarily constraining the scope of an instrument, supports the scaffolding of other areas related to developing musicality; playing with greater note accuracy, timing or dynamics for example. Indeed, the Orff progression approach of constructing experiences relating to observation, imitation, exploration and experimentation, improvisation and composing, and thus the leading on to developing greater independence, is a well-established model within traditional education. The findings of the previous four action cycles provide strong evidence of supportive outcomes for each area relating to this progression model. This research, and especially the flexible interface as part of action cycle five, permits the opportunity to align to traditional approaches to music education, like the Orff approach, in order to develop a greater connection to music technologies. Indeed, the music keyboard does not permit the physical keys to be removed; an Orff approach would require starting on a glockenspiel or a xylophone, before later transitioning to a keyboard, which represents a completely different playing action, even though the overall key (or note bar) layout remains the same. The developed flexible interface supports the temporary constraining, before enabling the possibility to fully expand to a more complete, or more functional, or even more recognisable interface, should the user wish to do so, and therefore enables the technique of 'playing the interface' to also continue. Through the development of flexible physical interfaces that can be constructed in a way that is bespoke to the user, the pedagogic benefits drawn from instruments like the glockenspiel and xylophone can be applied, and ideally further harnessed, through new music technologies. Figures 7.8 – 7.10 highlights a potential progression model that could be applied, depending on the expertise starting point. Figure 7.8 provides keys sequentially ordered, arranged in ascending pitch, figure 7.9 maps the same pitches to the where they fall on a keyboard, figure 7.10 fills in the gaps on the keyboard interface. Note, there may be no requirement to progress on from figure 7.8, but the possibility to do so is available to be scaffolded.

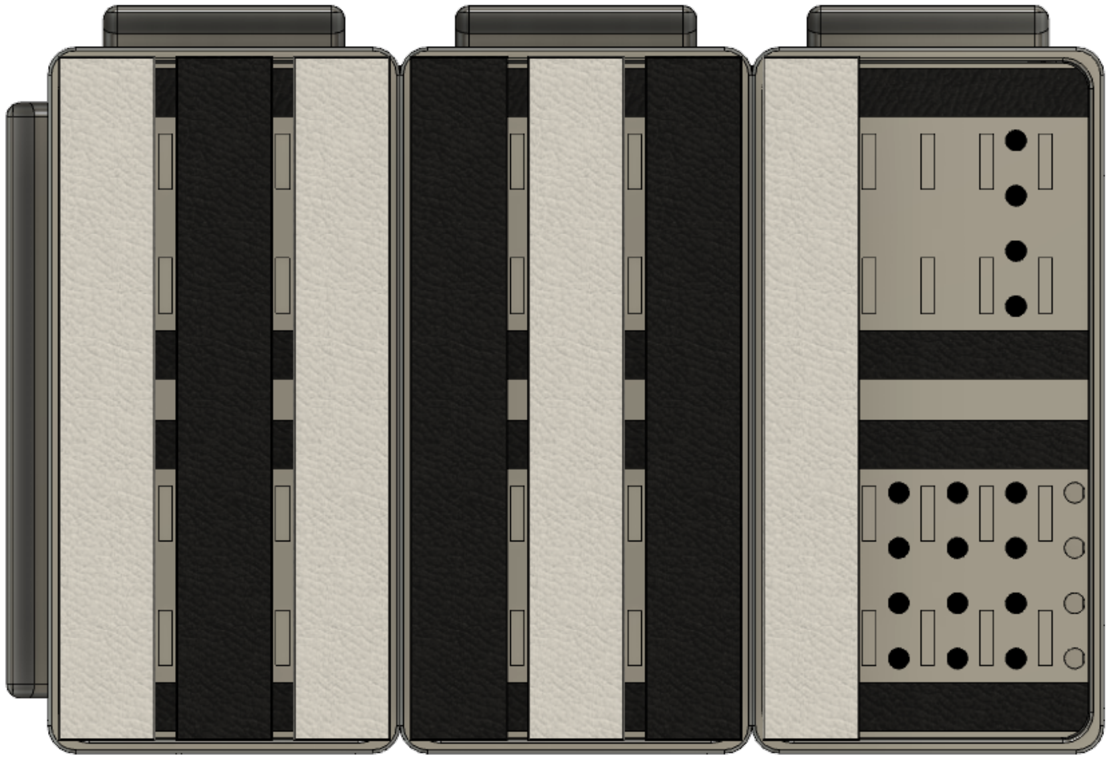


Figure 7.8. – First potential stage of the progression model.
This example uses a blues scale starting on the note C and therefore the keys represent the notes C-Eb-F-Gb-G-Bb-C. Within this figure, the notes are arranged sequentially across three connected shorter base blocks, and a mixture of long narrow keys have been used - the flattened notes within the blues scale are denoted here through the use of black narrow keys. In this example configuration, space remains at the end for additional elements to be added, for example further keys to trigger notes, or to provide the potential to control stylistic effects through the addition of further keys or potentiometers mapped to MIDI control change messages. In this example, the furthest right white key represents the octave above the furthest left key – the user could for example, choose to move this last key further to the right, in order to provide additional visualisation of the new octave starting, should they wish to.

Figure 7.9. – Second potential stage of the progression model.
This example uses the larger base blocks however retains the same number of notes for the same C blues scale used in figure 7.8. Here the notes have been arranged over four base blocks in order to represent where the notes are located on a traditional keyboard, however the spaces where notes that fall outside of the blues scale remain un-filled. This layout approach may support a pupil with their fingering and confidence with blues improvisation, and therefore offers an opportunity for scaffolding to take place, before the pupil potentially moves on to a traditional keyboard.

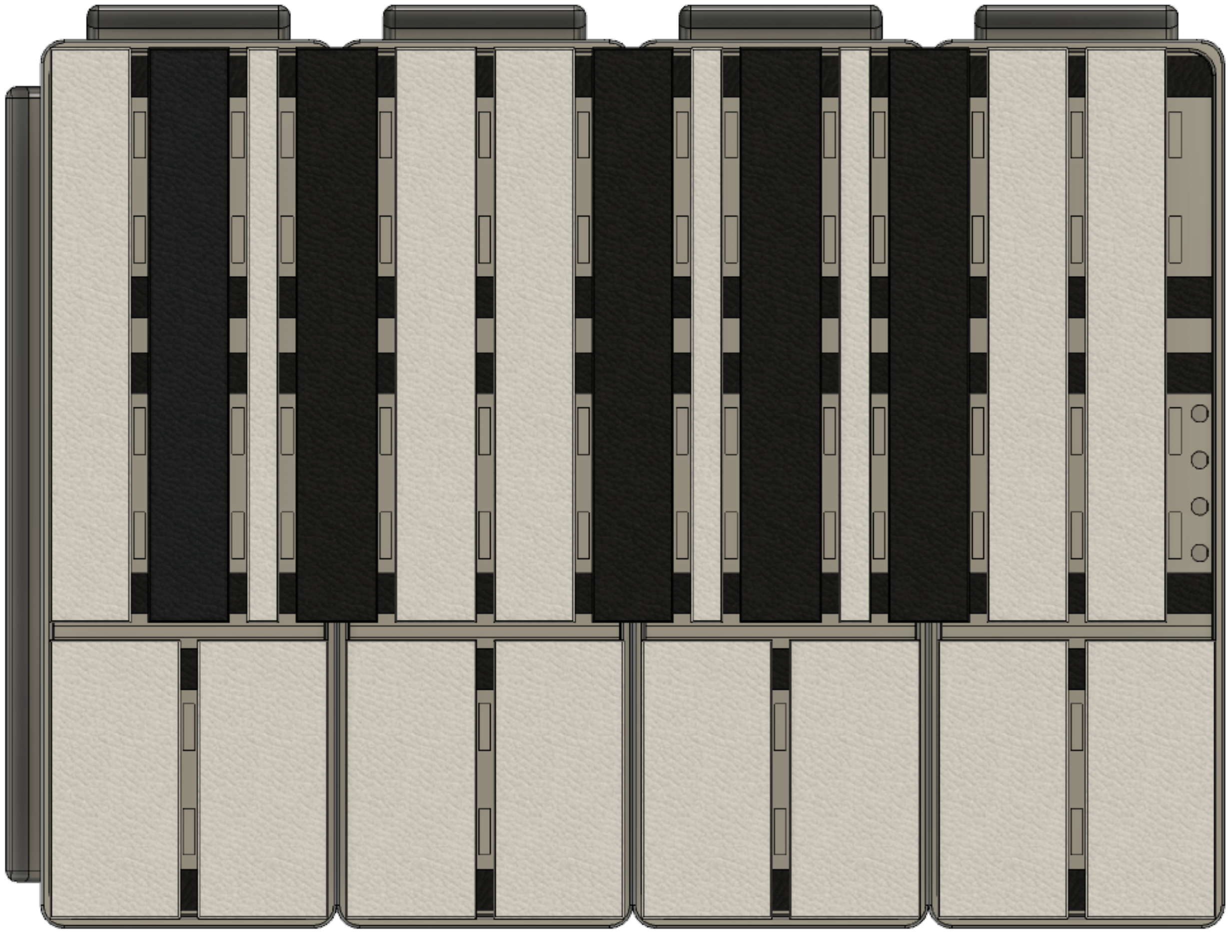


Figure 7.10. – Third potential stage of the progression model.
This example uses additional keys to 'fill in the gaps' on the constructed interface and represents the closest alignment yet to the design of the traditional piano keyboard interface. Such an approach when considered alongside the previous two figures arguably represents a removal of all scaffolding following successful progression through the last two stages.

7.4.4. Link 4: Connections through the software Layer to 'spark' ideas

Andrew's approach to use the developed software in action three to audition harmonic language, and then apply this discovered language through developing and *playing* (performing) his musical ideas on his chosen instrument, connects to Prior's (2018) cultural evaluation of Ableton live, and the encouragement of 'creativity and play'. This approach also aligns in some similarity to the informal and socially guided 'try then keep or discard' approach discussed previously. For Andrew, the ability to try something out, and then decide based on evidence, supported Andrew's decision-making process, and in turn this supported progression within his compositional work.

The approach taken by Andrew, alongside the ability for pupils to map parameters via the developed software layer in action cycle two, and the encouraging signs from teacher-pupil and peer-peer discussions on the best way to apply music parameters within action cycle three, provides evidence that within a project such as this, the software layer must do much more than just facilitate the communication translation between controller and computer. By extension the 'computer' element within the 'composer – keyboard – computer' model, needs to do more than just facilitate the capturing and layering of ideas. It was clear that the development of the software layer supporting action cycle five needed to embed opportunities for pupils to explore, audition and work on the development of ideas, and support evidence-based decision making. At this point of this thesis, this is the crucial element that I present as the necessary requirement to be able to form the foundations of sustainable progression. The software layer for action cycle five sees further integration of the merits afforded through the software layers in the previous action cycles (the ability to audition harmonic language through the use of pre-set scales and keys, and the mapping of music parameters to interface elements on the hardware controller), but also seeks to embed opportunities for users to build, audition and manipulate their ideas, to enable evidence-based decision making within the composing process. This work is channelled through the development of a series of modules within the software layer to further support the exploration of both harmonic language in the form of musical scales and chords, as well as providing the potential to construct and audition melodic lines and phrases within an idea sequencer. Success in this area indeed promotes the potential to break the impact of the DAW as being so 'dependant on the specific nature of literacy that students bring', with reference to Marrington's (2011) earlier quotation.

Providing access to a range of scales within action cycle two had proved an effective way for enabling pupil experimentation with harmonic language, and the software development work in the action cycles that followed continued to offer this functionality. However, I felt that the way that I had previously implemented the pre-sets within the software layer, still required the user to have some idea of the type of harmonic scale that they wanted to audition, given that access to particular types of scales was through a series of separate drop-down menus. With reference to figure 4.2 in chapter four, there was one for drop-down menu for major scales, another for minor scales, another for modal scales, and another for 'special' scales. This meant that arguably a pupil still required some musical understanding to select and explore the correct menu to be able to experiment with harmonic language for their pre-conceived idea. I sought a more refined approach to the pre-set process for action cycle five, with a single menu providing access to all scale types. Once a pre-set is created (saved), the user is able to map an individual note to their user-constructed hardware controller, with a colour-coded approach enabling the user to reference their created pre-sets as part of the mapping to hardware process. The following sections detail the rationale behind the developed software modules.

The developed 'Scale Creator' module

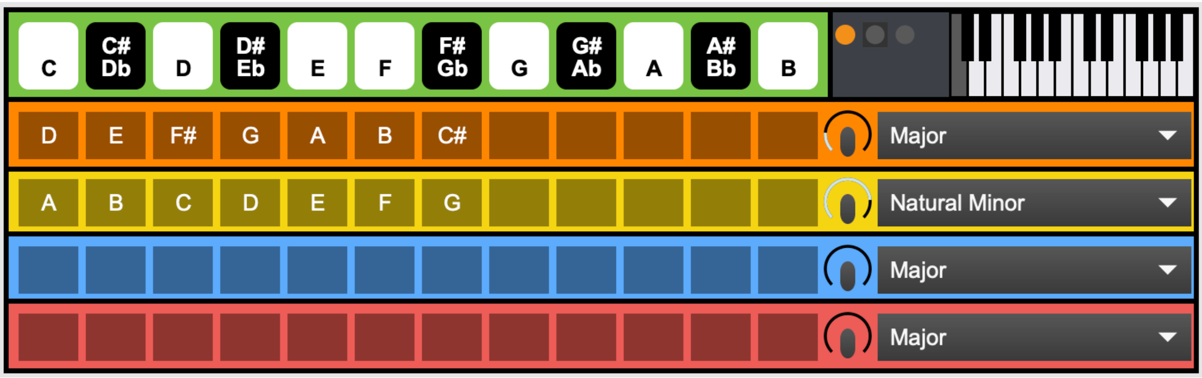


Figure 7.11 – An example of the scale creator module as part of the software developed for action cycle five.

Within the scale creator module, the green pre-set is fixed, and provides access to all notes available within the chromatic scale, beginning on the note C. This enables individual notes to be mapped to individual elements on the constructed hardware interface. The other colour-coded sections that follow underneath represent a range of pre-set scales that are able to be experimented with. The single drop-down menu within the colour-coded section provides access to a large range of grouped scales (table 7.1), where the user can experiment with the harmonic language first, and then map the individual notes from the scale to individual elements on their constructed hardware controller. The dial to the left of the drop-down menu enables the user to define the root note of the selected scale type, and the button within the centre of the dial enables the user to toggle between the correct spelling of scales (flats or sharps) where relevant. In the example provided in figure 7.11, the orange pre-set displays the individual notes of the D major scale, as 'Major' is selected from the drop-down menu; the dial next to the drop-down menu has also been turned to select the root note of 'D'. The yellow pre-set displays an A natural minor scale, based on the drop-down menu selection; the dial in this pre-set has been turned further to the right (the range of the dial runs from C – B, left to right). In this example, the blue and red pre-sets are empty as they have not yet been explored or set by the user.

Western / Traditional:	Major, Natural Minor, Harmonic Minor, Chromatic.
Diatonic Modes:	Ionian, Dorian, Phrygian, Lydian, Mixolydian, Aeolian, Locrian.
Alternative Scales:	Acoustic, Lydian Minor, Prometheus, Neo-Prometheus, Whole Tone, Leading Whole Tone.
Jazz Influences:	Major Blues, Minor Blues, Bebop Major, Bebop Minor, Bebop Dominant, Jazz Minor, Augmented, Diminished.
Pentatonic Mode Variations:	Pentatonic Mode A, Pentatonic Mode B, Pentatonic Mode C, Pentatonic Mode D, Pentatonic Mode E
World:	African Hardino, African Sauta, African Silaba, African Tomora Mesengo, Arabian, Balinese, Greek Houzam, Greek Ousak, Greek Niaventi, Greek Tsingankikos, Greek Periaiotikos, Greek Sabach, Greek Segiah, Gypsy, Hungarian, Indian Todi That, Indian Mela Kanakangi, Indonesian Slendro, Indonesian Pelog, Indonesian Selisir, Iranian, Japanese Ryo, Japanese Ritsu, Japanese Minyo, Japanese Hirajoshi, Japanese Iwato, Japanese Akebono, Kurdish, Spanish, Thai Seven Tone

Table 7.1 – The scales available for experimentation within the scale creator module developed as part of the software layer for action cycle five.

The developed 'Chord Creator' module

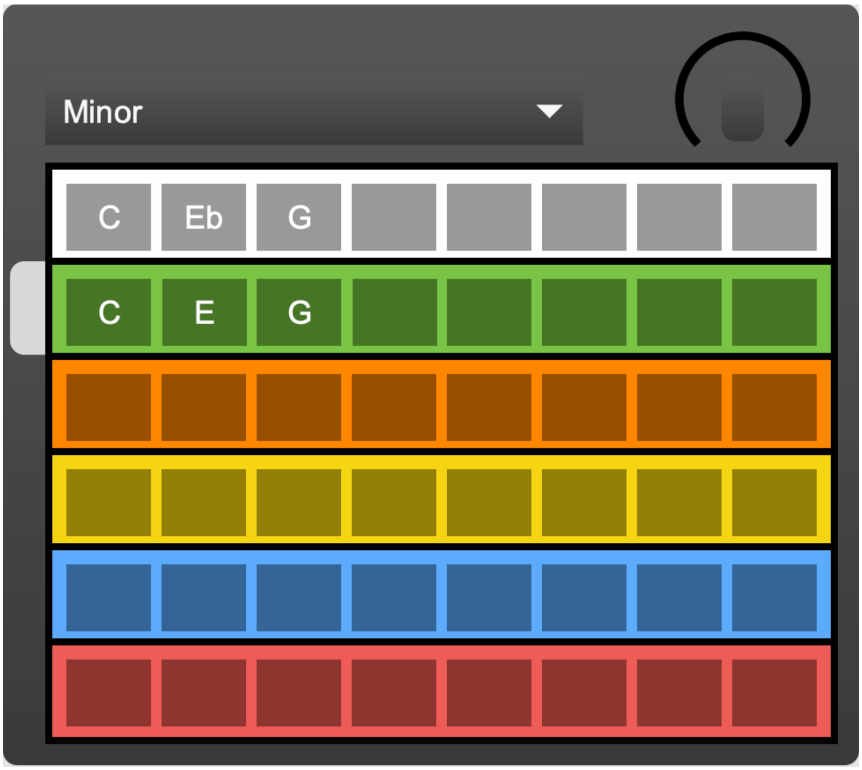


Figure 7.12 – An example of the chord creator module as part of the software developed for action cycle five.

The chord creator module permits the user to experiment with a range of chord types (see table 7.2), selectable from the single drop-down menu, with the root note again defined through turning the note dial. In common with the scale creator module, the button in the centre of the dial provides the functionality to toggle between correct note spellings (flats or sharps) for the selected root note. The notes displayed within the top white strip represent the individual notes that make up the current chord being auditioned (based on the root note from the dial and the selected chord type from the drop-down menu). When the user finds a chord that they want to 'save' to a pre-set, they click on the tab next to a colour-coded strip. This transfers the notes from the white strip to the selected colour-coded strip, and from here the individual notes from the chord can be mapped, or the full chord can, to a particular element on the created hardware interface. In the example provided in figure 7.12, the white strip shows the chord that the user is currently auditioning (C minor). The user has previously auditioned the C major chord and decided to keep it, in turn saving the chord to the green pre-set. The remaining colour-coded strips in this example remain unused, but are they are ready to take chords following further chord auditioning.

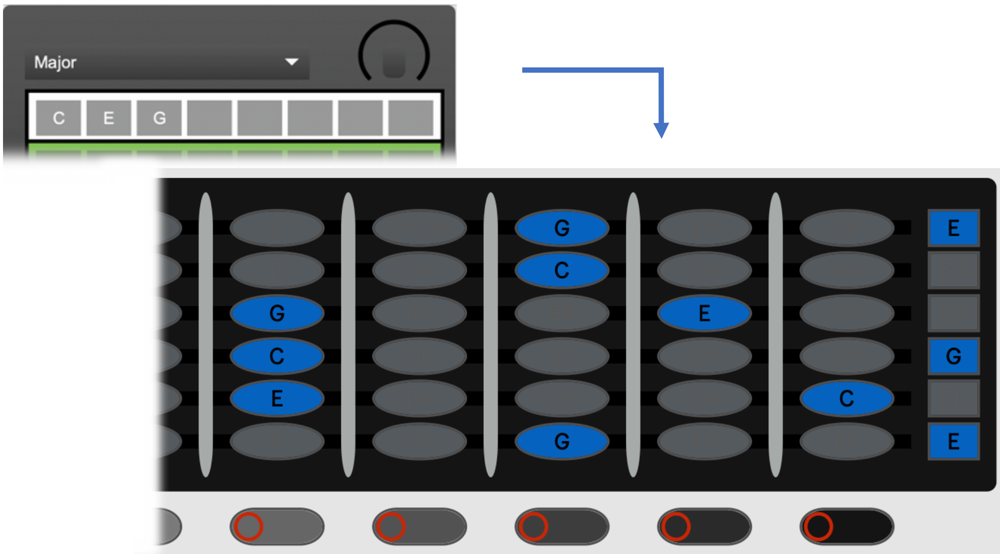
Core Chords:	Major, Minor, Diminished, Augmented.
Fifth:	5 (Power Chord).
Sixth:	6, 6 (with 9th), Minor 6, Minor 6 (with 9th).
Seventh:	Dominant 7, 7 (with flat 5th), 7 (with Sharp 5th), 7 (with flat 9th), 7 (with sharp 9th), 7 (with flat 9th & flat 5th), 7 (with flat 9th & sharp 5th), 7 (with sharp 9th & flat 5th), 7 (with sharp 9th & sharp 5th), Major 7, Major 7 (with flat 5th), Major 7 (with sharp 5th), Minor 7, Minor 7 (with flat 5th), Minor (with Major 7th), Diminished 7.
Ninth:	9, 9 (with sharp 5th), Major 9, Minor 9, Minor (with major 9th).
Eleventh:	11, Minor 11.
Thirteenth:	13, Major 13, Minor 13.
Suspended:	Suspended 2nd, Suspended 4th, 7 (with suspended 4th), 9 (with suspended 4th).
Added:	Added 4th, Added 9th, Minor (with added 9th).

Table 7.2 – The chords available for experimentation with as part of the chord creator module developed as part of the software layer for action cycle five.

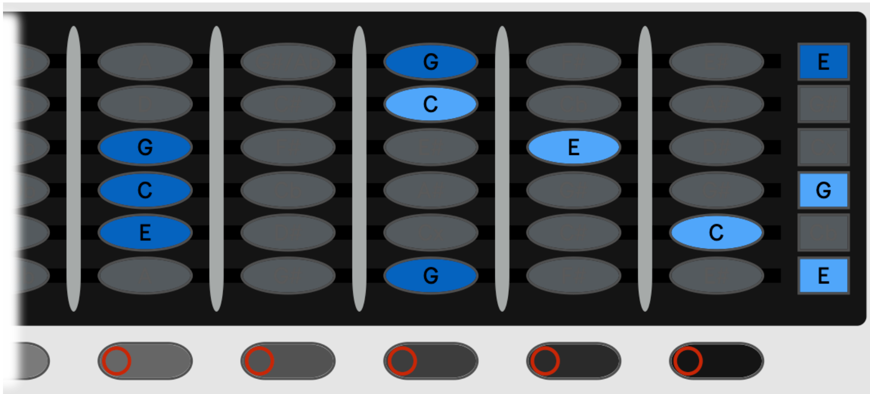
The developed 'Guitar Chord Creator' module

Within the review of literature in chapter two, I discussed the example scenario of the guitarist seen working out phases and ideas on a guitar, before needing to 'convert' these ideas via a keyboard interface in order to engage with music classroom computer technologies. The rationale behind the Guitar Chord Creator module is the targeting of support for 'non-keyboard' instrumentalists within the music classroom, but also framed through facilitating opportunities for experimentation.

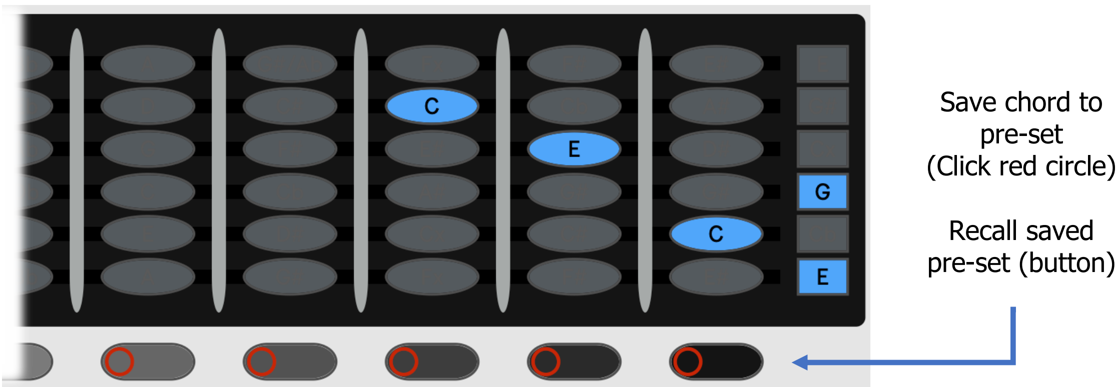
The Guitar Chord Creator connects to the Chord Creator module and permits the visualisation of auditioned chords from the Chord Creator (the notes of the chord displayed within the top white colour-coded strip) to be voiced on a graphic representation of a guitar neck. The user is then able to experiment with the voicing of their chosen chord on the guitar neck, turning notes on or off, therefore selecting the voicing that they want to use. Their chosen voicing is then able to be saved to a guitar neck pre-set for easy recall. This enables the potential for chords to be voiced in a similar way to typical guitar voicings or experimented with in a different (user-defined) way. Figure 7.13 contains an annotated example of the process.



First, audition a chord using the Chord Creator module. The notes from the displayed chord in the Chord Creator module also display in the Guitar Chord Creator module. The notes in the square boxes represent open strings on the guitar, and the notes in the oval boxes represent the notes in their fret position on the guitar neck.



The user is then able to select the relevant notes and experiment with chord voicings. Selected notes display in a brighter blue to denote that they are 'on', and this displays the user-defined voicing, within the context of the other notes from the chord. In the example above, the user has constructed a chord voicing that represents a C major chord voicing that is typical for a guitar.



Following the audition process, the chord voicing is saved to a pre-set fret slot, to facilitate easy recall. Only the notes that form the auditioned voicing are recalled. Other chords and voicings can be auditioned, and then saved and recalled via the other pre-set slots.

Figure 7.13. – Example workflow of the Chord Creator and Guitar Chord Creator module. For illustration purposes only a section of the guitar neck is displayed here.

The developed 'Melodic Idea Sequencer' module

From my time working in schools, I have seen many pupils using the DAW piano roll in order to cut and paste, or drag up or down, a melodic idea that they have created in order to hear their melody start on a different note, or attempt to facilitate a key change. Pupils' approaches to constructing melodies, hooks and riffs are often contour influenced in terms of pitch movement. It is common to see feedback from teachers and other pupils that attempts to provide strategies to enhance the idea(s) further through some exploration of musical devices in order to extend the potential of an initial idea. However, the tone – semitone relationship of the piano keyboard, and therefore the piano roll, means that moving a created melody up or down, often results in changes to the melody line itself, with certain notes chromatically altered. Through observations, I often find pupils, when they move their musical idea up or down in the piano roll, are aware that their musical idea no longer sounds 'quite right' and has changed in some way, but struggle to identify exactly what the change is without additional support as to which note (or notes) need adjusting. When seeking to modulate an idea by step, there is often a sense of perplexation as to why the same intervallic relationships do not apply to the transposed melody line. Further complexities often occur when pupils seek to transpose from major to minor, or to another harmonic language; indeed, this particular example is good example of the piano roll providing pupils with limited support to accurately facilitate such a change. Substantial knowledge of music theory is required in order for pupils to audition the transposition of an idea from major to minor, augmented or diminished, or indeed to any other key. For the novice musician, or musician with only a limited or developing knowledge of theory, the piano roll does not, in many cases, provide sufficient 'evidence' for pupils to effectively be able to decide whether they want to keep the transposition. As such, the piano roll is mis-aligned to support accurate decision making for these pupils.

The key merit of the developed melodic idea sequencer within my software layer for action cycle five, is that instead of the necessity to move the musical idea itself, the axis of the piano roll is instead adjusted, and this alternative approach enables the better supporting of the auditioning of ideas in different scales and keys. By viewing the piano roll as a graph, with time represented by the X axis and notes on the Y axis, if the actual data contained within the graph is temporarily uncoupled, the Y axis can be adjusted, and this then enables the opportunity to then hear the created melody line correctly in a range of scales and keys or via the adjusting of the reference root note. Figure 7.14 details an annotated instance of the idea sequencer that I developed within the software layer, and Figure 7.15 highlights the difference applied to the piano roll scale (Y) axis. In these cases, the contour of the created melody line remains identical, but the scale that the melodic idea plays back is changed. Building on from the success from action cycle two, and the mapping of parameters from the software layer directly to the hardware, the same functionality is applicable here too. The rationale being that a user can construct a musical idea that they like within the idea sequencer, and make use of the opportunity to hear it in a range of keys and root notes. This informs the evidence gathering stage, enabling the user to make decisions based on the tangible evidence of what they hear. Once they are happy, the individual notes can then be mapped to individual elements on their hardware controller. This in turn enables the user to *play* (perform) the musical idea that they have built in the idea sequencer on their created hardware device. This stage is particularly important because it is through such an approach that the composer – interface – computer model (note the replacement of keyboard with the term 'interface' here) can be honed to support engagement with compositional ideas. The created line in the idea sequencer is static, but the potential to perform the idea leads to the user being able to perform with expression, through pressure applied to the interface keys, to manipulate note duration, to re-order notes in order to perform with a sense of variation, all of which has been strongly supported through the ability to internalise the idea through hearing and modifying it at every stage of the idea's development.

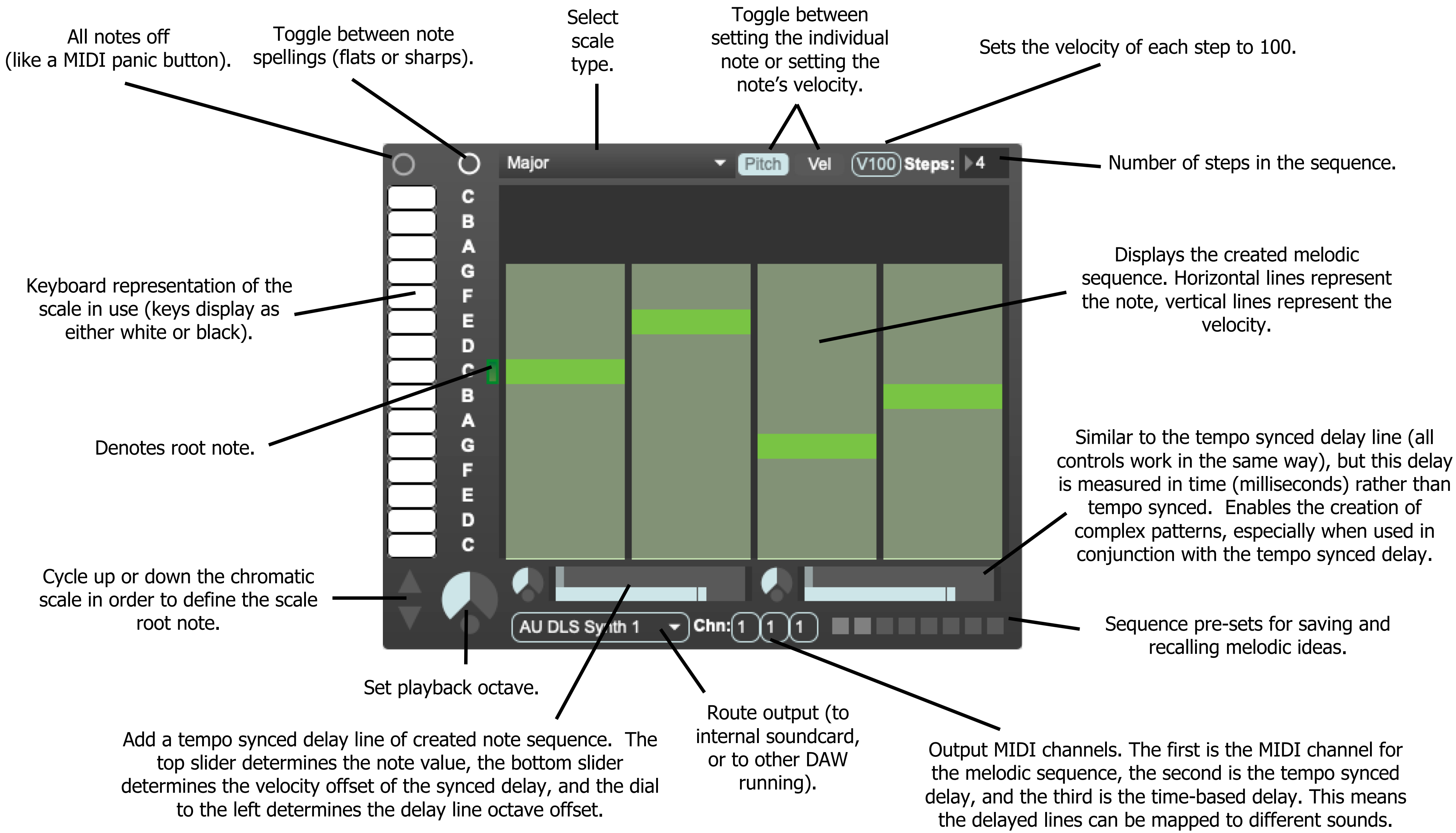


Figure 7.14. – An annotated version of the melodic idea sequencer detailing its functionality.

Figure 7.15. – A visual demonstration of the melody line remaining the same but the scale changed, creating the transposition from C major (left image) to D# major (right image). Note the correct spelling of F and C double sharps for the D# major scale. The button above the list of notes enables the scale to switch to its relevant enharmonic, in this case Eb major.

Developing an idea sequencer in this way also enables the possibility for users to experiment with looping, layering, and also the experimentation of complex time relationships that can exist between multiple ideas. Within traditional DAWs this is typically quite challenging to achieve due to the way that elements relating to 'time', time signature, and other elements that sync to grids for example, are globally defined. Figure 7.16 showcases another instance of the idea sequencer (shown in orange). The first instance in green consists of 4 steps, whilst over the same period of time, the idea in the second instance runs over 13 steps. In this case a musical motif of 13 against 4 is created; the user however is able to explore and audition interesting poly-rhythms. Individual steps can be silenced through the vertical velocity slider behind the note (a velocity of 0 equals note off). For each sequencer instance, the key, scale and defined root note are instance independent, which permits further (and often complex) harmonic relationships to be able to explored. Again, the ability to experiment, internalise and perform enables a greater sense engagement with the musical ideas at all stages of their development.

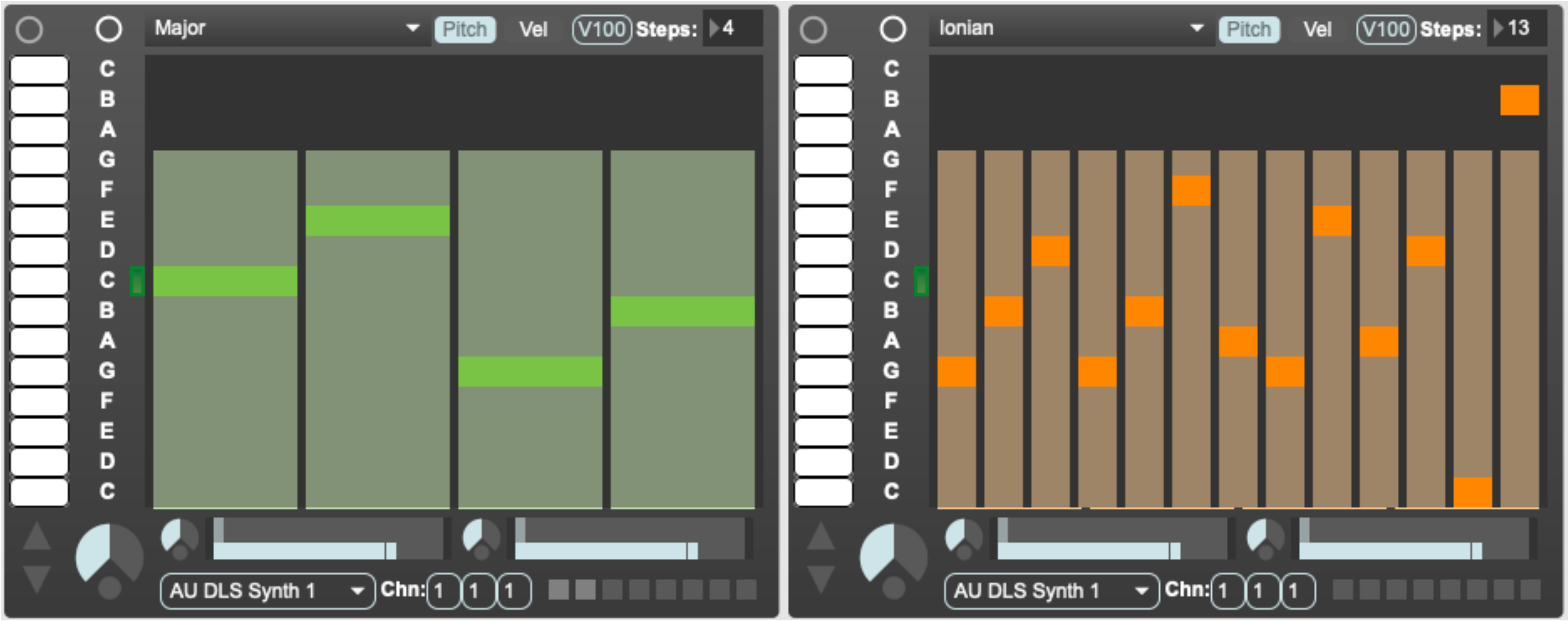


Figure 7.16. – Two instances of the idea sequencer, demonstrating a 13 against 4 rhythmical note pattern.

7.5. Ideal 4: Supporting affordable adoption for Schools

The budgetary challenges facing school education are well documented, and are referenced within the review of literature within chapter two. Arguably the biggest barrier for any new technology integration into the music classroom is its monetary cost, and the themes of technology affordability for schools verses the ethical challenges of the BYOD approach as a method of solving this, run through the action cycles of this research. Since the completion of these action cycles, the existence of digital poverty has been further highlighted through the Covid-19 pandemic, specifically its relationship to accessing learning opportunities at home. As such it is now even more important to recognise the social gap in access to technology that exists within areas of society. The scale of a digital divide further places challenge on the BYOD approach as a solution to integrating technology, within schools in particular, and there needs to be other ways identified in order to move forward.

Affordability does however not solely relate to just monetary cost. There are numerous other factors that impact affordance to be able to 'do something'. Adequate time, the availability of training, and the access to support, all impact affordable adoption for teachers, and these common themes that remain so prevalent within the school classroom, also weave through the findings of this research project, and the wider contexts explored within the review of literature. Buckenmeyer (2010) argues that a solution is to begin with the teacher, not the technology: to seek opportunities for professional development, to enable teachers to continue learning, alongside adequate support time, adequate technical assistance, and that this helps to shape attitudes towards technology.

The elements forming the basis for the proposed product within action cycle five focus on the enabling of individuals to construct interfaces relevant to their bespoke needs, through building their own meaningful interfaces from a series of available blocks that then enable the visualisation of their approach to be shared, discussed, and adjusted within social contexts. These ideals draw heavily from the 'Maker Culture' strand of technology enhanced learning. The connected concepts of enabling bespoke access and personalised learning is highly pertinent within the current education climate, and success in these areas can also be seen as supporting the reduction of the differential approaches to learning that are found in formal and informal contexts.

The emergence of 3D printers, and their growing provision within schools, offers significant potential to support maker culture, collaboration, and ways to connect learning in one subject to other areas.

The Department for Education (DfE 2013) report findings from a number of schools, that successful 3D printer integration can led to positive impacts on motivation, engagement and learning for pupils; although the same report does acknowledge the common affordability factors relating to time, training, and technical support, as continued challenges. It is too simplistic to simply suggest that 3D printers can solve the resourcing problems of our schools. If the affordance challenges relating to time, training and support can be managed however, there is significant potential through the provision of 3D printers in school, to harness these devices in order to support the wider integration and introduction of resources, and this research project, specifically relating to action cycle five, aligns with broader connections to promoting overarching maker culture.

7.5.1. The potential for schools to 3D print the physical hardware blocks in Schools

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Table 7.3: Creative Commons Licence Types, adapted from creativecommons.org

Through releasing the hardware blocks under creative commons, and aligned to the licence model of CC BY-NC-SA, potential is afforded to schools, and their pupils, to utilise the created data files pertaining to the developed product as part of action cycle five, in order create a stock of the interface building block enclosures for use in the classroom. The internal electronics could then also be supplied separately for insertion into the 3D-printed blocks, or printed circuit board (pcb) files supplied under a creative commons license to also enable in-house fabrication. These options enable flexibility to the standard approach to purchasing technologies from suppliers, and the potential afforded through creation of a 'kit' that the end product is made from, opens up scope to harness many learning opportunities, along with encouraging dialogue within the process. The licence potential to 'remix' and/or adapt also offers the opportunity to support user customisation; this is a highly popular area of current concern for emerging technology, in that it helps to support the creation of context, and a user's immersion within that context. One popular example of this type of customisation is the software 'ttrockstars', which supports primary aged pupils to learn their timetables. Many schools subscribe through a whole-school licence, and pupil success in recalling timetables within a time limit is rewarded through earning virtual currency to spend on shaping the user's 'Rockstar' avatar appearance; this customisation enables pupils to construct a meaningful relationship through their created avatar.

Within the trajectory of this research project, user customisation developed as a core and important component through the action cycle findings. A product licence that supports remixing and adapting is well aligned to the constructionist foundations underpinning this research, and ensures the potential for further tweaking and customisation of the design based on user-requirement, experimentation and exploration. Such an approach also offers ways to support pupils with forging connections to the numerous elements that connect in the development of new technologies. Indeed, collaboration within music is important, and ensembles form a significant contribution to the 'fabric' of music. In house manufacturing, and the feeding in of developments to design, offers the opportunity to work in ensemble with other departments, harnessing the skills of the other skilled professionals in school, and to explore potential cross-curricular links to other subject areas. It certainly offers schools and pupils further ways to connect science, technology, engineering and maths subjects, under the umbrella 'STEM' to arts areas. There are substantial potential future gains here if the various affordances relating to time, training and support can be managed.

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8 Conclusions and Recommendations

The initial stimulus for this research project was formed through the series of inter-connected strands that I had experienced and observed over my time working as secondary school music teacher: The struggle to excite and inspire pupils who appeared to view their school music lessons very differently to the commercial music they engaged with outside of school, the fact that I felt that many pupils had grown tired of an over-diet of keyboard use, and that there were limited credible other quality music performance resources or instruments available, in part due to limited department funding, in which to try and coax inspiration, or indeed motivation. My main aim was therefore grounded in a desire to seek to dismantle performance barriers to music composition through disrupting the composer – keyboard – computer model that I had found so prevalent within the music classroom. Exploring alternatives to the keyboard in the middle of the model offered scope to seek relationships to technologies found outside of the classroom environment.

The first two initial research questions were formed around the term 'digitally native', a term that has undergone significant criticism in the years since Prensky's original conception in 2001. Through this criticism however, broader development of thought has formed in order to shape the overall conceptualisation of just what digital nativism means. Evans and Robertson (2020) chart the historical lineage of the term's development through four key phases: Phase one as the initial conception argued by Prensky, phase two as 'reaction' and the temptation to adjust to pupils' preference of using technology, phase three as the requirement to centre around 'adaptation' due to the growth in awareness of a digital divide, and then finally phase four, the 'reconceptualization' posed through modern challenges, and the focus on seeking solutions to problems posed. When viewed through this lens, the initial rationale for this research shows clear roots in phase two: The music keyboard is positioned as the problematic component within the composer – keyboard – computer model, and the line of enquiry seeks to solve the problem of the keyboard through replacing it with a perceived 'preferential' technology; the aim is to seek to harness the potential of perceived child-centric mastery of a modern consumer technology, in order to secure an uplift in motivation. However, whilst the use of game controllers provided pupils with the opportunity to physically interact with a technology from outside of school within their music lessons, within the framework of this research, the findings highlight that the game controllers did not on their own promote or provide inspiration, or support sustained motivation to engage. It is possible here to argue that had the trajectory of this research focussed on the development of music games, perhaps in the form of games to support music training, then pupils' use of these controllers to 'win' these games, may have resulted in an uplift in their impact. However, given the very notion of using a device to win a game runs contrary to that of playing a musical instrument (Blaine 2005), the rationale of this research was to support the 'playing' of musical ideas through user-constrained harmonic language, and through enabling the user to remove, change, or re-form these constraints at any time, rather than 'winning' through succeeding at pre-determined structures.

The advice from pupils informing the initial development work for action cycle two, to 'make the application of the game controller use more akin to physical gaming' is nonetheless interesting, and requires comment here especially in relation to the 'temptation to adjust to preferences' as part of the second phase of Evans and Robertson's history of digital nativism. From the perspective of the pupils involved, this can certainly be seen as an indication from the pupils themselves, that a better experience could be achieved if the research was to align to, and able to harness, gaming preferences. At face value, seeking to harness pre-existing expertise seams a sound idea, but the findings of the later cycles of this research show a broader problem with such an approach. The problem with positioning gaming expertise as the core driver to support success, is that the approach again only caters for a selected few, in this case those who play computer games, and therefore risks limited positive impact, or indeed the forming of a different set of performance barriers for pupils that identify as non-gamers. It also fails to offer anything new to the research problem posed; just as a lack of keyboard experience throughout this research has been positioned as a performance barrier to the flow of compositional ideas from composer to computer, a lack of gaming experience could be considered, and result in the forming of, a similar barrier.

The case of Andrew and the concept of 'sustained progression' put forward by Machover (1992) highlighted that the initial rationale behind this research was too narrow, and that seeking to cater for a single group of pupils - only those pupils who had limited motivation for keyboard activities (initial research question three), missed opportunities to support other pupils, who despite being further on in their musical journey, still had other specialist needs, and still required support in order to continue to progress in their own development. The potential to map music parameters in the developed software layer to controller buttons within action cycles two and three arguably did provide some scope for pupils to align their own parameter mappings to pre-existing controller preferences that might have been developed previously through playing computer games if they wanted to, but this potential did not appear to a make significant positive impact, and was not naturally commented on by the pupils in the testing schools as a connection made. This is likely due in part to Blaine's (2005) position of using a device to win a game as contrary to that of playing a musical instrument, but also due to the lack of a surrounding game-based context.

The findings of each action cycle, and the response to these findings in order to inform the next action cycle, pushed the scope of this research past the initial research questions; the research became about more than simply trying to create a solution for pupils new to music, or seeking to enhance the motivation of these pupils to engage in music through the use of a recognisable device, or indeed seeking to draw influence from gaming expertise. The focus gradually changed in order to embed support for a variety of progression routes through both individual and social exploration, in order to provide appropriate scaffolding for pupils at varying points within their musical journeys. The use of game controllers in the first few action cycles required a reactive process of investigation: A reaction to harness controller functionality made available by console manufacturers with no scope to adjust or shape this physical functionality in a bespoke way for the user; a reaction to enable the latest controller release to remain compatible with classroom computers as the controllers were not designed to work proprietarily with windows and mac computers; a reaction to the positioning and heightened importance placed on two thumbs as the primary 'performance fingering' for the buttons located on the top face of the controllers, which in turn meant limited scope to depress multiple buttons from the left and right cluster of buttons at the same time. Pressing multiple buttons is however in all fairness, not considered compliant with standard or common game play processes.

Each of the three initial research questions place the game controller as a core variable, and as such, these initial research questions also become reactive in their nature. At the beginning of this research, the proposed antidote to the problem of a lack of motivation, and perceived lack of relevance in the keyboard, was through the use of a relevant and associable device. However, using game controllers as the solution arguably represents an extrinsic approach to dealing with the effect of the problem, rather than the dealing with the cause, and as the action cycles progressed, it became clear that the controllers were too simplistic to have a positive and sustainable impact on the dismantling of performance barriers to music composition, and that there was limited scope to ensure sustainable progression: A pupil wanting to progress their musical journey further, would likely need to move on from using a game controller to an alternative interface, and this therefore risked the reformation of performance barriers at a later stage. This is perhaps unsurprising given the explorations of Bijisterveld and Schulp (2004) and the concept of traditional instrument design as 'perfection'. As the action cycles within this research progressed, it became very clear that there was a need to move from a reactive approach; responding to problems faced through the use of the game controllers, towards a more proactive approach regarding interface development; using the collected evidence, findings and observations and channelling these into informing the development of a new device in which to enable the continuation of this investigation further. The developed software layer had supported the flexible application of musical parameters and their mapping to the hardware game controllers, but rather than attempting to shoe horn an existing popular technology designed for a different application entirely, and despite the merits the technology able to be considered as culturally relevant and associable, the hardware interface needed to also be flexible in order support a the move to a proactive approach to support music learning, development, performing and composing. The best way to achieve this was through extending the flexibility afforded through the software layer to the hardware interface as well, in order to support enhanced bespoke customisation through temporary constraining and scaffolding. Despite this move from reactive to proactive, the research findings from the game controller action cycles nonetheless provided the important foundations on which to develop, and as a result ensured the sharpening of the research focus to move towards supporting intrinsic and sustainable progression as the key 'benefit' for pupils.

8.1. 'Dismantling Barriers' - The relationship between this project and existing research

The review of literature in chapter two explores a number of connecting threads that both relate to and inform the broader context of this research area. This broader research context, and the findings from this project, confirm that there are other types of barriers that form, particularly around access, adequate provision, preconceived attitudes to music and music technologies and time to develop sufficient expertise. These other non-performance and non-music related barriers that apply to both pupils and teachers in the music classroom bear a significant relationship to this research as they often contribute to the performance barriers that this research seeks, to find ways to dismantle. Therefore, the potential to reduce this broader subset of music education related barriers is also evaluated here within this section through drawing connections back to existing research.

8.2. The dismantling of barriers for pupils

Csikszentmihalyi's work defining 'optimal experience' and 'flow', draws connection to both the need for perception and balance; the precondition for flow being at baseline that a person needs to *perceive* that they are capable of doing the particular activity. Balance is informed between considering the perceived challenge of the activity, and the skills the person is able to bring in order to meet the challenge. Flow then 'forces people to stretch themselves, to always take on another challenge, to improve on their abilities' (Csikszentmihalyi 1992:30). Therefore, in order to successfully dismantle barriers, performance or otherwise, it is important to arm pupils with sufficient means in which to support their perception that the challenge they face is both achievable and doable, and that through continued interaction and engagement, there is scope to stretch their abilities further. Regarding keyboards, despite their dominance in the music classroom (Savage 2010), their layout enabling both visual and spatial experimentation (Roels and Petegem 2015), their offering of expressivity through touch sensitive keys, and their multi-timbral potential; pupils do need sufficient keyboard performance mastery and skill in order to be able to channel musical ideas via the keyboard interface. The research surrounding pupils' perceptions that keyboards are 'difficult' (Dillon 2007), that they are ergonomically challenging for smaller hands (Wristen cited in Demus 2005), that scaffolding is only possible through task differentiation (Salaman 1997), along with broader concerns relating to their over-reliance (Kirkman 2007) and my own observations as a music teacher and previous research (Baxter 2004, 2007, 2013), suggests that there is a compelling argument for the need for an alternative interface for some pupils, that can provide better support for both initial scaffolding and stretch, but from a simpler starting base than is currently achievable via the use of keyboard technologies. The case of Orff instruments, and the potential to remove relevant note bars, represents an established approach taken by teachers and pupils, within the confines of traditional and conventional instrument contexts, towards device differentiation in support of scaffolding. However, the lack of such functionality and potential to do this from a keyboard perspective, especially given their dominance in the music classroom, represents a problematic limitation to their sole use. The findings from the use of game controllers in the first three action cycles provide strong evidence of the positive potential afforded through the temporary constraining and disabling of particular musical parameters, in order to support the development of other connected musical skills.

The initial conception of this research project arguably positioned a degree of expectation that through using a technology considered recognisable and associable, the tools that pupils use to conquer the challenge(s) faced in composing music could be enhanced based on drawing influence from, and connecting to, the relevance pupils place on such devices within their external lives. However, as the action cycles developed it became clear that such a position on its own, was largely superficial. Constructionist and constructivist thinking aligns the importance of enabling the user to be able to construct meaning in different ways, and therefore through the lens of supporting the occurrence of flow, pupils need to be able to draw meaning through considering the challenges that they face, alongside the alignment of their skills and available tools, in order to balance the perception of their capability to overcome the challenge. The findings and action cycles of this research project show that what constitutes a 'meaningful' device runs deeper than simply ascribing a sense of meaningfulness based on recognition and relevance afforded through a technology's use within an alternative context.

Over the course of the action cycles, a heightened sense developed that the dismantling of performance barriers to music composition for pupils lay in the removal of barriers to the experimentation of musical ideas. Within the formal classroom context, the experimentation and development of musical ideas usually takes place on an instrument, and certainly in the schools that I have worked in, this instrument is typically the keyboard. Experimentation to creatively develop musical ideas therefore holds an explicit connection to performance related skill, as the ideas are formed using the same instrument. It therefore stands to reason that if a pupil struggles to play the keyboard, they also risk the potential of further struggle through needing to use the keyboard to develop their compositional ideas. Evidence for this position is grounded in the various observations made over the course of this research, including the case of Andrew, whom despite being a talented keyboard player, needed the game controller software to support the development of his jazz sequence. Even at Andrew's comparatively enhanced stage of musical development, the keyboard interface did not offer sufficient support for his idea experimentation and development, however through experimenting, forming, and shaping his musical ideas on another interface and through using the developed software layer, he was then able to transfer his ideas back to the keyboard as his preferred instrument, for performing. Andrew's case offers strong evidence that when performance barriers and experimentation barriers are explicitly linked, they impact on each other, and when this is considered through the lens of flow, highlights a problematic scenario, especially with regards to the requirement to stretch, enable improvements in ability, and above all, develop the motivation to both engage and support a desire to want to improve. For those pupils from testing school A struggling to recognise the logical ordering of the keyboard pattern, reliant on note cards or writing the names of the notes on the keys using a whiteboard pen, there is a clear indication that a more user-appropriate situation is required, and that barriers to performance and barriers to idea experimentation need to be 'disconnected'.

In order to support this disconnection, the trajectory of this research over the course of the action cycles, moves away from the scenario where pupils must be able to translate their musical ideas through performing them via an instrument, or 'defined' interface, and towards supporting opportunities for greater experimentation of musical ideas through flexible, individualised and evidenced-based processes. Particularly so in the later action cycles, this became the driving focus of this research, where the strategic approach to providing such an evidence base is formed through providing opportunities for audible auditioning to enable pupils to be able to draw influence in order to inform their next steps. In action cycle two, this evidence base is formed through the incorporation of scale pre-sets and harmonic language pre-sets, providing pupils with the opportunity to draw evidence as to whether they had improved their ideas through performing in exactly the same way, but hearing their performance in differing scales and keys. By action cycle five, the need to physically play developing musical ideas is able to be pushed further back within the idea forming process for those pupils that need it. This enables those pupils that may find it appropriate and beneficial to assign parameters one by one from the software layer to the hardware layer to experiment with ideas through physically interacting with their developed device. Or, for those that struggle with such an approach, there is the potential for pupils to first develop musical ideas though an idea sequencer within the software layer, shape these ideas against a backdrop of different scales, keys, note durations, velocities and pattern lengths in order to build up an 'idea cell', and then once ready, unpack and assign the developed idea cell to their user-constructed hardware interface for playing, improvisation, further experimentation and further varying of ideas around their constructed and auditioned idea. Where pupils take such an approach, they are also able to build their constructed hardware interface *after* developing their musical idea cell, and as such this offers the complete 'disconnection' of experimentation and performance, as the performance element may take place after the experimentation stage. In turn, this redefines the linking of the performance and experimentation, through providing a disconnection at the start, and then supporting the re-connection at a later stage, importantly, once the initial experimentation, idea forming, and idea internalisation, has taken place.

The disconnection of experimentation and performance, and providing opportunities for interface scaffolding, within both the software and hardware layers within the experimentation stage, connects back to the broader contexts presented in this research, particularly those rooted in informal music learning approaches. Disconnecting experimentation and performance arguably seeks to enable an accessible entry point, much in the same way as the previously defined 'clever' technologies with their in-built intelligence, seek to do so. Equally, the tablet pedagogy approach supporting learning journeys through charting the journey though series of apps, highlights the established connection and potential, for supporting scaffolding and the forming of ideas on an alternative interface, or non-traditional instrument interface to the interface that might be used eventually. Indeed, given that flexible and bespoke approaches to learning are well supported through social-media platforms and informal music contexts, seeking to develop the potential for device flexibility, enabling bespoke and individualised learning possibilities, and enabling the disconnecting and re-connecting of experimentation and performance to be placed in the hands of the user, within formal music classroom contexts, is timely.

8.3. The dismantling of barriers for teachers

Helsper and Eynom's (2010) input into the digital nativism debate connects to this research through their position that defining digital natives and immigrants as two distinct and dichotomous generations is unhelpful: Whilst younger people are likely to come from 'media-rich homes', there are similarities across generations that are based predominantly on the experiences that individuals have with actually using technologies. Whilst pupils are at varying positions within their own musical journeys, music teachers are also at varying positions within their own journeys relating to integrating new technologies into the music classroom. Teacher's beliefs, attitudes, confidence and competence are all important in determining the adoption of ICT into an individual's pedagogy (Somekh 2008), and this is coupled with external factors including ensuring there is adequate provision and adequate professional development in which to support technology integration (Rogers 1997, Eyles 2018). At baseline, for any of the technologies developed as part of this research to be embedded future pedagogies, it is very important to ensure that additional, or new barriers are not erected for teachers. Reflecting on Pitts and Kwami's (2002) observations that composing supported by ICT requires 'mastery' of musical knowledge, instrumental skills and technology handling, there is important commentary to be made specifically around 'technology handling'. Thus far, this concluding chapter has reflected on the scaffolded approach taken within this research to support the development of musical knowledge, and through the flexibility afforded by the developed hardware and software, a sense of redefinition of the importance of mastery relating to instrumental skill. Technology handling often includes the need for teachers to be able 'troubleshoot', when things go wrong, often mid-class, and as such represents a core barrier for teachers that connects into the other factors identified.

The findings of this research highlight that using a bring your own device approach (BYOD) certainly proved limiting, both through risking the formation of unethical barriers to participation through variations of game controller functionality, and through erecting additional barriers for teachers through the need to complete a controller setup procedure prior to the initial use of the controller. The development of a bespoke hardware technology for the music classroom however offers the potential to better support teachers, and future research within this area is required in order to further ascertain how approaches supporting technology handling for teachers can be developed. This is especially important following the adoption of Midi Polyphonic Expression (MPE) in 2018 as an enhancement to the Midi specification, which in turn enables better support for the capturing of live expressive gestures whilst performing, or indeed the experimentation of musical ideas. Within in the original midi specification (1982), which the common electronic keyboard continues to use, the typical approach allocates one instrumental timbre to one Midi channel. This enables polyphonic performance and playback from a multi-timbral perspective, but aside from velocity (the speed at which a note is struck, and therefore relating to how loud or soft a note is triggered), other expressive and gestural parameters such as pitch-bend, vibrato, sustain and other effect control are applied to the overall channel, therefore affecting all of the notes being played for an instrument assigned to a specific midi channel at the same time. In contrast, MPE assigns each note its own MIDI channel, enabling every single note to be articulated individually, offering much greater potential for expressiveness. As such, the need to support teachers with technology integration, and supporting the wider integration of devices that support Midi Polyphonic Expression along the lines of the hardware developed as part of action cycle five, is particularly required.

8.4. Limitations, Implications and Contributions of this research

This research study was successful, with data able to be collected successfully from 'live' school music classrooms, and the interviews and observations at each action cycle yielded both sufficient and interesting findings in order the shape and inform the next action to be taken. The research questions were able to be answered, and were able to be built upon significantly, in terms of their scope and emergent line of enquiry as the subsequent action cycles unfolded. The action undertaken in the later cycles represents a significant step change to the initial cycles in terms of the hardware scope, but these initial cycles nonetheless provided the important base from which to build on from. It is however important that this particular research does not stop here! Action cycle five, whilst strongly grounded and informed from the findings of the preceding action cycles, and positioned as the next logical step to be taken, is only currently theoretically informed. The latest hardware and software have not been tested within the classroom environment due to the Covid-19 pandemic, and this testing within schools is required in order to confirm both expected and unexpected findings. The data collected would then be able to inform the continued trajectory of this research.

The current documented research findings are only drawn from three secondary schools, and this can therefore be considered a limitation of this research study. Additionally, the move to develop bespoke and flexible hardware has thus far only been able to be tested with an older year group, compared to the cycles relating to the game controllers - this therefore may affect both the validity of comparison along with strengthened validity that may present itself from testing across both additional schools and schools of a differing type, for example primary schools and middle schools. The developed flexible guitar controller as part of action cycle four has also only been able to be tested with a relatively small sample of pupils in comparison to that of the game controllers. Despite the challenges and limitations of the BYOD approach used within action cycles one, two and three, specifically the heightened barriers to technology handling for teachers, and the unethical mis-match for pupils brought about through variations in functionality, the BYOD approach to incorporating game controllers did enable the potential for wide adoption and immersion to be observed within full classes. The developed hardware as part of this research (action cycle four onwards) has so far not been able to be tested with similar numbers of pupils or teachers, and represents a clear connection to the challenge of enabling 'adequate provision', although the potential to deploy the hardware developed through action five through harnessing 3D printing technologies that are already found in schools will hopefully provide scope to support wider adoption and integration moving forward.

It is important to acknowledge here that this research project is not intended to replace existing technologies or resources that exist within current music classrooms, indeed one of the core findings of this research is that a singular interface can be responsible for the forming of barriers to learning, and that both enabling and encouraging flexibility is important. In the same way, this research project does not seek to position technology supported composition above other forms of composition - acoustic, ensemble, found-sound based and other types of music composition remain important to the fabric of developing musicianship and musical skills within a balanced music curriculum. However, the provision of a flexible hardware device within a music classroom, that is able to be constructed from modular principles, as in the case of the hardware developed as part of action cycle five, offers the potential for additional and interesting scope to further support the immersion of world musics and non-western scales into the classroom. Through action cycle five, the boundaries of the equal tempered scale are able to be removed through the ability to form a hardware device that is not formed from octaves, and this, alongside future adjustments to the software layer, provides an additional line of enquiry for future research.

The intended outcome of this research is to add to the existing technologies found within the music classroom, in order to support engagement with music composition. This research study offers suggestive evidence that a flexible, user-defined and scaffoldable interface, where the user is able to take active control in temporarily constraining musical parameters in order to support from a position of where they are currently in their musical journey, and when ready removing these constraints, offers beneficial scope to support learning. In addition, there is also suggestive evidence that there are advantages to enabling an evidence-based approach to music composition through temporarily disconnecting, and then later re-connecting, the link between experimenting with musical ideas and the requirement to be able to perform these ideas at the idea forming stage. This disconnection offers the potential for pupils to form musical ideas, listen to them, refine them and internalise them (offering a helpful connection to the development of music listening skills), with the complexities of performance temporarily removed and able to be instated, or even initiated, at a later stage.

The forming of an evidence base, in order to support pupils in their decision making, is positioned as a key element to the breaking and dismantling of performance barriers within this research. Further evidence of the benefits to support pupil decision making is found in action cycles three and four, and the resultant connections from these cycles inform the development of action cycle five. Here, further contribution to existing classroom provision is achieved through supporting opportunities for dynamic two-way discussions and conversations to take place between pupils and also between teachers and pupils. These later action cycles provide scope for visualising an individual's approach to music composition and performance – either through the mapping of parameters from the software layer to a connected controller, or through the construction of bespoke hardware interfaces.

When a teacher is able to construct their own relevant performance interface, and a pupil is able to construct theirs, this affords the opportunity for discussion to take place based on the respective rationales that inform the construction; in turn providing the 'evidence' from which interface refinements and learning connections are able to be made, following these discussions. Kuchera's (2011) warnings of 'chasing goalposts that are always moving' are worthy of consideration here.   Kuchera's point relates to the music game *Rocksmith,* where dynamic difficulty is an automated game element that seeks to respond to a user's current position, however the important difference here is that the process of refinement is conducted through human conversation and interaction.

Whilst this research started initially by seeking to connect to popular culture through an emphasis placed on using game controllers, the developments from action cycle three onwards, and the opportunities for social learning, in turn offers the potential to connect to multiple cultures, including the cultural backgrounds of teachers. This is especially the case with action cycle five where there is the potential to construct interface layouts that can either align to existing instrument design, for example the piano keyboard, or not. The harnessing of social learning in this way offers a direct connection back to established approaches within informal learning contexts, whilst channelling teacher's skills and experience to offer bespoke approaches to supporting students in the classroom has already gained traction through successful initiatives along the lines of *Musical Futures* that recognise the benefits of connecting informal learning approaches into formal (music classroom) contexts. In essence, these approaches hope to be able to contribute towards providing an 'antidote' to the positions of Sloboda (2001) and Hargreaves et at (2003), that teachers are the problem.

8.5. Final Thoughts

Mantie outlines a utopian position for the aim for technology in music education, but this position is nonetheless one that must be strived for:

> Our professional and ethical obligations must involve transcending naïve efforts aimed at mere competence with technology and music technology and should strive to engender critical engagement that sees students continually evaluating if and how various technologies can help them live richer and more rewarding lives in and through music. (Mantie 2017b:26)

It is hoped that this research project can act as catalyst for further school-based investigation into continued shaping and development of new tools that draw significant influence from, and feed the experiences, viewpoints, and interactions of pupils and teachers into their development. This is crucial in order to promote the gaining of self-identity as a musician for all pupils in our music classrooms. It is very clear from this research that from the position of performing and composing music within formal music education, a 'one size' to the approach taken to create or compose music, or the interface used in the process, does not fit all; therefore, moving forward, a single approach or single interface must not be the norm. Others (Bell 2014, Hein 2017c), have already put forward that the distinctions of composing, improvising, performing, and listening, as independent elements, and seeing these as separate entities, have collapsed. Indeed, within informal contexts in particular, the term 'producing' is often seen as the more appropriate overarching umbrella, and offers much broader and inclusive scope through positioning a 'producer' as simply someone who creates music in any capacity. This also then enables other terms including editing, mixing, programming, sequencing, recording to also be included as important elements within the creative process. Indeed, all these particular elements formed part of the processes undertaken at various stages by pupils in their creation (or production) of musical ideas within this study, and this adds to the importance of seeing pupils as 'creative producers' in formal music classroom contexts.

Aligned to Mantie (2017b), this project has sought to develop examples of potential technological tools for the classroom that can enable, elevate and support opportunities for critical engagement, continual evaluation, and promote a willingness to experiment, for all pupils at their varying stages of development. Ruthmann argues that we should 'leverage technology in support of active, social music making that emphasises the *doing* of music, rather than solely focussing on learning *about* music' (Ruthmann 2012:178), and in order to support this, this research project positions the best approach to be one that enables pupils and teachers to actively learn alongside each other, to be able to discuss reasons behind how they have constructed their own performance interface, and to dynamically discuss ways in which their approach can be improved, and their interface better utilised. This offers the potential for a progressive teaching method where openness and curiosity can inform meaningful strategies leading to richer and more rewarding musical lives.

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