The Sonic Blocks: Towards an Exploratory and Expressive Tangible Interaction

A thesis submitted in fulfillment of the requirements for the degree of Master of Design

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in the whole or in part, to qualify for any academic award; the content of the thesis is the result of work which has been carried out since the official commencement date of the approved research program; and, any editorial work, paid or unpaid, carried out by a third party is acknowledged.

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Abstract

Tangible User Interaction (TUI) has gathered much momentum over recent years as a way of physically representing and controlling digital information. Tangible User Interfaces privilege the control and action we, as humans, have with our highly developed motor and spatial skills. This physical mode of interaction with computation contrasts significantly with the visual mode of interaction we have with the Graphical User Interface (GUI) of the personal computer.

The context for this research inquiry is the design of a TUI, the Sonic Blocks, to encourage exploratory and expressive soundtrack making activities. This thesis gives an account of the design, development and deployment of the Sonic Blocks, with a small group of children in a primary school, to gain an understanding of their unique capabilities to enable a physical and embodied interaction for exploratory and expressive purposes.
1 Directions and motivations

1.1 Introductory directions

Computation is a medium which can represent such phenomena as sound or image to high degrees of accuracy as packaged bits of data. These bits of data can be manipulated, sent across the world and sent back in revised form. To carry out a similar task in analogue form takes longer and is nowhere near as efficient or compact. Take for example a sound recording. In analogue form it would need to be sent via mail as a magnetic tape, assuming we are in pre-compact disk times, and would take a number of days. It then needs a tape player to play it, or considerably more equipment and the original master tapes to edit it. I can do the same task tonight with software on my computer and send it to a colleague in the Netherlands ready to greet him for the working day. The point I would like to make here is that working with bits of data is a convenient and compact way of doing things and it presents remarkable opportunities.

But humans do not think or undertake tasks as discrete logical operations in the way a computer processes data. Consider playing a violin or guitar. This activity calls on our sensory motor abilities as we play the strings with our fingers using the spatial logic of the fret-board or neck to mediate the pitch we hear with our ears. This activity contrasts significantly with the mouse and keyboard operations we have with the personal computer. A divide has been created between this world of computation as discrete mathematical processes inputted
with machine like actions and our spatial and gestural world of acting, doing and expressing. This design investigation offers an insight into how to bridge this divide through considering the interface and interaction we have with computation for expressive and exploratory means.

1.1.1 New approaches and considerations for the design of interaction

Negroponte (1995) espouses the nature of being in a digital world and how it has had profound effects on how we do things. He considers computation to be a medium for creating new experiences that should be rich in sensory engagement. This argument has been extended by Ishii and Ullmer (1997). They posit that the world of bits (computation) and atoms (objects, surfaces and things) lacks sufficient coupling or connection, resulting in a disjointed relationship that creates problems for use and understanding. They suggest that digital bits, whatever their purpose, need to be coupled to physical artefacts that both represent and control them. They call this Tangible User Interaction (TUI). Considering computation and digital technologies as a physical medium has implications for design.

In the context of the digital age, a revolutionary approach to using computation was introduced by Weiser (1991) with the Ubiquitous Computing paradigm. In this the miniaturisation of sensing and display technologies were used to provide computation, for example, in the form of pads that could be written on and shared in a similar way to how we might share notes on paper. With the project, computation by the inch foot and yard, Weiser and his colleagues at Xerox Palo Aalto Research Center (PARC) paved the way for
embedding information and communications technologies into everyday artefacts to assist us with our understanding and use of them.

1.1.2 Designing for engaging experiences with computation

Whilst digital technology provides the means to send sound compositions across the other side of the world and do so efficiently, the ways in which these sounds are rendered, experienced and modified raises the issue and challenge of the interaction one has with them, particularly if you are experiencing these sounds on a personal computer. Designing for a rich and engaging experience with computation and electronic products using the sensory motor facility of our bodies has been a focus for the design and human computer interaction communities in recent years. Of particular note is the work of Hummels, Djajadiningrat et al. (2001). These authors offer the notion of the Aesthetics of Interaction which considers the physical and temporal ways of interacting with computation to be fertile territory for design exploration. The Aesthetics of Interaction has had a profound influence on the design thinking and the project within this inquiry.

1.1.3 Being creative and exploratory with computation

Accepting the opportunities for computation mediated through physically enriched interaction raises the last point of this introduction, and that is the activity carried out with it. Historically the computer and computation was developed for productive work oriented activities. The personal computer (Kay 1993) and the workstation was created for augmented office workers, hence its
form and functionality. But if we look at the fundamental ability of computation to generate data and then consider exploratory, expressive and constructive means to use this data, interesting approaches emerge. Resnick Martin et al (1998) look at computation in a visionary and exploratory way in the context of children’s constructionist learning which has its legacy with the work of Papert (1980). In this vision, coined *digital manipulatives*, computers are broken into physical bits that can be constructed and programmed, the familiar LEGO brick becomes a programmable module to construct physical objects driven by software programmed by children (Resnick 1993). In doing so it teaches children the power of computation as a medium for creating things through their own actions and creativity, providing a rich context to learn such skills as programming and applied mathematics in addition to the already physical skills of constructing and making.
1.2 Motivations for doing this research

1.2.1 My design practice experience

In my 15 years of design practice I had the good fortune to work with a small but successful practice that designed and constructed museum and interpretive centre exhibits\(^1\). Our aim was to tell *stories in space* and we used many techniques to encourage audience engagement. One of these techniques was the use of mechanical interactives, from turning a flywheel to simulate the action of a hydro-electric turbine to pushing and pulling handles to indicate the creation of an alternating current (see Figure 1 page over). These physical actions supported the written or spoken narratives central to the museum experience and provided an engagement that was motor sensory and action based, extending the text and images to impart a rich representation of the narrative. The design challenge was how they embodied and communicated these stories meaningfully through physical acts. This approach contrasted the predominantly visual use of websites with mechanical objects that supported the stories by doing. This was my introduction to using physical and tangible\(^2\) means to interact and explore.

In the formative stages of this inquiry I developed my understanding of what the design and research communities were doing in interaction design. An early review of literature revealed the concept and practice of tangible interaction, which I considered combined my interest in interaction design with the physical design skills and knowledge I have as an industrial designer.

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\(^1\) The name of this practice is Acumen Design (Australia) Pty Ltd, I worked for this practice from 1996 to 1998.

\(^2\) I use the term tangible here in a generic sense as these mechanical interactives were not coupled to digital data in the way that modern Tangible User Interfaces are.
Figure 1: Image of mechanical interactives. These are used to help explain electricity generation through action; they support the text descriptions of hydro-electric power generation. Photo: Hooper 1997

1.2.2 My children have inspired me

My children have a fascinating way of playing at home. I suspect all children do, but what also inspired me in the early stages of this inquiry was the open and exploratory ways in which they did this. My daughter who is eight years old will combine a length of wool and stick a face that she has drawn herself on one end. This then becomes a person or character in a narrative she constructs as she wanders around our house and garden. My son who is four years old draws maps in great detail for far off imaginary worlds that are constructed from his recent memories. These maps might support stories that are augmented by a collection of blocks or toys he gathers from his toy box. I observed this behaviour in my children and decided that providing physical objects that were coupled to digital data would be a fascinating way to extend this experience. My personal
motivations in this inquiry are to combine my interest in interaction design with the rich experience of children’s creative and exploratory activity.

1.3 Focus of this inquiry and summary of its findings

This design research inquiry offers insights into the particular nature of the interaction behaviours and activities offered by Tangible User Interfaces. The inquiry results in a designed prototype, the Sonic Blocks, which are observed in use with a small group of primary school aged children completing an expressive and exploratory soundtrack making activity. The methods used to achieve the design of the Sonic Blocks and observe them in use are a combination of research through design and ethnographic observation.

The insights gained into the nature of Tangible User Interaction in this exploratory context are:

- The affordances and physicality of TUIs can support thinking through doing
- meaning-making and aesthetic considerations play a role in the design of Tangible User Interfaces and their use in Tangible User Interaction
- designing TUIs for exploration and expression is a great challenge.
  The Sonic Blocks failed to engage the children in this sense
- there are limits of Tangible User Interfaces as compared to Graphical User Interfaces
- designers do design projects not gather ethnographic findings
- make good couplings: notes on making the digital physical.
1.4 Outline of this thesis

This prelude introduces the main directions, motivations and proposition of this inquiry as gathering an understanding through design and observation of the nature of Tangible User Interaction for exploratory and expressive means.

Chapter two lays the theoretical groundwork and provides an in depth discussion on tangible and exploratory interaction design. Three research themes emerge from the review of projects and literature to encapsulate my definition of Exploratory Tangible User interfaces to direct the design project.

These themes are:

- **action**, to encourage physical activity through objects within a TUI by considering their affordances, constraints and couplings to encourage perceptual motor activity meaningful to use
- **representation**, to enable meaning to be constructed through the formal visual semantics and analogies of the TUIs and their couplings to provide logical temporal sequences for use
- **exploration and expression**, to enable playful and explorative orientation towards an activity through the design of TUI objects that embody abstract concepts and are slightly ambiguous in their relationships and couplings.

The method used to undertake the program of observation, design and evaluation is the focus of chapter three. In this chapter I discuss the issues and reasoning behind this method as a conscious attempt to combine the ethnographic approaches of the social sciences to enrich the constructive agency of the design practice. Chapter four uses the methods and plans to practically observe the use of the personal computer and percussive instruments for the
explorative and expressive activities amongst primary school aged children. This chapter concludes with the main considerations taken from these observations to inform the design of the Sonic Blocks.

The design and development of the Sonic Blocks is the focus of chapter five. In this chapter the aims for design are outlined considering themes and first observations. These aims are followed by a chronological account of the conceptual and technical development of the Sonic Blocks in consideration of the design aims and the practical challenge of creating a robust functioning prototype.

Chapter six reports on the observations of the Sonic Blocks in use returning to the original observation group and environment. These observations are described and interpreted with respect to the research themes and design aims of the inquiry. Chapter six concludes with a position on the considerations and challenges of designing TUIs for exploratory activity, the particular nature of thinking through doing in observing the Sonic Blocks in use and the limits of TUIs in comparison to the Graphical User Interface (GUI).
2 Towards an exploratory embodied interaction

2.1 Introduction

The argument for a more embodied approach to our engagement with computers is a contemporary concern to designers and theorists. Physically engaging with objects and artefacts to represent and control digital information has gained traction in recent years as an alternative to the predominantly visual means in which we engage with and operate computers. This chapter discusses the development of the personal computer and charts the emergence of tangible user interaction (TUI) and the key concepts that describe it to inform the design of the Sonic Blocks. Finally the discussion concludes with play and exploration amongst children, and the ways to design a TUI to afford these types of activities, as this is the intention of the Sonic Blocks.

2.2 Background

2.2.1 Embodiment

Embodiment is the recognition of the body and its actions as part of the way we perceive and engage in the world. Embodiment gives a philosophical foundation upon which to consider tangible interaction as one approach to our engagement with computers and computation that is more spatially and physically enriched than the visual approaches offered by the Graphical User Interface. Dourish (2001) offers a carefully crafted definition of tangible and
social computing that points to embodiment as a unifying concept that connects these ideas in a foundational sense. But what is embodiment and what does it mean for this inquiry?

Merleau-Ponty (1962) considers the body to be central to the way we perceive and act. He appears consistently in contemporary writings about Human Computer Interaction (HCI) as a way of locating the importance of the body in perception with computation (Robertson 1997; 2002) (Dourish 2001). The theories of embodiment raise our consciousness of the nature of existence as being physical as well as mental. As such this inquiry has an interest in how our physical actions can enrich our interaction with computation. I have chosen an interpretation of Merleau-Ponty through the writings of Robertson (2007) which offer a foundation upon which to move forward.

*It is by moving that the world opens up to our perceptions because we move to different parts of it, move to orient ourselves in different ways within it and our bodily movements themselves are the means by which our senses act; for example, we reach out to touch, we feel by moving our fingers over a surface, we see by moving our eyes, our heads, our bodies, to look.* (Robertson 2007, p. 3)

Being conscious of the role of the body as it interacts with objects informs this inquiry. Dourish’s (2001) theories of embodied interaction inform the tangible user interaction approach and design of the Sonic Blocks. However Dourish articulates that embodied interaction is about the relationship between action and meaning, with action and meaning not just mediated through engagement with tangible user interfaces but situated through social collaboration. Fishkin (2004) has a narrower focus on embodiment than Dourish, one that does not consider the social nature of collaborative action but focuses on the device and its coupling to computation.

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3 Merleau-Ponty considers much more in this text, but the role the body has in perception is the focus of this inquiry.
In the first step of the script, users are attending to some object while they manipulate it. In the last step, they are being informed of the result. How closely tied is the input focus to the output focus. To what extent does the user think of the states of the system as being ‘inside’ the object they are manipulating (Fishkin 2004, p. 2)

Whilst totally sympathetic to Dourish, I take Fishkin’s (2004) narrower position on embodied interaction as one of artefacts coupled to computational systems and therefore how computation, and meaning, is understood to be embodied within these artefacts.

### 2.2.2 Affordances; form as a functional call to action

In his book the *Ecological Approach to Visual Perception*, Gibson (1979) describes the many aspects of the physical world that present us with information for action. From the visual recognition of the substances, surfaces and textures of materials and objects we extract enormous meaning about the world in which we act. This theory raises important considerations for the design of embodied interaction. As with Merleu Ponty’s concepts of the body and action as part of a human’s perceptual toolset, Gibson makes explicit the relationships we observe through visual perception. His concept of affordances is the most profound in terms of its impact on the product and tangible interaction design communities.

The concept of affordances, whilst first described by Gibson, was popularized for the design community by Donald Norman (1988) with his book the *Psychology Of Everyday Things*, later to be retitled *The Design of Everyday Things*. In this text Norman explores the notion of affordance and related concepts through actual examples in the world.

The term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just
how the thing could be possibly be used. A chair affords support and therefore affords sitting (Norman 1988, p.9).

Everyday objects from door handles and scissors to stove cooktops are used in this text to illustrate the properties of each of these devices as affording perceptible action through their physical structure and relationships. For example the holes in a pair of scissors only afford the insertion of your fingers, the size of the holes constrain the number of fingers you insert and the operation of the scissors is aided by the visibility of the moving parts. Affordances are relationships that can be established through visual perception to invite action.

*If a terrestrial surface is nearly horizontal (instead of slanted), nearly flat (instead of convex or concave), and sufficiently extended (relative to the size of the animal) and if its substance is rigid (relative to the weight of the animal), then the surface affords support. It is a surface of support, and we call it substratum, ground, or floor. It is stand-on-able, permitting an upright posture for quadrupeds and bipeds. It is therefore walk-on-able and run-over-able. It is not sink-in-able like a surface of water or a swamp, that is, not for heavy terrestrial animals.* (Gibson J.J 1979, p. 127)

Gibson indicates the nature of surfaces in this example affording support for terrestrial animals. However the reason why we make these relationships and perceptual motor distinctions is because of how these elements are composed.

*How do we go from surfaces to affordances? And if there is information in light for the perception of surfaces, is there information for the perception of what they afford? Perhaps the composition and layout of surfaces constitute what they afford. If so,*

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4 The holes in the scissors, and the scissors themselves, actually afford many imaginative uses. For example a person without the experience of using scissors would no doubt explore them differently to someone who has this knowledge. I am only interested in users who have some knowledge of scissor or hand held tool usage, as the physical scale, shape, and arrangement of these openings and the mechanical pivot connection in the scissor frame will cut a piece of paper that suggests appropriate affordances.
This focus on the composition of surfaces is significant for the act of design. Designers compose surfaces to create objects and artefacts to be perceived for use and activity. One aim of design, albeit pragmatic, is the composition of surfaces to create volumes. These volumes might have a relationship to the human hand that can be visually perceived and physically grasped. The theory of affordances offers a conceptual framework to imagine and realise artefacts and systems that offer a means to control and manipulate digital information. Norman (1988) develops the notion of affordances into key components which I found useful to consider in the design of the Sonic Blocks. He argues any digital system needs to provide feedback, have appropriate mappings, and be constrained to control appropriate action.

Mappings and feedback

Mappings in an interaction sense are a type of relationship between two or more things that act to illuminate changes in the system. Norman (1988, p.75) uses the example of an oven stovetop and the relationship between the controls and their burners as having appropriate mappings if they can be understood by their spatial relationships. Feedback (Norman 1988, p.27), in the context of human computer interaction, is the result of the action indicated to the user via some form of sensory means. For example a tone being played in a telephone earpiece once a button has been pushed correctly

Constraints

There are four types of constraints according to Norman’s classification (1988, p.84), Cultural, Semantic, Physical and Logical. This inquiry is primarily interested in the latter two as they have greatest relevance to tangible interaction design. Physical constraints aim to infer meaning in action through shape, size and physical relationships, for example round peg into round hole. Logical
constraints use reasoning to determine the alternatives (Norman 1999, p.86), for example one knows that all of the pieces need to fit the jigsaw puzzle.

2.2.3 **Sequential affordances and the temporal dimension**

Considering the opportunities and complexities of digital technologies and the concept of affordance, Gaver (1991) extends affordance to suggest its ability to reveal other affordances over time and to encourage exploration. He describes this concept as sequential affordance. Sequential affordances consider the temporal nature of activity with objects both digital and analogue. They explicitly refer to the actions in a continuous unfolding narrative of use. These narratives are supported by our perceptual motor abilities to inform us to act in this sequence. In extending Norman’s discussion of the door handle (Norman 1988, p.10) Gaver offers an insight into his concept of sequential affordance.

*The pivoting door handle may appear to afford grasping, but passive observation will probably not indicate the affordance of turning it or using it to open the door, however once grasped a random or exploratory press downwards will convey tactile information revealing the affordance of turning the handle. (Gaver 1991, p. 82)*

If you consider the many actions we perform in the world with tools and devices you will see that the temporal nature of the activity is important. The door handle affords grasping initially, but soon after you want to manipulate this handle as your aim is one of egress not of manipulating handles. The handle should therefore mechanically support, through a relatively friction free movement, its rotation which in turn releases its snib allowing the door to be opened. If the affordances do not reveal the next step, either through visual or sensory feedback, the activity breaks down.
Considering the temporal dimension is a new challenge for product designers (of ICT devices) who have largely to the present day been concerned with the formal and material relationships of objects. I count myself in this category. Computer scientists and software developers think temporally when they write code for a program as they textually construct commands that have a grammar (Dourish 2001, p 10) that the computer understands. This grammar is largely mediated by time, as the order of command has an effect on the resultant action by the computer. Time is not only used by computer science but also in the arts and design. Redstrom (2001, p.40) argues that time is a central design parameter in considering interaction design. Similarly Hummels, Djajadiningrat et al (2001) talk about the aesthetics of interaction as a consideration for the design of rich engagement with devices both mechanical and digital, which highlights time as a factor to consider.

Both of these authors argue that computer interaction, via the aid of objects, has more in common with endeavours that consider time as an important aspect of their aesthetic, such as film-making and music composition rather than conventional form giving approaches. Redstrom contrasts Gaver’s notions of sequential affordance in that his orientation towards time is concerned with poetics and aesthetics as opposed to the pragmatics of perception and affordance. However both Gaver and Redstrom articulate time as an important consideration to the way interaction unfolds in use and activity.

2.2.4 Form as meaning

I have talked about the form of objects in pragmatic terms as they aid perception and use, however this is not the only way to consider the form of objects. Another way to consider the design of objects is as carriers of meaning. In product design this approach is called Product Semantics. (Butter 1999, Krippendorff 1989, Krohn and McCoy 1989). With the Product Semantics
approach, design is a way of making sense of things. Krippendorf, when articulating the value of this design approach refers to the latin origins of the word Design.

De-sign is making something, distinguishing it by a sign, giving it significance, designating its relation to other things, owners, users, or gods. (Krippendorff 1989, p.1)

The importance of signification in design would seem an obvious tenet when considered against the definition above. However those that espouse a semantic approach to designing, or consider design to be foremost a meaning making activity, argue that the rational approaches of the modernist movement of the last century have reduced the products of design to universal representational archetypes. In modernism the role of meaning ascribed to an object or product has been lost or reduced due to other pressures such as the need to conform to the exigencies of manufacturing (Krohn and McCoy 1989, p. 112). These authors also articulate that

industrial designers have traditionally designed products that do nothing to acknowledge their surroundings (Krohn and McCoy 1989, p.118)

This lack of meaning giving to the form of an object started with the Bauhaus thinkers such as Mies Van der Rohe and Marcel Bruer who

moulded technology into a system of forms and celebrated the offerings of new technological processes and materials (Krohn and McCoy 1989, p. 114)

For example the bending of tubular steel to create lighter (visual) weight furniture which would have been conventionally fabricated out of timber. Later this rational approach was adopted by the Ulm Hochschule fur Gestaltung
which influenced the restrained design languages and familial relationships of corporate products by Dieter Rams for Braun (Burkhardt and Franksen 1981). A contemporary take on this consumer identity is the Ipod Classic family of Mp3 players from Apple computers. The Ipod classic has a shiny cigarette case form that makes little reference symbolically to the culture and use of digital Mp3 music players. They are elegant containers for digital content, but what do they tell us of what they contain and how you might access and manipulate these contents? There is no relationship between the form and its contents - all information of this type is to be accessed on viewing and interpreting the screen interface and buttons.

The formal vocabulary is limited to simple geometrically described lines, planes and Euclidian solids. Rather than making references to individual, culture, place, or time, it infers timelessness and placelessness. The other approach, which we call interpretive design, is concerned with reference. Visual analogies, metaphors and similes make connections between the object and the life and culture that support its making. (Krohn and McCoy 1989, p.112)

Whilst the scholars and practitioners of the product semantic approach offer a valuable criticism of modernist rationalism they also develop interesting connections to the concept of natural language as a means to inform the design of objects (Athavankar 1989). In particular they argue that the spatial semantics of an object, which I will call form in the context of this discussion, are influenced by the richness of spoken language as it is socially and therefore culturally constructed (Lannoch and Lannoch 1989). The words we use to describe objects are valuable cues for the development of culturally-meaningful form design that seeks to celebrate the uniqueness of a culture rather than a reduction to global universalism.

The Ipod range of devices from Apple, Copyright © 2008 Apple Inc. All rights reserved.
The product semantic approach to form creation argues that a designed product plays a valuable role as a symbolic tool, a carrier of meaning. I argue it is one of the great intellectual challenges within designing, to make these appropriate analogies and references in the conception of the form of a device or object. Therefore form plays a role beyond merely satisfying taste as it should invoke a response via its symbolical presence and connection to a deeper sense of meaning. The discussions of form, as both a perceptual and symbolic tool, thus far have been of devices that are analogue. This inquiry is concerned with the connection of physical objects to digital, or computational, systems as a means to enrich the interaction experience. In the next section I start to consider the nature of digital systems with their functions and operations having new representational challenges to enable meaningful interaction.

2.2.5 The semantics of digital content

When you consider digital information products that process bits of data to ultimately communicate a message or create something, for example an essay or piece of digital music, the challenge of how it is represented meaningfully is considerable. If the role of design is to create meaning, how is this achieved with abstract, and mostly hidden, digital data? This challenge has been articulated as part of the focus for the future of information technology products at design organizations such as Philips Design (Aarts and Marzano 2003) (Vetere and Feltham 2007). In the context of product or industrial design the semantic or representational challenges are quite different from those of the industrial age (Gursimsek 2005). No longer are we physically engaging with mechanical objects and systems which for the great part are perceptually self evident and mediate functions such as a drill for drilling or a knife for chopping. Rather we need to consider the functions of new media to create, store, classify, access, manipulate

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6 By this I mean not connected to digital technologies or systems.
and distribute and think of ways to give meaning to them through form. This calls
for the extension of computation generally beyond the personal computer and
into objects that call on our motor sensory perception (Djajadiningrat, Wensveen,
Frens and Overbeeke 2004).

Some consider a place to start is with the rich affordances of mechanical
devices used for measuring, such as sextants from times past (Ishii and Ullmer
1997, Ullmer and Ishii 2000, Ullmer and Ishii 2001). Whilst these mechanical
devices have affordances, they also can be read symbolically via their material
qualities and mechanical movement to assist use and meaning when interacting
with them. These authors were inspired by these objects in an age of haptic
interaction and argue we need a return to physical interaction with computational
technologies.

How we engage in the world through objects, devices and artefacts is
contingent on the what these objects afford, how these affordances reveal
themselves temporally and what they represent symbolically. In considering the
dual citizenship of our physical environment and cyberspace (Ishii and Ullmer
1997, p. 1) how computation and meaning is embodied in the objects or artefacts
is a central design concern. These are the foundational elements of this inquiry
into the design of the Sonic Blocks. In the next section I will place my focus on
the prevailing visual interaction model we know with the personal computer and
its graphical user interface.

2.3 The Personal Computer

2.3.1 The personal computer and its model of interaction

I want to sketch out the model of interaction we have come to know with
the personal computer for two reasons. Firstly it helps us to understand why new
models of interaction, such as TUIs, have evolved. Through giving a brief account of the history of the development of the personal computer and its interaction model, we can see why it can be insufficient due to its visual interaction model that does not call on our physical skills. This fuels the desire to develop more embodied approaches such as tangible user interaction. Secondly this inquiry initially observed children using a personal computer and its graphical user interface to frame the design of the Sonic Blocks, so it is useful to understand the origins of this interaction model to some depth.

A short history

The Personal Computer as we know it, with the Graphical User Interface (GUI), mouse and keyboard, was first introduced as the Xerox 8010 Star in 1981 and further refined as the Apple Lisa in 1983 and the Macintosh in 1984. This development was the result of the incremental work of several (often overlapping) project teams. The most directly relevant teams for this discussion are those of Douglas Engelbart’s NLS project at Stanford Research Institute in the 1960’s, and Alan Kay’s SSL Smalltalk team at Xerox PARC Palo Alto in the 1970s. Over a twenty year period, these two labs guided the development of a new model of computing that focused on the concept of an individual user working in concert with an individually dedicated machine. The predominant part of the personal computers interaction model was first conceived and prototyped by Engelbart’s NLS team. The mouse, the black-on-white textual display, hypertext navigation, networked collaboration and video-conferencing were all pioneered here. The project's stated goal was the empowerment of knowledge workers by the addition to their work practice of a continuously dedicated computer, controlled through a series of physical devices that integrated into their workplace environment (Englebart 1986).
The work of Alan Kay and his colleagues was significant in that it laid the foundations for ways of using computation as a productive tool that progressed beyond the technology to a new way of making and understanding complex models of things (Frenkel 1994, p. 14). Inspired by McLuhan’s (1964) notion of computation as a medium and approaches to thinking and learning from Montessori, Bruner and Papert, Kay developed the Smalltalk language to enable computation to be used as a medium and hopefully by non programmers and children. Kay believed that for the computer and its programs to be totally useful they had to allow one to construct knowledge and be productive. From this vision of Kay’s and a number of, often turbulent, years at Xerox Palo Alto Research Center (PARC) the concept for the laptop computer was devised as the Dynabook, although this was not able to be realised as the technology did not exist to build it. Work in this remarkably productive period included programming and interface developments such as menus and overlapping windows. This work culminated in the first personal computer the Xerox Star (Johnson, Roberts, Verplank, Smith, Irby, Beard and Mackey 1989).

Whilst Kay and Engelbart’s work provided considerable innovation and knowledge that led to the creation of the personal computer and its mode of interaction, there were two other projects that played minor but important roles in this development story. Sutherland created Sketchpad (1964) as the first graphical manipulation software for the creation of vector linework and geometry by the use of a lightpen. This was the first interface that influenced Engelbart’s later work with the mouse as a direct manipulation controller. Cranfield Smith developed icons whilst completing his PhD (Cranfield Smith 1975) and went on to popularize these when working on the Xerox Star (Myers 1998).

This short historical account gives an overview of the developments and some of the motivations that constitute the prevailing way we interact with the personal computer today. The Graphical User Interface (GUI) with its Windows,
Icons, Menus and Pointer (WIMP) all came from these research and development initiatives. Similarly, the ways we physically engage with these on screen objects through the coupling of mouse and keyboard owes its legacy to this work. My inquiry has an interest in the GUI as a way of spatially organizing data and information. The Sonic Blocks were designed and developed as a physical way of representing and controlling digital sound files. This physical model of representation and control was informed by the usage of an existing GUI. In the next section the discussion will move to the GUI as a way of graphically representing data as an advancement on the textual line command interaction that preceded it.

2.3.2 The Graphical User Interface

*Probably the most significant transition, in terms of the interface models that are familiar to us today, was the transition from textual to graphical interaction (Dourish 2001, p. 11).*

The significance of this transition was the move from command line textual input, with all of its syntactic complexity, to acting on visually persistent icons that show clear representation of the result of these actions. This approach is called Direct Manipulation (Shneiderman 1982) and I will discuss Direct Manipulation in an upcoming section as it complements the visual approach of the GUI. But firstly I would like to touch on some of the virtues of the GUI as a means of spatial and visual interaction. The arrangement of Windows, Menus and Icons within the GUI calls on the abilities we have developed through engaging spatially in the world, for example the arrangement of notices on a noticeboard for particular categories of importance. It is the GUIs two dimensional visual layout capability that has proven to be successful with contemporary interfaces.7

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7 I base this position on the ubiquity of the windows interfaces that we see in ICTs and argue that due to this, whilst they have problems, they have proven to be successful.
Dourish (2001, p. 12) describes graphical or two dimensional interaction as allowing a number of conditions and techniques to incorporate these human skills in ways the one dimensional textual interface did not. He argues that the same techniques that allow graphs, charts and other visual information designs to provide insight into collections of information are used when two dimensional space is exploited in the Graphical User Interface. Similarly the ways we use the space on the computer screen enables us to give attention to primary and secondary tasks and sets of information. This secondary information captures our peripheral attention.

Distributing information around a two dimensional space allows us to arrange it so that it can be selectively attended to. For example, many applications divide the screen (or window) into two areas – a large area taking up most of the space in which the primary interaction takes place, and a smaller area, at one edge or off to the side in which messages are displayed about the current progress of other tasks. This information is not central to the task but is helpful in managing my activity. By placing it at the periphery the application exploits my ability to focus on the one area while passively attending to the other activity in the edge of my visual field. (Dourish 2001, p. 12)

The space on the screen and GUI are arranged to afford spatial reasoning and recognition of the patterns of information to be productive in use. But what is inside the spaces of the GUI also gives important information for use and context. The icons and symbols that appear on the GUI give us cues as to what they are for. They often employ metaphoric links to objects and artefacts in the world that have meaning for use.

The most widespread is the office or desktop metaphor, in which information management tasks are based around a metaphorical model incorporating filing cabinets and trashcans, graphically
displayed on the screen along with basic data elements, and so conveying a sense of the activities that can be performed over the data. (Dourish 2001, p.13)

2.3.3 Metaphors and icons

The metaphor and icon has been a much contested idea within the development of graphical or screen based interaction. Their use within a GUI are considered as means to reduce the cognitive overload (Rekimoto and Nagao 1995, p. 29) between the abstract command line instruction of the computer and the knowledge of the user through using digital representations of real world objects and paradigms such as windows, trashcans, menus and file folders. Metaphors and icons create meaning in use through their symbolic connection with the real world to reduce the abstraction of the computer and computation.

When used in HCI, a computer UI might be considered to be a kind of “literary” description; a representation created to help the user understand the abstract operation and capabilities of the computer. These abstract capabilities are therefore presented as though they were something else that the user might already understand. A command “menu” can be understood by analogy to a customer choosing one of the dishes listed on the menu in a restaurant. A dialog “button” can be understood by analogy to pressing a button on a control panel. (Blackwell 2006, p. 494).

There are limits to this symbolic smoothing of digital data through the use of metaphors. Bolter and Gromala (2003, p. 91) state that metaphors have limits and that digital metaphors are never perfect analogies, and users soon realise that they are not meant to be. Metaphors are a symbolic introduction to an operation or task, but they are never a perfect facsimile of their referent, as often these referents are physical objects with material qualities and affordances.
In an article written to reinforce the meaning of affordance in the context of screen icons and metaphors and to prevent incorrect definition in the design community, Norman (1999) distinguishes between real and perceived affordances. Real affordances according to Norman exist in the physical world as possibilities for action, a slot for a coin for example. Perceived affordances are the icons and symbols in the virtual world as they appear on the computer screen, a virtual slot represented as a screen based image. The distinction lies in the scale of physicality of the potential for action and whether there is any interpretation required of an on screen symbol to enable effective use. The computer GUI affords actions through its keyboard, screen and mouse. What is represented on the screen is perceived as an affordance but relies on an interpretation through its metaphor or symbolism requiring further cognitive effort. An object in the world has its physicality to give us cues that unfold as we act on it. We can think as we do and this doing becomes part of the thinking, the object is not an analogy in the way a screen based icon is. Its three dimensional nature invites our sensory motor actions. In this way objects can invite high levels of creativity and exploration.

Metaphors are an integral part of language and thought. They help convey meaning through their analogous relationships and therefore play a role in establishing meaning in user interfaces. In their book *Metaphors We Live By*, Lackoff and Johnston (1980) look at the part that metaphors play in human cognition, and the many uses in language in which metaphors are suffused to illustrate a point or complete a discussion. Dourish (2001, p. 143) in discussing Lackoff and Johnston, articulates that *spatial metaphors are a key way of organizing our thoughts, that they are such a rich model for conveying ideas that it is quite natural that they should be incorporated into the design of user interfaces.*
But Dourish (2001, p. 101) makes the distinction between using the real world as a metaphor for interaction and using it as a medium for interaction. He compares the interaction we have with an immersive virtual reality game and our direct actions in the real world. In virtual reality gaming the use of computer generated imagery, as realistic environments, guides action and decision making. However this interaction is indirect as head mounted displays and data-gloves control and mediate our interaction. In contrast we inhabit our bodies and they in turn inhabit the world, with seamless connections back and forth. Tangible User Interaction seeks to exploit this directness via computation embedded in the world of objects, rather than surround us with elaborate virtual representations and metaphors mediated with head mounted displays.

The symbolic and analogous links made by metaphors to objects we know in our world is called remediation and is defined as the making of new media forms out old ones (Bolter and Gromala 2003, p. 83). Remediation can be an effective design tool in that it can take the familiar and place it in a new context, which is what TUIs do when they take objects that we have established understandings of and couple them to digital systems and data. Bolter and Gromala (2003, p. 92) use examples of digital art projects such as Magic Book, where the artists have created augmented reality images on the pages of a book, to illustrate their concept they call rhythms of remediation, which essentially is a balance between the new and the old to aid the participant in creating meaning in use. The Magic Book offers both a book, an old or existent form of presenting text with all of the affordances of pages to turn, with the augmented reality projection on the top of the page, which is a new media form that extends the narrative presented by the book into a 3 dimensional image or film. The challenge when designing new media combinations and forms is in this rhythm or as I would rather state it balance between the elements, digital and physical, to

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8 Magic Book, a collaboration between HIT Lab at the University of Washington, the ATR MIC Labs and Hiroshima City University in Japan.
present a cohesive narrative of use and experience. The designers of TUIs need to be aware of this narrative balance for effective and enriched user experiences.

2.3.4 Direct manipulation with the Graphical User Interface (GUI)

The ways in which we interact with the metaphors and icons of the GUI are called direct manipulation. This term was introduced by Shneiderman (1982) and has been discussed and described extensively in Hutchins, Hollan et al (1986). Put simply the objects on the screen represent the data, and direct manipulation is the enaction on these screen objects. Direct manipulation employs our actions with the computer screen through the agency of the mouse and keyboard but it also has important characteristics in the way it displays these actions as persistant updates on the screen. Shneiderman (1982, p.237) outlines the key factors of a direct manipulation interface as having:

- continuous representation of the objects of interest

- physical actions (movement and selection by mouse, keyboard, touch-screen etc) or labelled button presses instead of complex syntax

- rapid incremental reversible operations whose impact on the object of interest is immediately visible.

- layered or spiral approach to learning that permits usage with minimal knowledge.

One of the common known direct manipulations is dragging a file into the trash bin within the Macintosh operating systems. Its development occurred through a continual series of innovations from a variety of research projects but was established as a means for common computer interaction through Kays
(1977) article about the Dynabook (cited in Myers 1998, p. 47). The innovations from this work introduced selecting an object by pointing, manipulating text with a cursor, using pictorial icons to represent abstract relations and relocating objects with a drag and drop manipulation. With direct manipulation actions have replaced typing line commands and the developments from Kay’s paper laid the foundation for the physical manipulations of the Graphical User interface we know today. The development of the GUI and the direct way in which we interact with it has informed the development of Tangible User Interfaces and Interaction.

*Direct Manipulation interfaces exploit and extend the benefits of graphical interaction. Because the system can be controlled entirely through the manipulation of on-screen objects, all opportunities for action are out in the open (Dourish 2001, p. 13).*

Describing direct manipulation in greater detail Hutchins, Hollan et al (1986) posit that the feeling of directness is relative to the fewer cognitive resources needed when engaging or using the interface, in other words the more thought required to use an interface the less direct it feels. In discussing Hutchins, Hollan et al (1986), O’Malley and Stanton Frazer (2004, p. 13) define the key aspects of direct manipulation to be *Articulatory* and *Semantic* directness:

*Articulatory Directness refers to the extent to which the behaviour of an input action (eg moving the mouse) maps directly or otherwise onto the effects of the display (eg the cursor moving from one position to another). Semantic Directness refers to the extent to which the meaning of a digital display, an icon representing a wastebasket, as the degree to which input actions map onto output displays.*

A high level of articulatory directness suggests a clear relationship or mapping to the user, between the action of the mouse and the reaction of the cursor on the screen. In usability terms this is desirable as the cognitive
resources or thought required to do these actions is low, enabling the users to focus their thinking on the activity at hand. The articulatory directness is a measure of the effectiveness of the mapping of physical actions to a graphical response on the computer screen.

Fishkin, Gujar et al. (2000) extend the notion of direct manipulation with their term really direct manipulation in which they argue that the body of the device, they use the example of a Personal Digital Assistant (PDA), is part of the interface. These authors also argue that the sensory-motor experience with the computer is with the screen and the metaphoric graphical representations it contains within its borders, but that the physical computer itself is an anonymous invisible box. Their argument is that the physical housing of the handheld device affords interaction opportunities such as squeezing, shaking and tilting. Therefore design efforts need to be directed to enabling these natural actions as part of the interaction experience.

Interpreting visual signs mediated by a computer screen is the prevailing model of interaction with the personal computer and screen based devices today. These visual signs are organized spatially and call on our abilities to reason spatially and recognise patterns through the Graphical User Interface. We engage physically with this visual information in a direct way through our actions on the mouse, pointer and keyboard. These interfaces are defined as direct either through their mapping of actions to a screen response or the meaning embodied in the symbology of the icon to be acted upon.

Considering the personal computer as a case in point we have seen that through its historical development it has become progressively more physically and spatially engaging. A further progression, beyond the GUI and direct manipulation, has lead to re-imagining the computer and computation in a more embodied way, resulting in new models of interaction such as Ubiquitous Computing and Tangible User Interaction.
2.4  Tangible User Interaction

Tangible User Interaction (TUI) is an approach that has emerged in Human Computer Interaction over recent years that fundamentally challenges the largely visual mode one uses to interact with the personal computer and its GUI. In this section I will start with an overview of the origins of Tangible User Interaction as a formal program of research and lead into a discussion of the concepts and projects that have influenced both the intellectual position and the design approach for the Sonic Blocks.

2.4.1  Ubiquitous computing

Ubiquitous Computing established a bold new conceptual direction upon which computation was to be imagined in the world. I would describe the Ubiquitous Computing paradigm to be the marriage between the philosophy of embodiment and the technological capability to wirelessly transmit with handheld and smaller devices in an interconnected network. The author of the seminal paper on this approach Weiser (1991), whilst not stating explicitly the notion of embodiment⁹, was doing just that with the Ubiquitous Computing paradigm. The re-imaging of computation within a suite of devices that could talk to each other in a network was more than just a technological feat. It was a techno-social forecast for the future, it gave consideration to the ways we collaborate and share to achieve goals and used emerging wireless technologies to achieve this with computation. It suggested that the computer should take the form of digital paper and notepads therefore becoming part of world rather than be obscured within beige boxes.

⁹ Weiser did not explicitly refer to embodiment, but he did use the term embodied virtuality which would seem to be an oxymoron in that if something is embodied, strictly it needs some physical form, so how could it be virtual. Language aside Weiser defines embodied virtuality as being the virtuality of the computer data brought into the physical world. This I was satisfied was similar to Fishkin and Dourish’s concepts of embodiment in a digital technology sense.
......we are therefore trying to conceive a new way of thinking about computers, one that takes into account the human world and allows the computers themselves to vanish into the background. (Wieser 1991, p. 3)

This bold vision was predicated on the notion that the computer had failed to become a technology that was to mature into a natural tool in the same way that writing had become for communication and thought, as Weiser makes explicit:

*Computation is approachable only through complex jargon that has nothing to do with the tasks for which people use computers* (Wieser 1991, p.3)

Weiser's (1991) research project *computation by the inch, foot and yard* consisted of new computational devices that were developed consisting of tabs, pads and boards. With tabs being inch scale devices providing information on your location in a building or network, pads being foot scale devices that behave something like a piece of paper and boards being yard-scale displays that are the equivalent of a blackboard or bulletin board.

*One way to think of pads is as an antidote to windows. Windows were invented at PARC and popularized by Apple in the Macintosh as a way of fitting several different activities onto the small space of a computer screen at the same time. In 20 years computer screens have not grown much larger. Computer window systems are often said to be based on the desktop metaphor -- but who would ever use a desk only nine inches high by 11 inches wide? Pads, in contrast, use a real desk. Spread many electronic pads around on the desk, just as you spread out papers. Have many tasks in front of you, and use the pads as reminders. Go beyond the desk to drawers, shelves, coffee tables. Spread the many parts of the many tasks of the day out in front of you to fit both the task and the reach of your arms and*
eyes rather than to fit the limitations of glassblowing. Someday pads may even be as small and light as actual paper, but meanwhile they can fulfill many more of paper's functions than can computer screens. (Wieser 1991, p. 6)

Ultimately the devices in Weiser's project were all for communication of ideas in a business or work sense but they were visionary in their attempt to support the human activity of creating and sharing knowledge. Importantly they sought to do this through reducing the complex jargon of the conventional computer through embodied physical interfaces and interaction. Tangible User Interaction in part responds to Weiser's bold call in that it aims to embody computation in physical devices and call on our actions rather than our interpretation of textual and iconic languages. Ideologically Weiser considered that these ubiquitous computing devices may make an important contribution to the ways we seek to use computation in the future.
2.4.2 The beginnings of tangibles

Graspable User Interfaces (Fitzmaurice, Ishii and Buxton 1995) were a new way of physically engaging with digital data that was to that date largely separated from the physical world and mediated visually through the GUI. Graspable user interfaces were evolutionary in that they built on the interaction conventions of the Graphical User Interface but at the same time were a radical departure from the mouse and keyboard as physical controllers. Some of the ways Graspable User Interfaces improve and extend the mouse and keyboard (Fitzmaurice et al. 1995, p. 443);

- They externalise traditionally internal computer representations
- Take advantage of our keen spatial reasoning skills
- Shift to more specialized, context sensitive input devices
- Offers a space multiplex design with a one to one mapping between control and controller
- Affords multi-person, collaborative use

The key differences and advantages of Graspable User Interfaces for this research lie in their ability to take advantage of our spatial reasoning skills, be space multiplexed and lastly their distinct mapping between control and controller.

In discussing their work in more detail (Fitzmaurice et al. 1995), the authors describe a tangible-controller which acts as a physical controller of digital handles that appear as small black boxes along segment of a lines in computer aided drawing software. This Lego brick, with a wireless sensor to enable location,
is manipulated by hand over a Wacom electronic tablet that senses its position. Each manipulation of the brick affects the digital shape or line below it as it appears on the tablet.

In a later study Fitzmaurice and Buxton (1997) complete an empirical evaluation of the differences between time multiplexed and space multiplexed input devices. Time multiplexed devices use the same device to control different functions at different points in time. The computer mouse is time multiplexed as it can perform different functions at different times. Space multiplexed devices however are specifically assigned to a single function, the authors refer to the motorcar with its steering wheel, brake, clutch and gears all being dedicated controllers that are combined to enable the motorcar to be driven. The study involved a comparison of the two input conditions in a controlled experiment. The controllers consisted of a rotor controller, stretchable square, Lego brick and a puck. Each of these controllers were coupled to a Wacom tablet and had a corresponding central processing unit (CPU) which produced a graphical representation on its screen. In discussing the results, the authors state that these controllers could be used simultaneously with two hands, so that directly manipulable physical controllers enjoyed time advantages in comparison to the indirect mouse acting on an icon via its pointer in a time multiplexed manner. The dual hand usage and the space multiplexed functionality is comparable to ways in which we interact with tools and objects in the world.

2.4.3 **Tangible bits**

Graspable User Interfaces introduced the concept of physical manipulation of digital computational data. A further development on the concept of Graspable User Interfaces was the notion of Tangible Bits (Ishii and Ullmer

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10 Wacom tablet, from Wacom technologies Inc. a horizontal surface that digitally recognises location data from a transducer.
Tangible Bits expanded the ideas from Graspable User Interfaces and presented three key concepts - the use of interactive surfaces, the coupling of digital bits with physical objects and the introduction of ambient media as a means to provide information to the periphery or background. Another important aspect of this research was the articulation of the differences in the interaction model of the GUI as compared to the Tangible model. Central to this is the concept of foreground and background of activity.

**Figure 2:** Diagram illustrating the relationship between foreground and background activity, Image taken from (Ishii and Ullmer 1997)

The development of Tangible Bits was influenced by Weiser’s ubiquitous computing vision in that it sought to distribute computing beyond the keyboard, screen and mouse into objects and surfaces that allow the representation and control of digital data. This connects with Norman and Gavers applied concepts of affordances. In the foreground, objects represent and similarly control the data. These objects create semantic links with the data. The control is initiated by its affordances. The TUI also relies on the mappings between the digital data and its physical object and the constraints offered by the total system.
2.4.4 An interaction model for TUIs

Another major influence on the development of Tangible Bits was the Graphical User Interface itself. The GUI is a point of departure for both Fitzmaurice et al’s Graspables and Ishii and Ullmer’s Tangible Bits. It is the model upon which these two approaches seek to improve through physical perception and action. Ullmer and Ishii (2000) posit a model of TUI that places greater focus on the relationships between the representational and control attributes of physical objects in computational systems. They argue that historical examples such as the abacus seamlessly control and represent information. For example the abacus beads are numerical representations that can be reconfigured to form new representations. In contrast the GUI separates the control and representation of its information with the mouse directly manipulating screen icons but not forming any representation of these icons. The intent with tangibles is to get closer to the seamlessness of the abacus and move away from the separation of the GUI. In this work Ullmer and Ishii (2000) put forward a conceptual framework as a means to think about how tangibles should be designed.

Figure 3: Image showing the comparison of TUI and GUI interaction models. Image taken from (Ullmer and Ishii 2000)
The left diagram in Figure 3 shows the Model View Control\textsuperscript{11} (MVC) (Burbeck 1987) interaction model of the GUI. This diagram shows a clear separation between the input with the mouse being non representational with all meaning assigned to the digital output on the screen. The right diagram shows that with Tangible User Interaction the information is graspable, controlled and partially represented in the diagram as CONTROL and REP-P or physical representation. The physical representation is coupled to digital representations indicated in the diagram as as REP-D which are non graspable digital outputs such as sound or video. With Tangible User Interaction the shift is to Model Control Representation physical and digital (MCRpd) (Ullmer and Ishii 2001), which has recently been updated to MCRit, Model Control Representation tangible and intangible (Ullmer, Ishii and Jacob 2005).

What is significant with the MCRpd model of interaction is that there is less emphasis on the use of icons and symbology mediated by an illuminated screen. Rather there are actual objects that can be picked up with your hands and placed in a spatial arrangement such as a grid or map. These objects afford physical movement and that movement or action has meaning for use and participation in the activity undertaken.

The objects have embodied in their form meaning relevant to their use, a semantic relevance. An example of this is Music Bottles (Ishii, Mazalek and Lee 2001) in which sounds are perceptually seen as being inside a selection of glass bottles and when the stoppers are removed from these bottles the sound is released or played. I discuss this project in the upcoming discussion on TUI projects, but the point I would like to make here is that the semantics of these bottles assist in the meaning construction in use. What is becoming apparent with new and emerging contexts in computation – such as the ubiquitous or disappearing computer paradigms – is that the information feedback or output

\textsuperscript{11} The MVC model of interaction was developed for the Smalltalk 80 programming language.
does not always require the complexity or visual capabilities of the GUI, but rather simpler lightweight feedback or output such as that offered by the Music Bottles appropriate for the exploratory playing of digital sound files.

The combination of control and representation in tangible or graspable objects is a conceptual leap from the mouse as an input device. The mouse has little representational significance (Ullmer and Ishii 2001) and does not bear strong relationship or meaning to the actions you might perform. Some argue that the mouse does not mean anything (O'Malley and Stanton Frazer 2004) and that it is a generic object designed to control many – arguably too many – actions and tasks in its time multiplexed manner. So the key intent of a graspable interface is that it should afford representation of and meaning for the data, task and context in which it is used.

In summing up their position on Tangible User Interaction, Ullmer and Ishii (2000, p. 918 and 919) offer four key attributes to describe TUIs as distinct from the conventional GUI.

- physical representations (rep-p) are computationally coupled to underlying digital information (model).
- physical representations embody mechanisms for interactive control (control)
- physical representations are perceptually coupled to actively mediated digital representations (rep-d).
- the physical state of interface artifacts partially embodies the digital state of the system.

TUI artifacts frequently may be read both by people and computers by their physical state, with their physical configurations tightly coupled to the digital state of the systems they represent. The TUI model of Ullmer and Ishii has been
the strongest influence on the design and development of the Sonic Blocks. The clear description and contrast offered by this model to that of the GUI had relevance for the Sonic Blocks because they were a physical and spatial attempt to afford the digital music making activity seen with the Garageband GUI. There are other positions on tangible user interaction that helped me think through the issues of physical representation and control.

2.5 Other positions on tangible interaction

Fishkin (2004) discusses the nature of tangible interaction through a review of notable projects. He offers a taxonomy to classify the TUIs which is characterized by two key categories, *Metaphor* and *Embodiment*. Metaphor in Fishkin’s definition is a mechanism within language that has helped create, explain and communicate our theories of the world. It occurs throughout philosophy, science and the arts and therefore can be applied to the design of TUIs as a model of representational thought (Fishkin 2004, p.349). Fishkin also discusses product semantics within industrial design as an example of how metaphor can be used to create symbolic links for the meaningful use of the product. In Fishkin’s terminology, metaphor in a TUI can refer to its shape defined as a *noun* or its action defined as a *verb*. There can also be combinations of noun and verb. Fishkin’s definition of metaphor is a useful way of describing the variety of shapes, actions and their combinations within TUIs and begins to map out a theory of what constitutes a TUI.

Embodiment, in Fishkin’s categorisation, refers to the states of input and output as being inside the object being manipulated (Fishkin 2004, p.348). As with metaphor there are different scales and types of embodiment. With *full* embodiment the input and output are the same device, like the abacus. At the other end of the scale is *distant* embodiment whereby the input for example is
with an object on a table that has a projected video output on a wall at the other side of the room

2.5.1 Embodiment and coupling

Fishkin’s concept of embodiment has similarities to the notion of coupling. In the design of TUIs coupling is the relationship between the actions you have with a physical artefact and the digital feedback that you get from the system as a result of these actions to inform of its state. Gorbet (1998) articulates that coupling refers to this feedback in an effective physical way. He uses the example of the Music Bottles project (Ishii et al. 2001), discussed earlier to illustrate this notion of coupling.

...... the Bottles’ two modes can be thought of as playing and stopped. Opening a Bottle puts it into playing mode, which is clearly indicated by the open bottle. The physical states of the Bottles are tightly coupled to their digital modes. (Gorbet 1998, p.40)

The computational coupling of physical representations to digital information is considered a central aspect of Ullmer and Ishii’s (2000) model of TUI. It questions the relationships between the objects and the digital data and the ways these relationships are effective. Coupling can be therefore described as the relationship between the object and the digital data that make up the system of use. This is particularly salient in the case of TUIs as they call on the many affordances that physical objects offer us in their relationships to the world. In tangibles this affordance needs effective coupling to the abstract digital information it is controlling to be meaningful for use.
2.5.2 Containers, tokens and constraints

Another way to conceptualise the different physical elements within a TUI are Containers, Tokens and Tools (Holmquist, Redstrom and Ljungstrand 1999). Essentially containers hold information without reference to its nature through form, tokens refer to the form, and tools refer to the computational function. Tokens and Constraints (Ullmer et al. 2005) take these ideas further and give consideration to ways of ordering digital syntax through the use of physical relationships. An example is the physical location zones within a table interface that constrain or infer position for a token to be placed. Tokens and constraints draw heavily from the logic of board games to constrain location and movement of objects, for example a chess board and its pieces. These classifications of the different coupling relationships that have appeared in recent projects are useful as a broad conceptual tool when designing and developing TUIs.

However each TUI design project carries particular cultural and social factors that may infer certain symbolic design opportunities for its form factor and material properties. Therefore whilst decisions may be made broadly to use a token and constraint model the semantic and symbolic references the TUI will make still need to be designed. Further discussion of tokens and constraints will occur in chapter 5 when describing the development of the Sonic Blocks.

2.5.3 Aesthetics of interaction

On ideas of Tangible Interaction, Hummels, Djajadiningrat et al (2001) extend the idea of affordance as a way of evoking pleasurable experiences. Their term Aesthetics of Interaction (Hummels et al. 2001, p.5) proposes that the
interactions we have with electronic products\textsuperscript{12} should be both temporally and sensorially engaging activities and considerations for design.

They contrast the mechanical actions one has with a gas cooktop against the keypad entry one has with a remote control or a thermostat keypad. The crux of their argument is that the mechanical actions, with the latter cases, have disappeared or in the least been reduced. In their place are buttons and icons that have many functions, but are represented without any consideration for the perceptual demands of the user. For example with a similar sequence of button presses you can program the thermostat temperature, set its timer or toggle through the variety of modes that its visual readout offers. The affordances and mappings are abstract and the feedback is minimal, leaving the user with the question, what the results of these actions? The gas cooker has the subtle resistance of its dials and the sounds from its timer which all contribute to a richer engagement and greater aesthetic of interaction. These actions we have as both input and feedback are important for an engaging experience that contribute to an aesthetic of interaction.

Taking this theme and extending it Djajadiningrat, Wensveen et al (2004) talk of the physical affordances designed products can have as a way of engaging perceptual motor skills. They argue appearance and action are both ways of enabling meaning in interaction and that examples from Ullmer and Ishii (2001) don’t use the spatial affordances of objects to the degree they could. These authors articulate two approaches to the meaning construction in the use of digital products. I have found these approaches useful as a point of departure from the TUI approaches and models discussed earlier - that these authors argue have a data centred approach to representation. The first is what they term the \textit{semantic approach} which is characterized by:

\textsuperscript{12}Electronic products in the context of this paper are consumer electronic devices that exist in households today. The authors use examples such as the electronic keypads on devices such as television remote controls and thermostat keypads to illustrate the prevailing visual and cognitive approaches that such devices use.
using the knowledge and experience of the user, the product can communicate information using symbols and signs (Djajadiningrat et al. 2004, p.295).

The second is called the direct approach and it takes behaviour and action as its starting point.

_Here, the basic idea is that meaning is created in the interaction. In this approach, respect for perceptual and bodily skills is highly important. What appeals to us in the direct approach is the sensory richness and action-potential of physical objects as carriers of meaning in interaction._ (Djajadiningrat et al. 2004, p.295).

The principles of aesthetics of interaction and direct approaches to interaction, whilst focussed on electronic consumer products, can be applied to the personal computer and its GUI. I would argue that consideration for ways of meaningfully physically engaging with the personal computer become all the more salient as it has the greatest number of buttons and icons, and therefore the greatest number of abstract actions and symbolic readings for the task at hand. Norman (1998) is critical of the personal computer as a converged consumer device, he argues it has many capabilities but not the interface to enable a fruitful interaction with these capabilities. The notions of aesthetics of interaction and direct interaction are ways to imagine, design and realise meaningful physical interactions with the personal computer and its GUI. Critically they consider interaction beyond ideas of functional usability that is central to Norman’s (1988) notions, and consider aesthetic ideas such as the temporal sequences of events and the rich sensory feedback that physical objects can have.
2.5.4 Key Tangible User Interfaces

To illustrate the dual role of graspable digital information, I want to discuss three projects as case studies to illustrate the key concepts of representation and control. I have created a criteria adapted from the categorisations and descriptions of TUIs, from the preceding concepts and authors, upon which to describe the capabilities and unique physical approaches they offer in interaction:

- what *affordances and constraints* are used to suggest action and control the system
- what *design semantics and metaphors* are employed to create meaning
- what *coupling and feedback* is used to complete the temporal sequence.

These projects all control and represent digital music sound files and have been chosen due to their variety of approaches to doing so. It is not a conclusive collection of projects but rather a curated collection that have each had a strong influence on the way that I have conceptualised and designed the Sonic Blocks.
2.5.5 Music Bottles (Ishii et al. 2001)

The Music Bottles (Ishii et al. 2001) are a simple tangible interface that consists of three to four clear glass bottles of different physical volume and shape that each have the ability to activate sound files. These sound files are activated by the removal of their stoppers. The interaction sequence is simple, remove the stopper and its sound plays, replace the stopper and it stops. Technically this is made possible by the use of wireless sensing technology consisting of small electromagnetic sensor tags placed around the neck of the bottle, and ferrite embedded into the stoppers.

Affordances and constraints

Each bottle affords opening through grasping and removing the stopper. On removing the stopper you release the sound of the bottle, with each bottle having a different sound. Apart from grasping and opening, these bottles afford shaking and mixing of their content. The authors did not use these gestures in the conceptual interaction design as they considered shaking and mixing to be complex interactions that may be interpreted in many ways. So grasping and opening were the basic physical actions to control the system.
Design semantics and metaphors

The bottles do not seem to give any indication through their form as to the type of sound they contain. For example a violin might have a slender form compared to a cello that might be more bulbous, indicating its deeper tonal range. There was reference to three genres of music that music bottles could play - jazz, classical and techno music. The jazz bottles are refered to in the literature describing the project, but it was not made explicit as to whether a the form of a jazz bottle was different to a classical bottle.

System, coupling and feedback

In use a bottle is placed on the stage (see Figure 4 on previous page) which is a frosted glass or acrylic surface within the overall system table. Once the bottle is placed a light shines from below the stage to indicate the bottle is digitally active. When the bottle stopper is removed the three lights of the system move in a dynamic sequence. The bottles are therefore coupled to their subsequent sound file with the light arrangement giving confirmation of the sound’s successful activation.

2.5.6 Audiopad (Patten, Recht and Ishii 2002)
Audiopad is an interface for musical performance that:

*aims to combine the modularity of knob based controllers with the expressive character of multidimensional tracking interfaces. The performer’s manipulations of physical pucks on a tabletop control a real-time synthesis process. The pucks are embedded with radio frequency (RF) tags that the system tracks in two dimensions with a series of specially shaped antennae. The system projects graphical information on and around the pucks to give the performer sophisticated control over the synthesis process (Patten et al. 2002, p.1).*

Audiopad extends the concept of the Music Bottles into the realm of real time performance and synthesis. The sound groups are able to be manipulated at a level that allows a real time performance in a meaningful and poetic way.

![Image showing the two token controllers in Audiopad. Image courtesy of Patten et al. (2002)](image_url)
Affordances and constraints

Due to the sophistication of the activity with the sound files, Audiopad provides two physical pucks, a circular sound group puck and a rectangular selector puck (see Figure 6 above). These pucks afford pushing over a table surface which is tightly coupled to the visual graphical interface projected on the table surface.

Design Semantics and metaphors

The pucks are fundamental geometric shapes, similar to game board pieces or coins. It is the graphical display that gives them meaning and context.

Coupling and system feedback

Audiopad offers a rich coupling between the action of moving the pucks and the associated graphical and sonic feedback. As the selector puck is moved a tree interface is revealed as a graphic projected display (see Figure 5). This gives the user a selection of modifications that can be made to the sound of the group puck. The manipulation of pucks in this way provides richer coupling between graphical feedback and movement compared to a mouse control over screen based GUI.
2.5.7 **Blockjam** *(Newton Dunne, Nakano and Gibson 2002)*

![Image](image.png)

**Figure 7**: Image showing Blockjam with its path and play blocks arranged in sequence. Image courtesy of (Newton Dunne et al. 2002)

Block Jam takes advantage of both graphical and tangible user interfaces. Each block has a visual display and two modes of input, clickable and gestural. The blocks also contain a sound group that can be chosen via the gestural input and a clickable input changes a block functionally (e.g. start or stop a sequence). Thus musically complex and engaging compositions can be rapidly assembled (Newton Dunne et al. 2002, p.1). The designers of block jam had at the core the consideration that music in the digital age will no longer be linear but a dynamic and collaborative experience in which the distinction between the composer and listener will be blurred. The arrangement of the blocks physically maps a series of interconnecting sonic patterns that can be interacted in both face to face and co-located activities.

*Affordances and constraints*

As each block both controls and represents a sound file physically, they afford placing and arranging in a structural manner similar to a wall of children’s
construction blocks. The geometry of the blocks suggests alignment to connect electronically, that is the sides need to be in line to create this connection. This is analogous to construction blocks in that if the blocks are out of alignment the structure fails mechanically and visually. The graphic icon on the top surface indicates the block’s functional state. These icons borrow quite heavily from the icons of the screen in the GUI.

*Design semantics and metaphors*

Semantically the Blockjam blocks are clearly electronic blocks, largely due to their persistent LED matrix displays on their top surface. It is hard to get past these visually and their intent is provide an unambiguous level of feedback, the on the state of the system and the music playing in a functional sense. The user still needs to decode the icons on the these displays, but they could be discovered through use.

*Coupling and system feedback*

In use Blockjam consists of two types of block, the play block which has an icon that looks like an arrow and the path block which is represented by the plus sign (see figure previous page). A sound sequence starts with a play block that is supported by a path block to give it a direction. When the play block is depressed it launches a sound sequence that follows the path assigned by the path blocks. At the end of the path the sound returns to the play block in a looping fashion. The LED displays on the top of the blocks pulse to indicate the sound playing through them, providing a visual coupling to the sonic feedback. There is also a GUI which shows both an animation of the blocks playing and a representation of the blocks present on the active play surface. It is not clear what role the GUI plays. My assumption is that it supports online collaborations where two users are composing in separate locations.
2.5.8 What is Tangible Interaction

I want to reflect on the statement from Dourish (2001, p.126) in the introduction to this chapter.

*Embodiment is about the relationship between action and meaning*

Dourish talks here about embodiment as being the combination of both tangible and social interaction with computer technologies. Whilst sympathetic to the activity that is socially situated, the focus of this research is on the ways one can interact with physical representations of digital data that are sufficiently coupled perceptually and technologically to digital sound feedback.

The relationship between action and meaning is important in these physical representations. Physical artefacts can encourage action using the full complement of our perceptual motor senses to provide rich and engaging experiences (Hummels et al. 2001) (Djajadiningrat et al. 2004) (Hummels and Van der Helm 2004). Or they can extend the world of the GUI in a physical sense by a shared representation and control whilst often still being coupled to a screen or projected video feedback (Ullmer and Ishii 2000) (Ullmer and Ishii 2001).

Actions can be contained and constrained to suggest arrangement and syntax by the physical design of the TUI, which starts to suggest ways to think spatially (Ullmer et al. 2005). Fishkin states that meaning in graspable objects can be *metaphoric* and vary in scale from having no analogy to other objects in the world, to having some through visual look or actions with, to not needing any, as what is physical is digital. Similarly the embodiment relates to the level of coupling of the actions between object and the digital data. It can range from being *full* with the output device being the input device, to being *environmental* whereby actions on an object are around the user, to being *distant* with the actions on an object being in another location (Fishkin 2004).
2.5.9 Encapsulating Tangible User Interaction, research themes 1 and 2

Whatever terminology or variation in orientation towards semantics and embodiment, the two broad themes that characterize TUIs are the relationships between action and meaning for the use and exploration of TUIs. Action is invited through the physical affordances and the constraints of the objects within TUIs and their couplings to digital feedback in the system. Inviting actions is a design consideration. Meaning is enabled through the representation of all components within the TUI, physical or digital. So representation is also a design consideration, it enables one to construct meaning.

Therefore the first two concepts to describe TUIs in the context of this research through design are:

- **action**, to encourage physical activity with the objects within a TUI, with consideration through design toward the affordances and constraints to enliven perceptual motor activity as meaningful to use

- **representation**, to enable meaning to be constructed through the formal visual semantics and analogies of the TUI and their couplings to provide logical temporal sequences for use.

These two themes provide a framework to consider the design of the Sonic Blocks. In the next section I will discuss the playful and explorative activity that provides the context in which the Sonic Blocks are to be used.
2.6 Play and exploration

Play and exploration are the activities that motivated the design of the Sonic Blocks. The observations gathered, which I discuss in chapter 4, are of four children playing and exploring a narrative through the making of a soundtrack using both a computer and software and handheld percussive instruments. Play is a unique way of doing as it has no tight goals and whilst the children were set a broad goal in these observations, they were not constrained by these goals and undertook the activity both playfully and exploratively. I will discuss prominent theories on the nature of play and touch on theories of constructivist learning to background this inquiry.

Constructivist learning and computation have in part a shared history. Papert (1980) who developed the notion of constructionism (Ackermann 1996) worked with Jean Piaget on theories of developmental cognition and learning. Alan Kay (1993), who was part of the Xerox PARC team, visited and was inspired by Papert with his work on the Smalltalk computer languages.

Resnick et al (1998) with their notion of digital manipulatives and projects such as programmable bricks have at the core the idea of learning through physically engaging with artefacts that control computation, and cite influences such as Froebel and Montessori. Finally interacting playfully and exploratively is a way to consider interaction design. Gaver, Bowers et al (2004) consider ideas of ambiguity as ways to encourage playful interaction with digital technologies. This last section of the chapter looks at the third concept that informs this inquiry, that is what is playing and exploring and what implications does it have for the design of a tangible user interface.
2.6.1 Why play and explore.

My interest in play was triggered by watching my son and daughter engage with their toys in our home. What I found fascinating was the ways they combined and mixed these toys to satisfy an emerging narrative of their own creation. This play had no predefined rules, or none that can be described without considerable observation and rigorous analysis. These toys were combined and manipulated in ways that their makers never intended. Cardboard boxes with action figures, pieces of string around stones from the garden, all selected and arranged to take part in this spontaneous moment of creation and discovery.

In his book *Homo Ludens*, Huizinga (1970, p. 18) argues that play is not in culture but of culture. By this he states that play predates culture, it occurred before society was established by man and has influenced all cultural activities of modern civilisation such as art, law, poetry and even war. *Homo Ludens* translates to mean Man the player and with this Huizinga posits that play is an essential part of human existence that must always remain distinct from all other forms of thought in which we express the structure of mental and social life (Huizinga 1970, p. 25). Huizinga also states that there are important and unique characteristics of play.

*It is first and foremost a voluntary activity, playing to set patterns or order is no longer play. Play is about being free to explore and not about ordinary or real life but rather moving into an imaginary existence of make believe and pretend* (Huizinga 1970, p. 25).

2.6.2 The value of play for children

When I was growing up play was viewed as an activity not really essential to the development of one’s intellect and capacity to succeed in life. Rather it was considered a means for children to have fun or burn off some steam
as my mother would always say, a necessary part of a child being a child almost like an informal rite of passage into adolescence and adulthood. This popular conception of play is ignorant of the actual benefits of the cognitive developmental potential of playing and exploring.

Play is an experimental dialogue with the environment (Eibl-Eibesfeldt, I. (1967) cited in Fagen 1981, p.501) and is well acknowledged as a critical part of early childhood development (Vygotsky 1976) that can result in innovative contributions to problems (Dunn and Dale 1984). It can be seen therefore that there is value in the activity of play for developing a creative potential in children for problem solving and engaging with the challenges that society and culture offer.

2.6.3 Collaborative and constructivist learning

Early in this research I was interested in the collaborative and social nature of learning as in the Vygotskian (1976) tradition and ways to possibly enable it through tangible interaction design. Similarly I was interested in Piaget’s notion of peer based activity to construct new understandings. Piaget places some considerable importance on the notion of conceptual change in cognitive development, and this occurs for Piaget any time when existing knowledge is restructured to accommodate new knowledge through collective exploration of a topic with peers (O’Malley 1995, Piaget 1977).

However, whilst peers will have roughly equivalent levels of understanding within their age groups, there must be sufficient differences in perspective if effective conceptual change is to occur. This change is generated through a productive cognitive conflict which arises from children’s attempts to reconcile their perspective differences, driving a return to equilibrium with modified conceptual structures (O’Malley 1995).
It can be seen therefore that collaborative and constructivist learning needs to foster conceptual change for learning to happen. There is an abundance of literature that articulates the shortfalls of the personal computer for social and constructivist learning and makes recommendations for incremental improvements to the software and hardware. This I decided was not a focus of this design research as it was concerned with the existing models of interaction with the personal computer, whereas I was interested in the emerging interaction model of TUIs.

There is also considerable work done in area of tangibles for learning and collaborative construction of knowledge (Marshall, Price and Rogers 2003, Price, Rogers and Scaife 2003) (Stanton, Bayon, Abnett, Cobb and O'Malley 2002, Stanton, Bayon, Neale, Ghali, Benford, Cobb, Ingram, O'Malley, Wilson and Pridmore 2001). This work has uncovered some interesting findings on the nature of the activities with tangibles, most notably the categorization of expressive and exploratory tangibles for learning (Marshall et al. 2003). However after much deliberation I decided that this research into tangibles had concerns for ways of learning with tangibles whereas I was interested in encouraging exploration and initial creativity and the role tangibles could play in this. This refocus had me consider playful exploration and how it is different to learning as exploration was what had originally inspired me when I informally observed my own children.
2.6.4 Play and exploration as a contrast to learning

Playful exploration among children may be especially important for developing new solutions to a problem, as information obtained by goofing around with the materials may suggest novel, creative solutions to problems down the line (Rogoff 1990, p.186).

Play is a spontaneous activity that encourages exploration of an idea, whereas learning follows a programmed curriculum, even within the constructivist methods such as Steiner, Montessori and Reggio Emilia. Huizinga posits that play is about being free to explore (Huizinga 1970). Bruner et al suggest that, freed from a tightly held goal, the player can substitute, elaborate and invent (Bruner, Jolly and Sylva 1976, p. 244).

In contrast learning often has a set of outcomes associated with it. It is based on achieving knowledge and competencies at certain key stages or grades or age based assessments and these stages satisfy an organised program of development. Play contrastingly calls on creative and spontaneous responses to activity.

2.6.5 Playing and exploring with artefacts

The activity focus of this inquiry is playful exploration, observed through the use of the Sonic Blocks. But before we enter the domain of technology I would like to combine the earlier discussions on embodiment and perceptual motor abilities with the playful exploration of non technological artefacts. We can learn much about playing with materials and artefacts through the approaches to early learning from both Montessori and Froebel.

13 I refer to these approaches generally as constructivist as they all share in common the focus on children developing their own knowledge through doing.
Let us suppose that we use our first object, - a block in which solid geometric forms are set. Into corresponding holes in the block are set ten little wooden cylinders, the bases diminishing gradually about the millimeters. The game consists in taking the cylinders out of their places, putting them on the table, mixing them, and then putting each one back in its own place. The aim is to educate the eye to the differential perception of dimensions. (Montessori 1964, p.169)

Montessori’s blocks enable a fundamental education of the senses through the affordances of the block and its cylinders. Gibson (1979) would suggest the surfaces are composed to make up the volume or the object. Through grasping and perceiving the cylinders they are placed into their corresponding holes and the relationships of volume and proportion are explored. The block and cylinders represent the abstract concept of dimensions, a mathematical concept, by virtue of the volume and size of the cylinders relationships such as biggest to smallest can be explored. Froebel (Brosterman 1997) had similar convictions to Montessori. His ideas of using manipulable materials predated and inspired Montessori. His gifts were carefully designed to help children recognize and appreciate the common patterns and forms found in nature (Resnick et al. 1998, p. 281). Physical objects have a rich history in learning. Resnick, Martin et al (1998) have been inspired by this pedagogical approach and have extended these objects to be embedded with computational power. This has built on familiar associations to create new and novel ways to explore such phenomena as system dynamics and mathematical concepts.

2.6.6 Playing and exploring with digital manipulatives

In discussing how Montessori and Froebel differered, Zuckerman et al provide a useful distinction between their respective approaches in the context of
the design of TUIs for learning through physical relationships and activity (Zuckerman, Saeed and Resnick 2005). These authors discuss objects and toys which they term manipulables. They articulate two types of manipulables, Montessori Inspired Manipulables (MiMs) and Froebel Inspired Manipulatives (FiMs) (Zuckerman et al. 2005, p.859). The essential difference between these two categories is that MiMs use physical objects as a way of representing a conceptual idea such as volume for mathematical relationships in a figurative sense, whereas FiMs use objects as literal representations of real world things, such as the use of building blocks to make a castle.

The Sonic Blocks, introduced and discussed in chapter 5, represent and control digital sound files narrative through five electronically augmented timber blocks. The Sonic Blocks were inspired by the work of Montessori and MiMs in that they seek not to represent the sound through formal literal expression but rather present figurative building blocks as chunks if time to be explored and manipulated. This figurative approach calls on the notion of product semantics discussed in section 2.2.4, in which physical form suggests meaning through its analogy to something else to assist its use. There are numerous projects that use physical form to embody conceptual ideas which could be described as MiMs. Of note is Systemblocks (Zuckerman and Resnick 2003) an example of a MiM that explores system flow such as population growth or the equilibrium of an ecosystem (see Figure 8 next page). These values are physically engaged with through electronic blocks that help make concrete these abstract concepts.
An example of a FIM is the kinetic manipulative building toy Topobo (Raffle, Parkes and Ishii 2004). It can be constructed to represent a horse or bug as illustrated in Figure 9 (above). Any pushing and pulling movements made by hand are replayed as a sequence of electro-mechanical responses. I classify
Topobo as a FiM as it literally represents something in the world rather than an abstract concept. This is further enriched by its ability to move. In Fishkin’s (2004) taxonomy, Topobo is an example of a tangible with full embodiment and metaphor. In a representational sense this means the virtual system is the physical system, acting on the Topobo provides kinetic data that is repeated in response via the Topobo’s animated movement and not on a display or another mediated device.

2.6.7 Ambiguity and playful interaction

The ways we use digital technologies need not be predetermined by logical narratives but rather be ambiguous and thus encourage exploration. Gaver, Bowers et al (2004) consider ambiguity and openness to be a consideration for interaction design and consciously offer interesting artefacts that are coupled to computation. They describe this approach as Ludic Design (Gaver et al. 2004, p.887) inspired by Huizinga’s (1970) Homo Ludens. Their Drift Table is a project that demonstrates these ideas.

In use the Drift Table is an electronic coffee table that allows you to navigate through a changing view of the British landscape. The engagement with this landscape image is through a small circular view port that is placed in the centre of the table’s top surface. The image drifts as you apply weight to one of the tables four corners through the use of weight sensors. The lens in which you view the image is circular and not much larger than a tennis ball, this aperture in the table top sits above an LCD display which is housed in the table. The lens has a fresnel quality that adds a depth and distortion to the image, heightening its
evocative appeal. The authors report on the table in use and articulate a fascinating array of experiences that the participants had from sightseeing to visiting places of their youth. The most significant finding for this research was the ways in which the Drift Table was incorporated into the activities of the share house. The participants would set the table on a course by placing artefacts over the weight sensors and go out and return some time later to discover where the table had travelled to. This I consider to be playful and exploratory behaviour.

Whilst physically and computationally quite a contrast to projects like Topobo and Systemblocks, the Drift Table nevertheless is a device to explore and construct meaning. It was designed to consider the cultural and physical

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14 The Drift Table was placed in a share house in London as a cultural probe to establish just how its ambiguous interface and novel physical affordances would be taken up in this social and cultural setting.
constraints of domestic activity and not as a learning tool for children. It is a carefully considered device that on first appearance is curiously illogical. Why would you have a small circular screen in the middle of a coffee table? This I consider is its strength as it draws one in to explore its capabilities through use; it has no clear narrative thus fostering one’s own interpretation and construction of meaning.

2.6.8  Theme 3 - Exploration and expression

Play is a central part of our culture and important for expressing who we are. In the context of childhood development it fosters creativity and novel solutions to problems. Play also benefits from being a social activity. There are many examples of using computation and digital technologies to support and encourage play and exploration. Research indicates that enabling these activities with computation cannot be achieved by using the conventional GUI with its visual and symbolic interaction models, but rather by extending computation into the world through artefacts in an embodied sense and thus affording perceptual motor engagement. This inquiry will focus on play and exploration as an activity to design a TUI. The third concept of this research is therefore:

- *Exploration and expression*, to enable a playful and explorative orientation towards an activity through the design of TUI objects that embody abstract concepts and are slightly ambiguous in their relationships and couplings.
2.7 Conclusion to chapter

The first two concepts, action and representation are concerned with the physical attributes of Tangible User Interaction as a means to afford action and physically represent the state of digital data as meaningful to the activity at hand.

The third concept, exploration and expression, considers the nature of playful and exploratory activity as a consideration when designing and developing TUIs. The proposition is that physically afforded actions, at the right level of abstraction and ambiguity encourage different types of exploration to the visual and symbolic GUI. These research concepts define what I consider to be key concerns of exploratory tangible interaction and provide a boundary to focus and direct the design activity within this inquiry. The next section will discuss the methodology and study design of this inquiry to enable the design and development of the Sonic Blocks.
3 Methodology and research plan

3.1 Introduction

To gain an understanding of the research themes as they apply to an actual situation of use, I combine the qualitative and observational methods of ethnography with the synthesis and creation of designing and prototyping. This chapter outlines the rational for combining these two distinct but complementary approaches. It then outlines practically how the inquiry will proceed as a series of planned phases to respond to the design aims and themes of the inquiry. The chapter then outlines the need to obtain research ethics approval when working with children and the particular nature of the constructivist learning approach of the school the children attend. Finally it concludes with a justification of its particular combination of methods to enable a robust inquiry.

3.2 Ethnography, observation and qualitative methods.

What is Ethnography, and why has it proven to be so influential for the realm of Human Computer Interaction and Interaction design? A robust definition for Ethnography as it relates to this research comes from Atkinson and Hammersley (1994, p.248):
In practical terms, ethnography usually refers to forms of social research having a substantial number of the following features:

- **a strong emphasis on exploring the nature of particular social phenomena, rather than setting out to test hypotheses about them**

- **A tendency to work with primarily “unstructured” data, that is, data that have not been coded at the point of data collection in terms of a closed set of analytic categories**

- **Investigation of a small number of cases, perhaps just one case, in detail**

- **Analysis of data that involves explicit interpretation of the meanings and functions of human actions, the product of which mainly takes the form of verbal descriptions and explanations with quantification and statistical analysis playing a subordinate role at most.**

The key points I would like to emphasise in the above description, are that ethnography is about exploration and description rather than hypotheses setting and testing. This inquiry will engage in two phases of observation, with and without the Sonic Blocks. The aim of these two observations is to firstly learn about the interaction with music making software and its associated GUI\textsuperscript{15} to inform the design of the Sonic Blocks. Secondly I return to the field with the Sonic Blocks to observe their use. There is no hypothesis to test and I am not measuring differences between GUIs and TUIs or providing scientific comparisons. Rather I am interested in describing the activities and actions that result from the use of the Sonic Blocks through the collection of data that is unstructured

\textsuperscript{15}The GUI I refer to here is the Garageband timescale that was a popular tool of the children in their soundtrack making activities. Garageband is digital music making software that enables you to record Real and Software Instruments, add loops, arrange and mix a music project. It is available as part of the Macintosh suite of software and is a trademark of Apple Computer, Inc.
prior to collection and involves the explicit interpretation of the meanings through the key concepts established in chapter two. These descriptions will be discussed to provide a conclusion on the nature of tangible interaction and its way of entwining action and meaning.

### 3.2.1 The use of ethnography within design projects

It is becoming commonplace in design projects to see the use of ethnographic research providing information leading to questions, and design providing concepts and ideas that attempt to answer these questions (Bueno and Rameckers 2003). Sanders (2002, p. 6) articulates the different roles and skills that designers and social scientists bring to human computer interaction design.

*Social Scientists bring frameworks for the understanding of user experience to the table, while designers know how to synthesise and embody ideas and concepts.*

Similarly research into educational development with ICTs has used ethnographic inquiry to empirically inform its practice (Druin, Bederson, Boltman, Miura, Knotts-Callahan and Platt 1999), (Rizzo 2003, Stanton et al. 2002), and has proven to uncover deeper and richer understandings of learning contexts and the roles digital technologies can play within them.

The use of ethnographic methods to gather useful information for design has become common practice within the Human Computer Interaction (HCI) and Interaction design communities. Ethnography as a method adds value to design through the rich descriptions of social and technological activities that provide useful frameworks and boundaries for design to evolve. I have chosen to become immersed in the exploratory activity world of children to gain greater insight to the ways they interact socially and technologically. Doing this has enabled a framework upon which to conceive and create the Sonic Blocks.
3.3 Designing and prototyping

Industrial and product designers have central to their practice the act of prototyping as a means to resolve and come to terms with the objects they are designing. A prototype in this sense is akin to a three dimensional argument for a particular combination of form and material. It helps the designer understand their conception through its physicality. In the realm of digital product and tangible interaction design the notions of three dimensional form are coupled to electronic circuitry and digital software. In this section I will discuss the emerging method and techniques for tangible interaction prototyping and the argument for achieving the highest quality to enable rich experiences of use.

3.3.1 Prototypes at the Eames office

Historically one of the most important practitioners of prototyping in the modern industrial design context was the Eames design office who amongst other achievements created and developed the first commercially available compound form plywood armchairs in 1946 (Kirkham 1995). These armchairs followed significant form and technological development that was evaluated by the photography of high quality prototypes. The quality of design through prototyping used in the Eames office has influenced the refinement and manufacture of plywood furniture the world over. Methodologically this approach of creation and refinement has become part of the universal industrial designers’ sets of skills.
3.3.2  Electronic prototypes in tangible interaction design

To create an interaction experience with TUIs there have been a variety of electronic prototyping toolkits\textsuperscript{16} that have become available in recent years to enable a physical input such as a voltage shift from a potentiometer to be converted to digital data. The Sonic Blocks make a number of physical connections that enable a small voltage to be read by the software Max MSP which in turn selects and plays a sound file\textsuperscript{17}. These toolkits enable a high quality representation of how a TUI will work and behave for design evaluation purposes.

3.3.3  Prototypes as data collectors

Placing technological prototypes into social settings has also become quite commonplace within the HCI and interaction design communities.\cite{Hutchinson2003} use the term technological probes to describe the deployment of digital technologies into domestic settings to establish their use as social tools. They take the position that these technologies are not unbiased meaning that they have an effect on the behaviour of the users. I would extend this notion to comment that technologies presented in novel physical forms mediate new experiences that can be quite unexpected.

There is also an argument for the fidelity of the prototype, by this I mean the resolution of both its physical and digital form. Hummels and van der Helm (2004) illustrate this with their project ISH which is a multi media installation that uses a range of tangible devices to create and manipulate sound and video. Each

\textsuperscript{16} For good examples of these toolkits see http://www.makingthings.com/ or http://www.arduino.cc/
\textsuperscript{17} I will discuss the electronic design and development of the Sonic Blocks to a greater level of detail in Chapter 5.
of these devices are evocative invitations to act through their considered affordances that amplify sensory motor perception. This invitation to act is also due to the resolution of their physical form. The authors have central to their approach ideas of *aesthetics of interaction* and *resonance* and call on their backgrounds in industrial design to create prototypes that are aesthetically and technically resolved.

The Drift Table\(^\text{18}\) (Gaver et al. 2004) which I discussed in section 2.6.7 in the last chapter, was a highly resolved technological prototype that revealed interesting ways in which people interact with devices that are open to interpretation and encourage play. From a methodological standpoint the findings were enriched due to both the Drift Table being immersed into the participants’ household for six weeks and the high resolution and quality of the prototype both materially and technologically. To get the deeper discussion of the sociological motivations for this project and others see (Sengers and Gaver 2006). What I would like to emphasise here was the resolution of the prototype’s aesthetic and and material qualities added to the experience of use. Participants commented on the aesthetic qualities of the Drift Table as a domestic artefact and made comparisons to other objects they liked.

These brief descriptions of prototypes in interaction design highlight that conventional design notions of resolution of form, material and build quality are important to their experience in use. These aesthetic concerns extend beyond notions of functional usability and enable the opportunities for playful and delightful experiences. As part of my method I therefore consider the construction of a resolved and workable prototype to enable rich experiences to be observed and described.

3.4 Research through design as creative production

The act of designing and making (of prototypes and artefacts) as a valid research inquiry has come under some scrutiny over recent years within the academic design community. Issues such as reliable knowledge in design research (Durling 2000), the notion of design as a problem solving activity (Dorst 2006), and the distinction between problem solving and creative production (Scrivener 2000) are raised in the discussion of design and how it makes or does not make a contribution to knowledge. Similarly Schon’s notion of the reflective practitioner (Schon 1983) and Downton (2004) who argues that designing and making if done as a consciously reflective and documented process can make a reliable and robust contribution to knowledge.

In recent years I have attempted to publish in the HCI (or CHI) communities\(^\text{19}\) which has considerable membership from computer science and engineering. Generally speaking the notion of a designed prototype on its own does not have value to this audience as they want to see it tested and evaluated. A criticism I have of this CHI audience\(^\text{20}\) is that they seem to use the word design as a noun and verb quite liberally and without due respect for the complexity it holds as a process of thinking. I don't feel that this audience has a respect for the process of design as a way of thinking that is robust and worthy.

To help describe this design research as creative production, an alternative to scientific problem solving approaches, but at the same time robust and worthy, I describe this inquiry using the definitions laid down by Scrivener (2000)

\(^{19}\) The score on my publishing record to a CHI audience is 2 out of 4 as at the end of 2007.
\(^{20}\) I was present at a design discussion workshop at OZCHI 2006 at which Bill Gaver was a panellist. The opinions offered within the audience were polarised on the definition of design ranging from ideas of art practice to a technical engineering discipline. Of which I suggest design is neither but a practice in itself.
3.4.1  Creative production as knowledge

Scrivener makes the distinction between creative production and problem solving projects in the context of PhD art and design research (Scrivener 2000, p. 4). Which raises the question for this inquiry, is this a problem solving or creative production project? In evaluating these two types of projects he offers the criteria:

In problem solving projects has the research student:

- Demonstrated that there is a problem to be solved

- shown that the solution to the problem will result in a new or improved artefact.

- shown that the problem is one that the world would like to see solved.

- demonstrated the usefulness of the solution.

- demonstrated that the knowledge exemplified in the solution can be abstracted (ie, described and /or formalized)

- considered the general applicability and transferability of this knowledge.

- proved this knowledge (ie demonstrated that the problem has been eradicated or ameliorated by the solution)

Or contrastingly with a creative production project, has the research student:
described the issues, concerns and interests stimulating the work, i.e., something that will contribute to human experience

shown the response to these stimulants is likely to be original

shown that the issues, concerns and interests reflect cultural preoccupations

shown that the relationship between the artefact and those issues, concerns and interests

presented original, high quality and engaging artefacts that contribute to human experience

communicated knowledge, learning or insight resulting from the programme of work

shown themselves to be a self-conscious, systematic and reflective creative artist or designer.

I started this inquiry by attempting to define a problem. Some of the issues that arose from my literature review were situated within the domain of the conventional computer interaction being insufficient for collaboration and creativity with groups of school children (Brouwer-Janse, Fulton Suri, Yawitz, de Vries, Fozard and Coleman 1997). I had come from a problem solving culture with my commercial design practice experience, so the initial response was to offer up a solution to this problem. Simple, or so I thought. Research into newer interaction approaches for learning such as the use of tangibles and augmented reality had also influenced my decision to follow this problem solving path (Stanton et al. 2001) (Rogers, Scaife, Gabrielli, Smith and Harris 2002) (Price et al. 2003). After reviewing this work I saw the problem as structured around the
design of a tangible user interface to enable children’s collaborative and constructivist learning activities. The personal computer was proving to be insufficient for this type of social learning and this was largely to do with the physical interaction it afforded, or didn’t afford. This focus for tangible interaction design therefore presented fertile ground for a project. On reflection and discussion, with peers and colleagues and presentation of the project proposal to a conference and two seminars, there was ample validation of the project as a testable design problem.

The only issue was that to provide enough testable evidence the research needed the rigour and duration of a PhD. I was committed to a masters for personal and academic development reasons and therefore resolved to limit the investigation and focus on achieving mastery in the process of tangible interaction design from concept to prototype. But the issue of the testable question as a problem solving project remained and was raised at one of my progress reviews. Scrivener’s definitions are a valuable way of articulating what constitutes a problem solving project. I have used these definitions to describe my method and motivations, and will reflect on my approach to this inquiry through these.

Scrivener starts by suggesting in a problem solving project has the student:

- **Demonstrated that there is a problem to be solved**

I had a problem but not an effective way to solve it. In discussing what I was attempting to do, responses from the review panels indicated it was an interesting project but to effectively design a TUI to answer the question would need extensive observation and at least one iteration of the prototype. Later feedback was directed towards being able to demonstrate that the children had learnt through using this introduced TUI, and was that really what I was
interested in. So this criticism was all directed at the scope of the project. It was too large in the context of the masters program.

Scrivener’s notion of a problem solving project also asks, has the student:

- *Shown that the solution to the problem will result in a new or improved artefact.*

- *Shown that the problem is one that the world would like to see solved.*

- *Demonstrated the usefulness of the solution.*

The inquiry would offer up a new artefact, the Sonic Blocks, but as to whether they were an improvement on the Garageband GUI would not be effectively measured. There is enough literature in existence that supports the need for social and physical learning with computer technology so I was satisfied I could put the case for TUIs to do this. However demonstrating the usefulness was problematic because ultimately this measure is in comparison to the Garageband GUI that the children used in the first stage of observations. To measure usefulness the study would need to be over a greater period with a number of different social settings. Scrivener also articulates that problem solving projects:

- *Demonstrated that the knowledge exemplified in the solution can be abstracted (ie, described and/or formalized)*

- *Considered the general applicability and transferability of this knowledge.*

- *Proved this knowledge (ie demonstrated that the problem has been eradicated or ameliorated by the solution)*
As I could not effectively design the TUI to be compared to the personal computer and its GUI, I could not abstract a solution, generally apply this knowledge nor prove it. So initially what I considered to be a problem solving project with reasonably defined boundaries and attainable aims and objectives was not. These objectives were beyond the scope of what could be achieved within the timeframe and intention of the project I was attempting. Similarly offering a solution to the problems with a PC and its interface was not what was really being done within the TUI design community. All of the projects concerned with TUIs and social learning (Stanton et al. 2001) (Rogers et al. 2002) (Price et al. 2003) were looking at early stage opportunities for learning with Tangibles. They did not explicitly offer comparisons to the PC and its interaction model but rather described the novelty of the TUI as an opportunistic space for further research.

On reflection and consideration of Scrivener's definition of problem solving design research, this inquiry does not comply. It would be beyond my expertise and interest. However, to consider the project in terms of creative production as defined by Scrivener was closer to the mark in terms of the focus I had on tangible interaction. It opens up the space for discovery and description rather than closing it down to definable results and comparisons to existent technologies.

In the context of creative production projects Scrivener starts by asking, has the student:

- *Shown that the issues, concerns and interests reflect cultural preoccupations?*

The notion of play with interactive technologies has emerged as a cultural preoccupation within many members of the Human Computer Interaction and Interaction Design research communities. One of the key concerns is the
prescription of the PC interface for playful and creative activities. Through design this project can demonstrate and amplify these issues through both the agency of the TUI and the description of its initial use within a playful and creative context.

- *Presented original, high quality and engaging artefacts that contribute to human experience?*

The design of TUIs is fertile and at a stage of infancy that a considered effort through design will result in an original artefact. The quality, level of engagement and contribution to human experience will be demonstrated. However it must be noted that Scrivener’s points of evaluation are based in a Phd and not a Masters submission. With this project an attainable level can be achieved.

- *Communicated knowledge, learning or insight resulting from the programme of work?*

- *Shown themselves to be a self-conscious, systematic and reflective creative artist or designer.*

This research will offer a considered description of both a tangible prototype in use through key categories that respond to the research themes and an account of the reflective process of the prototype design. On balance this research sits more comfortably as a creative production project with some rich descriptions offered as an insight into the nature, potentials and opportunities for TUI design in this playful and creative context.

### 3.5 The research plan

To understand play and exploration it was decided to observe children playing and exploring both with computers and without. These first observations
were to precede of the design of the Sonic Blocks. My review of literature led me to the Reggio Emilia (Edwards, Gandini and Forman 1993) approach whereby children are encouraged to learn through their playing and exploring in a constructivist manner. After discussing the project with my supervisors it was agreed to look at who was conducting Reggio Emilia programs in Melbourne and to begin to develop an ethics application to enable an observation study to take place. With this observation activity established the next step was to translate this knowledge gathered from the first observations into TUI design concepts and ultimately a working prototype, the Sonic Blocks. With the Sonic Blocks built a return to the Reggio Emilia classroom was the last stage planned to observe them in use in a playful and exploratory context. This section will describe the phases of the research to unpack the particular aims, methods and instruments used to conduct the inquiry.

21 Reggio Emilia also uses computers and digital technologies willingly in its pedagogy to support project activities unlike other constructivist approaches like Steiner.
Figure 11: Diagram of the research plan showing the four phases and their aims and methods.
3.5.1  What does the diagram mean?

I would like to describe the rationale behind the diagram which represents the inquiry as temporal phases of knowledge development. These phases as represented are not suggesting a step by step linearity akin to following a recipe. Rather they represent this inquiry as a robust account of how the Sonic Blocks were informed, designed, made, used and experienced.

3.6  Phases of the research plan described.

3.6.1  Phase one – Literature review and first observations

The literature review, chapter two, provided the intellectual background and research concepts for this inquiry. It was conducted as a critical gathering of the theories relevant to describe the need for an embodied approach to computing and a historical account of the development of the personal computer, which has resulted in the lack of embodiment in the interaction models used the GUI, keyboard and mouse.

Moving forward the overarching method used for the observations in this phase, and phase three, is called Contextual inquiry with children (Druin et al. 1999). This methodology and its antecedents will be discussed in section 3.7.1, but for now I would like to offer a pragmatic discussion of the research instruments, methods and motivations used within each phase. The first observations will involve observing the children using both traditional hand held musical instruments and a personal computer and software to collaboratively create a soundtrack to a story that the children have read as part of their Reggio Emilia learning program. The manual activity with the musical instruments and
the activity with the personal computer will be separate activities held at separate times. The research instruments and data collected will be a video recording of the children undertaking the set activities; informal questions and responses of the children will also be recorded on the video tape. The aim at this stage will be for me to understand how the children make soundtracks both with and without computer technologies.

Another aspect, whilst not central to the research concepts, will be the collaborative nature of the activity and how this plays out. Finally I will get a sense of the particular nature of the Reggio learning environment and how it can inform and inspire the design of the prototype. This data will then be transcribed using a Contextual Inquiry diagram as a means of capturing the patterns of activity in a structured way to establish key themes and design directions. The Contextual Inquiry diagram will be discussed in more detail in section 3.7.1

3.6.2 Phase two - designing and making the interaction prototype.

Based on the first observations and the key concepts that have been established in the literature review, design aims will be established. These aims will enable a framework from which to design the prototype. The design stages will be broken into conceptual design (without electronics) and design development (proof of concept with electronics and refinement). Having these two design stages will allow sufficient feedback to enable a process of critique and refinement in response to the design aims and challenges that are revealed as the project develops. The conceptual design will be evaluated internally at RMIT through gaining feedback from both of my supervisors and will be presented to an academic panel of experts at the RMIT School of Architecture and Design Graduate Research Conference (GRC). Broadly speaking the conceptual design will be evaluated using these two forums to test the conceptual validity against
the design brief. The conceptual design will be revealed to a wider audience of interaction designers and researchers for criticism to aid the refinement and development. Once the conceptual design has been critiqued and refined it will be presented to the teachers at the Reggio Emilia program for feedback with respect to the activity planned with the Sonic Blocks and any problems or opportunities that arise.

With due consideration given to any issues within the critiques and subsequent refinements made, the conceptual design will enter a stage of development to establish how it will be achieved as a working electronic interactive in the context of the classroom activity. Once the first electronic mockup is sufficiently robust to demonstrate the control and representation of and interaction sequence, it will again be presented to the GRC for critique and approval. On the basis of this critique and considering the suggestions offered, the final prototype will be developed to demonstrate full interactivity and allow use in a classroom test situation.

3.6.3 Phase three- Observation of children using the tangible prototypes

This phase will involve observation of the children using the tangible prototypes to gain an understanding of particulars of use. As with the first observations, the research instruments and data collected will be a video recording of the children undertaking the set activities, notes in a journal made after the activity and informal interview data gathered the day after using the prototype. The activity with the prototype will be developed with the teachers and will follow a similar set of events to that with Garageband for creating the soundtracks as in the first observations.
3.6.4 Phase four - The analysis of data.

This stage will include transcription and analysis of the video data from the third phase (second observations) using observation criteria generated from the research concepts. The analysis will also draw comparisons and contrasts to the first phase data and will be carried out using a Contextual Inquiry diagram that I will discuss in section 3.7.2.

3.7 The methods and instruments in the phases

3.7.1 Contextual inquiry with children

To enable the observation program and data collection to be sensitive to the playful and exploratory nature of children creating in groups I have used Contextual Inquiry and will discuss this approach in this section. Recent advances in observing children have lead to the development of a modified version of Contextual Inquiry (Beyer and Holtzblatt 1998) called Contextual Inquiry With Children (Druin et al. 1999). In this method children are observed at home or in favourite public spaces allowing them comfort and control due to their familiar surroundings to encourage participation. Druin et al. (1999, p.56 and 57) have outlined 10 techniques for effectively undertaking Contextual Inquiry with Children to encourage to participation these are:
• Go to their territory, this is important to make the children feel as comfortable and to encourage them to behave as naturally as possible

• give children time, children need time to settle in to an activity before questions are asked

• wear Informal clothing to avoid being labelled as an authority figure

• do not stand with children, be one of them, sit on the ground with them

• use an object as a bridge, to give a reason for interaction between interviewer and user

• ask about their opinions and feelings

• use informal language

• the interactor must not take notes

• use small notepads

• Note-takers should not move, to avoid distracting the children.

These factors help guide the orientation toward the observation and make me the observer aware of my role and place in the activity. How I transcribe the observation data from video tape will be achieved by the use of a contextual inquiry diagram.
3.7.2 A diagram for contextual inquiry

Druin Bederson et al (1999) used a technique called Contextual Inquiry (CI) diagramming to capture activities and comments children do and make. A CI diagram consists of 6 columns in a cell based format (see fig 12 below). These columns consist of Time, Quotes, Activities, Activity Patterns, Roles and Design Ideas. Data is collected for the first three columns in an observation session. The time column is used to synchronise quotes with activities. The quotes column contains phrases and sentences said by the child or children during the session.

<table>
<thead>
<tr>
<th>Time</th>
<th>Quotes</th>
<th>Activities</th>
<th>Activity Patterns</th>
<th>Roles</th>
<th>Design Ideas</th>
</tr>
</thead>
<tbody>
<tr>
<td>36:45</td>
<td>Oh look there’s a kitty. The kitty meowed (Laughs)</td>
<td>The game begins on the computer. Child sees the kitty on the screen for the first time and is excited by the sound.</td>
<td>Child is sensitive to feedback from the computer</td>
<td>Explorer</td>
<td>Design technology with sound</td>
</tr>
<tr>
<td>37:73</td>
<td>The kitten meowed again</td>
<td></td>
<td></td>
<td>Explorer</td>
<td></td>
</tr>
<tr>
<td>39:20</td>
<td>I want the playing one</td>
<td>Child clicks on the scared cat and tries to take out another one. It doesn’t work</td>
<td>Difficulty with mouse dragging</td>
<td>Look for alternative input devices or don’t use dragging with a mouse.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 12: Contextual Inquiry Diagram (Druin, Bederson et al. 1999)

I have adopted the CI diagram as it is both an accurate and rigorous way of interpreting the activity recorded on the video tapes. It can be used to quickly establish, for example, patterns of computer usage and comments made between the children.
### 3.7.3 Trialing the CI diagram

I decided to trial my version of the CI diagram by observing and interacting with my daughter at home. The results had me converting what I considered a well planned CI diagram into an informal notepad. My daughter was using an interactive book and the major problem with this diagram was that it was too difficult to capture activity using notation in this form. This led me to adopting a technique of observing and questioning. For example she would use a function of the interactive book and I would ask her how she knew how to do this. Her responses were brief but rich, and gave me a good understanding of how and why she undertook the activity.

![Figure 13: The Contextual Inquiry Diagram, early attempt](image-url)

<table>
<thead>
<tr>
<th>Stage 1 observation Journal</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project name:</td>
<td></td>
</tr>
<tr>
<td>Interaction using traditional means</td>
<td></td>
</tr>
<tr>
<td>Description of media and activity</td>
<td>levels of engagement (Scale 1 to 5)</td>
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<td></td>
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</tbody>
</table>

**Figure 13:** The Contextual Inquiry Diagram, early attempt
But this approach of always asking questions interrupts the activity. What I found was that I had to capture the activity through video-recording that could be looked at later in detail through the CI diagram. Questions could be asked after the activity so as not to disrupt it. To compare the two approaches the original CI diagram allows for the observations and recording of data to happen naturally and not presuppose categories for the actions of the children. The raw data such as time, quotes and activities is collected by a researcher during the activity. When I trialed my initial checklist I found that I really only had time to record the data as a set of brief notes. These notes could be used to refer back to the videotape. However categorizing data as I collected it requires reflection that cannot occur whilst the data is being collected. What is needed is a technique that allows for reflection and a finer interpretation after the raw data has been gathered. I have therefore adopted the two stage approach of collecting raw data on videotape and transcribing and categorizing it later.
Figure 14: The Contextual Inquiry Diagram revised version

The revised CI diagram has a simpler format to enable data to be interpreted from the videotape. The left hand columns collect raw data and the right hand columns categorise and establish a finer grained interpretation of the data.

3.7.4 Unstructured and semi structured interviews

To attain a greater sense of meaning for the video observation data I used unstructured and semi structured interviews to help explain the activities captured on video. Preece, Rogers and Sharp (2007, p.298) articulate three types of interview that are relevant to this research. Unstructured or open ended, semi
structured and structured or closed interviews. Selecting which type is
determined by the goals of the interview. In both stages of my observations I
wanted a discussion around a set of topics. In the first observations I used an
unstructured interview to ask the children questions about their actions with the
personal computer to give me a greater understanding of the video data. These
questions pertained to the use of the software the children were using to
complete the soundtrack activity and they served to help me understand the
activities that would be transcribed from the video data. In the first observations
these questions were asked directly after the activity. In the second observations
I used a semi structured interview that was developed after the activity and
delivered the next day.

3.7.5  Written account of the activity.

To get my immediate impressions of both the first and second
observations I wrote summaries of the activities two to three hours after I had
observed them, whilst it was fresh in my memory. These gathered any brief notes
or impressions I had during the activities and they served as useful ways to give
an overall description of what was gathered and whether it was successful. I did
this prior to any transcriptions with the CI diagram.

3.7.6  Research through design in phase two

Researching through designing and making is knowledge that is exclusive
to the designer’s stockpile of design experiences (Downton 2004). Designers
consciously or subconsciously use this knowledge to design, but it is not
necessarily ordered or predetermined as design projects do not present
themselves in this way. Each project has its unique set of constraints and
concerns that the designer needs to skillfully act upon through framing, doing and
reflecting. This framing and reflecting is referred to by Schon (1983, p.163) as the reflective conversation with the situation, and it is the way a designer moves through the challenge of a design by critical self analysis to achieve a suitable outcome.

The second phase of this design inquiry encompasses an ongoing reflective design conversation in the creation of a TUI for exploratory soundtrack creation. This phase is quite distinct from the observation and analysis that occurs in phases one, three and four in that it calls upon a different set of skills and knowledge. The reflective design conversation will be documented chronologically in chapter five. It will include images and notes that chart the development of the Sonic Blocks.

### 3.8 Other factors in the research

**3.8.1 Reggio Emilia**

Many early childhood centres in Australia have attempted to draw from the work of educators in Reggio Emilia (Millikan 2003). After discussion with colleagues and my supervisors the decision was made to choose Reggio Emilia to conduct the ethnographic inquiry as it places value in developing the expression of children through their own creative means as a way of constructing knowledge. It also encourages children to play and explore which fits nicely with the third concept of this inquiry. With Reggio Emilia the room and environment is seen as a space to create and explore. Efforts are made to break the institutional feel that you may experience with conventional teaching classrooms and the ways they are

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22 Doing the ethnography in a classroom environment will give some structure and purpose to the play and exploration. Whilst the authors of the Contextual Inquiry with children method seek to capture children’s activity outside the classroom in favourite public places or at home, this was not deemed practical with my experience of carrying out such an observation. Doing the observation in the classroom also had the added support of the teachers and their experience.
used to enable learning and exploration. This principle is known as the environment as the third teacher (Frazer 2000). Therefore observing within a Reggio Emilia approach was considered to be the most beneficial as it encouraged constructivist and exploratory learning. Reggio Emilia also fosters making and physical exploration through models and other craft based activities. Lastly personal computers and other digital technologies such as cameras were are used seamlessly throughout the Reggio Emilia explorations. The introduction of new digital and physical interfaces (TUIs) could be successfully integrated into the children’s learning without any interruptions to the learning program. Therefore I structured my ethics approval on an observation program within a Reggio Emilia program in Melbourne, Australia.

### 3.8.2 Research Ethics

As the observational data is to be collected by video camera of children, this inquiry needs to be sensitive to the identity and rights of the children appearing on the video tape. Before the observation could begin this research required ethics approval from both RMIT University and The Education Department of Victoria, as the observations would be conducted in a primary school under its jurisdiction. Philosophically the ethics process was one I had respect for as I have two young children myself, one of whom is school age. The ethics process enables valuable research to be undertaken within sensitive situations and informs all responsible parties and the parents of the scope and intention, whilst giving them the right to refuse participation. This project was granted ethics approval to conduct the video observation. The observations commenced in July 2005 once the relevant participant consents had been granted.
3.9 Conclusion

In this inquiry the combination of observation, collection and analysis, (ethnographic and social scientific methods) are combined with the synthesis, creation, reflection and making (research through design) to complete the method. This process of design is fundamentally different to the collecting and observing of ethnography. It is supported through a documentation of the process through sketches, notes and models arranged chronologically, or as faithfully as can be remembered whereas the ethnographic methods serve to inform and evaluate the design outcome, the Sonic Blocks.

This method has been designed to enable a robust investigation and one that demonstrates my approach to be systematic and reflective in practice. How this method is applied I discuss in the next chapter which outlines the first observations that inform the design of the Sonic Blocks.
4 First observations

4.1 Introduction

This chapter reports on the activities of four children in their primary school classroom using both a personal computer and handheld percussive instruments to make sounds and soundtracks. These observations give an account and present findings on the particular interactive nature of these activities with a focus on their actions and gestures. The aims of the first observations are to empirically inform the design investigation of the playful and collaborative activity with the personal computer, and the expressive activity observed with hand held percussion instruments for making a soundtrack.

4.2 Background to the Observation program.

4.2.1 Determining the observation activities

Once I had obtained all of the appropriate consents to undertake the study as per the requirements for research ethics, I discussed the types of activities to be observed with both the leading teacher and her assistant from the Reggio Emilia program. At this stage I had a plan for both activity with and without personal computers and the discussions revealed some interesting responses. The teachers were unanimous in stating that creating soundtracks
using the software Garageband\textsuperscript{23} was the most successful and engaging computer based activity that the teachers had observed. On recounting stories of these activities it became apparent that due to their popularity and success it suited the types of observations and data that I was seeking to gather.

Garageband is music composition software that comes packaged with the Apple suite of software. It consists of a library of pre-recorded sounds that can be selected and placed into a timeline. This timeline is akin to continuous musical score. It represents the sounds as bands of colour clearly indicating each sound in comparison to one another.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{garageband_gui.png}
\caption{Image showing the Garageband GUI with sounds represented as coloured bands within the timescale. Image sourced from \url{http://osx.iusethis.com/screenshot/} accessed 14.3.08.}
\end{figure}

\textbf{Activity one – Cloudland soundtrack using Garageband}

To enrich the activity with Garageband, the teachers also suggested that the children create a soundtrack to a story, Cloudland (Burningham 1999), that

\textsuperscript{23}Garageband is available as part of the Macintosh suite of software and is a trademark of Apple Computer, Inc.
they had read as part of their other learning activities. This further development of content and themes is what is known as Mastery in the Reggio Emilia approach to pedagogy (Edwards, Gandini and Forman 1998). Using a familiar story would provide narrative themes to enable the children to create a new soundtrack together. The teachers played me examples of the soundtracks the children had completed as part of previous activities. These were quite sophisticated in their arrangement and showed an interesting translation of verbal themes into a musical score. Based on this evidence I decided that this soundtrack making activity would offer fruitful observation data on the personal computer usage in this context.

**Activity two – Cloudland with instruments**

I wanted to also get a sense of how the children worked in an embodied sense via analogue means to determine if bodily actions and perceptual motor channels were used and enjoyed in making sounds. Therefore as a contrast to using the computer and after discussions with the teachers, it was decided to have the same group of children using hand held percussive instruments such as maracas and cymbals. The children had used these handheld instruments in other activities with a visiting musician to some success. The teachers indicated that there was evidence of physical expression, therefore I decided to continue this sound making activity to a narrative with percussive instruments.

4.2.2 **Rationale for observation activities**

The personal computer and the Garageband software are tools that enable the development of a soundtrack. Previous evidence had demonstrated the children’s ability to take an abstract theme and translate it into a sounds in a musical arrangement using these tools. I was interested in how the children would interact with the Graphical User Interface within the software as it represented and controlled the sound files.
How this would translate in the second activity was unknown as using analogue instruments without the selecting and editing capabilities of the digital tools is a considerably different exercise. I was interested in the children using their bodies to create and express sounds, this would give some insight into the gestural nature of such an activity that would inform potential directions for a tangible user interface.

In approaching the teachers I had some knowledge of the theories and approaches of Reggio Emilia. However I was interested in how they practiced this approach and was led by their knowledge and understanding of what would work as a successful program of activities with the children. I went into the conversation with the teachers without any designs on what the activities should be, rather I was open to suggestions on what had previously worked in fostering exploration and expression. This led naturally into the discussion of the group formation and the children were purposively sampled (Dixon, Bouma and Atkinson 1987) by the teachers. As a group they had worked together before and there was a sufficient set of skills for both computer usage and social collaboration. The group was made up of two girls and two boys, all 9 years of age, in the Reggio Emilia program together.

4.3 Activity one- making a soundtrack with Garageband

The setup of the observation was the four children seated around a Macintosh G3 computer with a video camera secured to a tripod and a microphone connected to the camera placed on the table surface near the computer monitor. This computer was placed on a table that was within a large multi-purpose room in which all of the classroom activities took place. In this room the children typically would break off into groups to undertake activities
such as reading and drawing. Activity one was one of many activities happening within this multi-purpose space.

**Figure 16:** Image showing the children at the PC for the Garageband activity

### 4.3.1 Broad description of soundtrack activity

Approximately 45 minutes of video data was gathered for activity one. Ten minutes of this video footage was transcribed in detail as this provided a sufficient sample of the patterns of behaviour and interaction. The teachers were indeed correct when they mentioned the enthusiasm the children had for Garageband and the activities it fostered. In this activity the group split itself rapidly in two, with the two boys taking the roles of computer operators, and the two girls reading the storybook into the group collaborative effort. The boys were Ben and Dean, the girls were Zandra and Deborah\(^\text{24}\). As operators the boys controlled the selection of the sounds from the Garageband loop browser using the mouse and pointer to select and the keystrokes to edit. Once the sounds were selected and placed in the timeline, they appeared as a band of colour, mediated through the computer screen. This graphical image was the compelling and

\(^{24}\) Names have been changed to protect the identity of the research participants.
productive representation of the selected sounds and their relationships, it was
the virtual activity area. Refer to Figure 15 for Garageband GUI layout.

4.3.2 Identification of themes from the soundtrack making

At a meta level there were two broad modes in the soundtrack making, these were creation and reflection. Creation was the selection of the sounds and the building of the soundtrack in a constant and frenetic cycle of interaction and negotiation. Reflection was less frenetic and occurred when the children felt it necessary to sit back and listen to their selection efforts. The most profound difference between these two activities was that during creation the children were pointing and gesturing at the timeline on the screen and rapidly commenting on the state of the soundtrack and the adjustments made to it. When reflecting they sat back, listened and commented to each other on both the overall composition as a collection of sounds and the temporal logic of the soundtrack as a representation of the narrative. As a breakdown of the 45 minutes, reflection accounted for 11 minutes and 27 seconds of activity, constituting one quarter of the time observed. Creation therefore constituted three quarters of the activity observed within, which the majority of gestures and actions occurred. As the creation activity has greater relevance for the tangible and physical focus of this inquiry, further analysis will therefore focus on the creation activity.

4.3.3 Analysis of the creation activity

To explain creation at a finer grained level, it had what I term as operative stages of negotiation and interaction. These two stages were intertwined and they did not occur separately, in fact they occurred in rapid
cycles. *Negotiation* was what happened socially between the children and largely consisted of the use of spoken language, for example:

<table>
<thead>
<tr>
<th>Participant(s)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deborah</td>
<td>go back to here cos we’re gonna do when he gets caught</td>
</tr>
<tr>
<td>Dean</td>
<td>What should we do, something like a little bit happy</td>
</tr>
<tr>
<td>Ben</td>
<td>Yeah, now go to bass</td>
</tr>
<tr>
<td>Ben</td>
<td>Go rock</td>
</tr>
<tr>
<td>Dean</td>
<td>Rock Blues</td>
</tr>
<tr>
<td>Deborah and Zandra</td>
<td>No (not rock blues)</td>
</tr>
<tr>
<td>Zandra</td>
<td>maybe when they do the music</td>
</tr>
</tbody>
</table>

**Table 1:** Participants and their comments when using Garageband

These quite rapid conversations were a constant dialogue amongst the children about the sound choices and how these sounds were appropriate for the narrative. Deborah was holding the book and was turning through the pages to keep track of the narrative. Zandra was assisting with the narrative themes.

The sounds were selected on the basis of their names and categories as they appeared in the loop editor for example, *go to guitar* and *I like the blues that’s a good song*. With the girls as narrative advisors, they stuck with the task of ensuring the sounds related to the narrative by focusing on the book and would use adjectives to describe how they interpreted the sounds in relation the narrative theme, for example *sounds too happy* or would be critical of the sound choice for not fitting the keyword used to describe the narrative theme, for example *it doesn’t make sense.*
The children used keywords or themes to simplify the narrative to components that a sound could be chosen for and negotiated, for example *oh catching, yeah catching*. This social negotiation is not something unique to using Garageband. Children socially negotiate meaning and activity throughout all of the project based learning within the Reggio Emilia program. In the context of the observations with garageband, *negotiation* was the reasonably constant dialogue that occurred through the *creation* activity and was mediated by verbal discussion. The *interaction* operative stage consisted of the physical acts that both influenced and activated the sound choices. I make this distinction in line with the tangible and physical interaction focus of this thesis to describe the logical physical operations for a finer interpretation and understanding of the role the GUI and screen played in mediating this. The interactions consisted of pointing at the screen and activating the sounds through selecting them via the mouse pointer and placing them in the timeline. Sound activation was limited to largely Dean’s control and sometimes Ben’s input, but not without negotiated argument. If we are to look again at the earlier sequences of dialogue this helps describe the cycling between negotiation and interaction.

<table>
<thead>
<tr>
<th>Participant(s)</th>
<th>Comment</th>
<th>Activity types in exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deborah</td>
<td>go back to here cos we’re gonna do when he gets caught</td>
<td><em>Here we see negotiation and interaction.</em> Deborah is pointing to a section of the timeline whilst also verbally instructing Dean to move the mouse pointer and adjust the relevant sound section.</td>
</tr>
<tr>
<td>Dean</td>
<td>What should we do something like a little bit happy</td>
<td><em>Negotiation,</em> Dean asks the question of the group as to what theme is appropriate prior to choosing the sound.</td>
</tr>
<tr>
<td>Ben</td>
<td>Yeah, now go to bass</td>
<td>Ben verbally instructs Dean to select the bass sound in the loop browser whilst pointing at the screen.</td>
</tr>
<tr>
<td>Ben</td>
<td>Go rock</td>
<td><em>Negotiation and interaction,</em> as Ben instructs Dean to select rock, which is a category of bass within the loop browser, whilst pointing at the screen.</td>
</tr>
</tbody>
</table>
Table 2: Participants their comments and the resulting actions

<table>
<thead>
<tr>
<th>Participants</th>
<th>Comments</th>
<th>Resulting Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dean</td>
<td>Rock Blues</td>
<td><em>Negotiation and Interaction</em>, Dean corrects Bens description of the category name, rock to rock blues and selects it with the mouse/pointer, rock blues bass appears on the timeline.</td>
</tr>
<tr>
<td>Deborah and Zandra</td>
<td>No (not rock blues)</td>
<td><em>Negotiation</em>, the girls both disagree with the choice of rock blues</td>
</tr>
<tr>
<td>Zandra</td>
<td>maybe when they do the music</td>
<td><em>Negotiation</em>, Zandra makes a suggestion for another placement of the rock blues bass sound loop in the thematic context of the narrative.</td>
</tr>
</tbody>
</table>

The examples above illustrate how the cycles of interaction and negotiation occurred in the creative phase. This was the work of selecting and placing sounds in all its frenetic and immediate vigour. This account is given to unpack and describe the intertwined nature of action and conversation in all of its complexity.

The narrative was a guiding conceptual framework upon which the children negotiated the choice of sounds from the sound loop editor within the Garageband GUI. These comments were all directed at the timeline within the Garageband GUI, it gave constant graphical feedback on the state of the soundtrack as a built collection of sounds. The coloured bars within the timeline were an effective way of representing the sounds as comparative chunks of time and also gave information on how many layers of sound were being played at any one time. In playback mode a virtual slider moved over these static coloured bars to indicate the progress of the soundtrack as a visual set of relationships to support the sounds as they played.

4.3.4 *The advantages GUIs for soundtrack making*

The use of digital sound loops in Activity one was an organized and convenient means of selecting and placing sounds that was heavily mediated by
the Garageband GUI. The perceived affordances (Norman 1999, p.39), in this case the sound loop editor and timeline, were spatially laid out and graphically composed inviting manipulation with the mouse pointer and keystrokes. They were not hidden away in abstract menu structures or icons, rather they were graphically visible in the GUI. The adding of sounds in chunks of time is analogous to building a structure. This structure represents the sounds you hear. As a conceptual model it was easy to interpret, resulting in a productive interface.

4.3.5 What was learnt from Activity one with Garageband

The computer and Garageband offers a convenient and visually organised way to mediate the exploration of a thematic sound arrangement activity. The children were able to negotiate and interact with one another and the visual representations of the sounds afforded by the Garageband GUI.

In the context of tangible user interaction I need some insight into the ways that children interact and negotiate with the same narrative, but this time with hand held instruments using greater physical and gestural action.

4.4 Activity two - playing the instruments

In this activity the children were to create sounds in a similar way to Activity one with hand held percussive instruments such as maracas and cymbals. The intention was for the children to play the themes of the narrative rather than select them from a digital library of sounds to give some insight into the motor sensory activity and determine if this should be considered in the design of the TUI. The group was similar in membership to Activity one with the exception of Ben, who was replaced with Arnold. Arnold was considered by the teachers to be
a valuable contributor to this type of social learning activity. Apart from this change Dean, Zandra and Deborah all continued their involvement.

The sequence and setup of the activity was planned in two stages. The children would re-read Cloudland to reacquaint themselves with the themes of the narrative. This was to encourage one or more of the children to take ownership of the text in a similar way as it occurred in Activity one. After reading Cloudland they would gather around the instruments that were arranged on the floor nearby and perform to the narrative.

![Figure 17: Image showing the children and their percussive instruments](image)

### 4.4.1 Broad overview of explorative sound making

What was found was that the children became consumed with playing the instruments in what I describe as exploration. Zandra initially took control of the narrative by holding the book and reading the key themes or events out to the other three children and they would respond with sounds from the instruments they held. There was approximately 8 minutes and 40 seconds of this activity. In the initial stages the children would comment after the sounds were played in
terms of relevance to the narrative in a similar way to the negotiation operative stage within Activity one, however this dialogue was short lived. The children, particularly Zandra, increasingly deferred to my feedback and the activity structure broke down with Dean, Albert and Deborah just playing with the instruments without any dialogue with Zandra. This experimental activity served ultimately to familiarize the children with the instruments and how they might approach playing the narrative, but it was clear it would not continue.

To give structure and encouragement to the children playing sounds we introduced a teacher, Louise, to tell the story and emphasise key themes and events. With Louise narrating there was 9 minutes and 22 seconds of explorative and expressive activity. The explorative activity was mediated by the percussive instruments at hand and there was a clear attempt to interpret and articulate the themes as told by the teacher with the playing of the instruments.

4.4.2 Description of the exploration with the instruments

As a collaborative activity there was little evidence of the interplay that one might expect when a common theme is being explored. The children generally did not combine their efforts or gesture to each other to any real extent, but rather largely focused their attention on the teacher narrating and responded to this. The children could clearly hear the sounds others were making, but apart from increasing the intensity and volume of each of their efforts, there was not any evidence of shifting dynamics to accommodate each other sonically.

Whilst the collaborative nature of the activity was quite low there was evidence of some interesting individual efforts in terms of expression and exploration. Both Zandra and Dean moved freely about the instruments. Zandra was often dancing as well as playing a cymbal that she had for half the duration of the activity. At approximately halfway through the activity she knelt down on
the floor and in response to a strong wind from the narrator proceeded to try the brushing of a cymbal, twirling of a shaker and not being satisfied picked up a large tin can and blew into it with a swishing sound. At this moment Albert proceeded to lightly tap a cymbal. This was the only moment of interplay within the entire activity and was an interesting exchange.

Deborah was the most prolific in terms of instruments used, she stayed seated throughout, but managed to nestle maracas between her knees, have a cymbal in her left hand, a pan flute looped around her right hand with a strap, and a circular plastic tube filled with beads gathered under her foot. She would alternate quite skillfully amongst these instruments to get the desired sound or texture she wanted and was the most committed of the children in the performance of the sounds.

Albert on a number of occasions both prior and during Louise’s narration was experimenting with the dynamic of the sounds he played on cymbals and drum skins. He also made a contribution conceptually to the types of sounds that could be created beyond with verbal suggestions, for example for splashing he suggested a large tank of water that you could slap with the whole of your forearm because the hit of your hand won’t work you need more help for your hand. Albert was demonstrating just how he would slap his forearm onto the water surface to achieve this sound. Ultimately the children demonstrated a willingness to create sounds. Whilst there were momentary lapses in discipline they sought to physically explore the themes of the narrative through the playing of the percussive instruments.

4.4.3 Physically exploring and expressing

The aim in part of these observations was to see if I could come to any conclusions about the nature of the engagement and if there was any noticeable
difference with the collaborative and expressive aspect of the activity, given that the children had a selection of instruments. Moreover what was the nature of the motor activities the children would demonstrate with the playing of the instruments in an open setup on the floor and not tethered to a chair, desk and computer? Playing the instruments in Activity two has indicated the children’s desire to experiment and explore the themes of the narrative with the creation of their own sounds.

The children did this by exploring the sounds through extensive modulation of the volume and intensity, generally through softening the attack with wrist and finger movements. There were also some examples of interesting rhythmic patterns as responses to events such as falling or dancing. This exploration was a positive observation in the context of this inquiry as it suggested the desire to manipulate the volume and texture of a sound. This is a consideration for the design of a tangible user interface.

On a number of occasions the children had some interesting ideas conceptually for sounds. Falling from great heights quickly translated to the notion of air pressure and its physical effect on the body that *made your body go up* with the wind making swishing sounds around you. This dialogue translated into action with the children making swishing sounds by blowing into their hands, which influenced the choice of a pan flute played rapidly to and fro across the mouth. So imagination, exploration, experimentation and expression were all evident in Activity two.

### 4.5 The contrast of the activities.

To provide a contrast Activity two was one of exploring the narrative through the making and expressing of sounds whereas Activity one was one of selecting and placing already recorded sound loops. Given the sounds were
already made, the exercise was one of producing and arranging, which encouraged negotiation and discussion.

As collaborative exercises, Activity one offered greater opportunities for discussion due to the easily interpreted timeline and graphical indicators of sounds within it. Also there was the considerable technological advantage of being able to play back these sounds and watch them unfold on the GUI. However the open nature of Activity two with its basket of instruments for play and exploration indicated that children will use their bodies to express a sound and attempt to make the connection sonically to an abstract narrative with these actions, from gross motor such as dancing and moving to fine motor such as delicately tapping a cymbal with a drumstick. The challenge was greater with Activity two in that the sounds had to be made, the translation from conceptual idea to sound execution had to occur. Could some of these motor actions be afforded and encouraged in a digital system of convenience and logic?

The considerable advantage of making a soundtrack digitally compared to analogue means is in the ability to reflect on the activity and edit the sounds as you please. With software such as Garageband you have the sound loops at your fingertips that can be modified after they have been added. There is something compelling in the act of placing digital sound files that I conclude has to do with its immediacy and efficiency. By this I mean that a good quality sound loop can be played and arranged with a point and click.

The sound is already made in Garageband whereas using instruments to make sounds becomes part of the activity, one of making that precedes the higher level activity of its arrangement as an expression of the total narrative. What was also compelling with Garageband was the control and access to so many sound loop options. This was clearly desirable as the children sampled and or placed numerous sound files in the 10 minutes that were transcribed. Similarly
the ability to rapidly play this back and track it on the GUI with the time slider was clearly advantageous as evidenced in the findings.

4.5.1 Lack of affordances, but!!

The advantages of the access and control of the digital sound files were quite clear in Activity one. However the physical actions were limited to the affordances offered by the personal computer, the desk it was perched on and the room in which it resided. The children were sitting at a table in chairs, crowding around the computer screen and listening to the sound choices through two desktop computer speakers placed on the table. There were particular physical limitations to this way of operating. But within these limits there were some interesting motor activities of the children. These activities were all mediated by the computer screen and its GUI. In the period transcribed from the video tape, the screen was touched by the children 72 times, with the placed sounds the objects of discussion. The computer monitor surface and the GUI was an excellent central resource in terms of the graphic representation of the time allocation and names of the sounds to choose or edit. It was akin to a digital notebook that could be referred to quite accurately by pointing and gesturing to assist the conversation about sound choices. The building metaphor of the timeline helped with the concept of time for the children.

The children could really understand what sound was where temporally and spatially as a representation of the narrative, and these sounds could be edited and rearranged with relative ease and as many times as desired. Whilst the sounds were able to be placed effectively, they were not manipulated tonally in any considerable way. Garageband has the facility to adjust such parameters as pitch and sustain but there was no adjustment done of these individual files by the children throughout Activity one. The reason I believe is because any parameters need to be accessed by opening them in the GUI, by pressing a
virtual button, they appear as a secondary window underneath the timescale once opened. Their hidden nature contributed to the lack of use. Not being immediately visible and due to their virtual, non physical, nature they did not encourage play and exploration.

4.5.2 Gross motor expression in the soundtrack making

Another type of interaction took place which used far greater bodily facility and was largely situated in the reflective phase in Activity one. These were the gestures to express the sounds as they were playing. Examples of this were the two boys mimicking the playing of violins as their sound played or dancing in their chairs to eastern sounding rhythms. I interpreted these actions as an affirmation of the sound as an appropriate selection for the soundtrack. Similarly there was evidence of these dancing or bodily gestures influencing the sound choice. For example there were occasions where Zandra and Ben acted out sounds for Dean to find.

This was similar to the pre sound making exercises in Activity two as it was a means to express conceptually the keyword or theme of the narrative. A brainstorming through movement helped the children understand the nature of the theme or event within the narrative, for example what does falling sound like. The children would act out falling which helped to unpack further ideas for how it should sound.

4.5.3 A lack of equitable access

There were issues with the control over the selection of sounds that lay with the keyboard and mouse operator. Collaboration occurred through discussion amongst group members but decisions could be influenced by the operator due to
their ability to select and persuade. The Garageband model gives greater control to the mouse and keyboard operator. A potential solution would be each group member having equal access to the controls or physically being able to reach the controls equally. In other words, the discussions about the sounds would generate appropriate conflict over their relevance to the storyline, but the act of selecting could be overtly influenced by the operator of the mouse and keyboard. It is clear from the findings that the physical arrangement of the Macintosh computer on the table with four children huddled around it could be improved upon dramatically. This problem was particular to the nature of the keyboard, screen and mouse. Given that this is an important act in the context of collaborative activity, equity of access is important to enrich the diversity of musical or sonic arguments in the timeline.

4.6 Conclusions for design

What can be taken from the data to inform the design of a tangible user interface?

The evidence suggests that the digitally mediated activity with Garageband was indeed compelling and this was due to its immediacy, efficiency and the productive layout of the GUI. These observations raise the possibility, through the TUI design, for expression physically both at gross motor and fine motor level to potentially express the narrative. The conceptual model of placing or constructing sounds on a timeline is strong metaphor that I will seek to incorporate into the TUI design. So the question leads to extending and fostering the positive virtues of this conceptual model as a physically embodied suite of actions.

Activity two has shown that there is value in encouraging motor expressiveness and exploration of thematic ideas through handheld instruments.
There is potential in the TUI for not only sound placement and arrangement, but sound manipulation and expression as actions to be afforded by the TUI objects. In the next chapter I take these findings and combine them with the three research concepts to develop the design aims for the Sonic Blocks.
5 Design and development

5.1 Introduction – towards design.

The ultimate goal of the design phase of this inquiry is to create a working and testable tangible user interface that would extend the soundtrack making activity seen with Garageband into the physical domain. To be testable this prototype needs to be robust physically, mechanically, electronically and digitally. It needs to hold together in use, make good electronic contact all of the time and have programming that can read the analogue data and successfully translate this data into the activation of digital sound files.

As an afforded activity the TUI needs to be thought of as a series of events that would encourage exploration amongst the four school children, with consideration given to the temporal flow of such an activity. This chapter gives an account chronologically of the creation of the Sonic Blocks, from setting aims to prototype fabrication. It also offers a discussion of the important design decisions to meet the aims and motivations.

5.2 Aims for design

At the conclusion of chapter 2, I arrived at three research concepts to define TUIs and describe the exploratory and playful ways of engaging with them. In combining these concepts with the findings of the first observations, I have developed design aims to frame the design stage of this inquiry.
These aims take up the theoretical position of the concepts and are extended to consider ways of enabling and exploratory sound creation activity with the four children of the first observations. They provide a cohesive set of considerations upon which to frame the design of a TUI, the Sonic Blocks. With the aims established, this chapter then gives a reflective and chronological account of the design steps taken to create and evaluate the Sonic Blocks. This account is based on journal sketches and notes and the minutes I had taken from discussions and meetings.

5.2.1 Action and control

In Ullmer and Ishii’s definition, physical representations embody mechanisms for interactive control (Ullmer and Ishii 2000). In the context of this inquiry, action is a perceptual as well as technological concern. The action one has with a tangible artefact or object has meaning both for the system and the user, action is part of the thinking in this context. Action calls on our perceptual motor and sensory abilities and takes an active role in the temporal nature of interaction with digital technologies. There are many opportunities for action in the activities observed in the first observations. The Garageband GUI offers a digital way of organising sound as graphical chunks of time and this offers a model to consider in the design of a tangible user interface.

To conclude the design aim is:

To consciously consider the physical form of the device, its constraints and couplings as a means of inviting action and control as meaningful to the thematic sound creation and arrangement activity.
5.2.2 Representation and meaning

Considering the theoretical model of Tangible User Interfaces (Ullmer and Ishii 2000, Ullmer and Ishii 2001) something and somewhere to place the sounds that bears some relevance to a timeline is desirable - a model of sound that is embodied in the physicality of the object that invites action through its affordances. As observed, the timeline is the central point of gathering, representing and discussing the progress and nature of the efforts. It needs to become tangible by being physically represented and controlled. How the sounds and their associated timeline are represented will be a considerable challenge within this theme. Issues such as the visual language of the objects need to be explored, as they are to be representations of sound or time. The sounds in Garageband were defined via an arbitrary system of names, such as 80s dance bass synth 07, that means little to child who was born in 1997. Any objects designed will need to also make reference to the other elements in the system. This coupling is a semantic concern as well as a technological one. Finally, the overarching conceptual model will need to make strong analogical references to relationships we know in the world if they are to be are a meaningful means of identifying, selecting and placing the sounds for each of the four children.

To conclude the design aim is:

To consciously design, give meaning to, the digital data through the formal and visual semantics of the TUI. This includes consideration of the material properties and the aesthetic values that contribute to the encompassing conceptual model of the TUI, and the ways in which the conceptual model unfolds as a temporal set of physical actions to support the sound sequencing activity.
5.2.3 Exploration and expression

Whilst the first two questions are concerned with control and representation and look to the effectiveness of suitably afforded and coupled physical artefacts, the last design aim is interested in encouraging a certain way of acting and behaving. The first observations taught me that a well conceived GUI will afford engagement due to its on screen icons being directly manipulated with the mouse and keyboard. However the activity with the Garageband GUI was limited to placing and sequencing of the sounds. I argue this was a low level exploratory and expressive activity as the sound parameters were not manipulated to affect their tonal quality.

In Activity two, there was evidence of exploration and expression with the percussive instruments. The tone and rate of the beat were explored through the children playing, which raises the question - how might this be enabled in a digital sense?

In activity one, the sound parameters weren’t modified. I argue this was due to the interface having too many functions obscured by menus which results in the access to these modifiers needing to be uncovered, creating a cognitive overload and hampering exploratory activity. A tangible prototype will need to afford adjustments to these sound files with engaging physical actions that are highly visible to encourage exploration.

As physical exploration, the actions in activity two demonstrated both the gross and fine motor crafting of sounds, or playing, with the percussive instruments. Activity one also uncovered the gross motor mimicking of sounds as an affirmation of their fit to the narrative within Garageband. Therefore coupling these gestures and actions in some way to the manipulation of the digital sound could offer some interesting opportunities for exploration, expression and
collaboration. This could be addressed a system that enables both a selection and manipulation of the sounds with some sort of tangible gesture or movement.

To conclude the design aim is:

To consciously consider the features and combinatory nature of the system as a way to encourage the manipulation, exploration and expression of the sounds and their sequences in the soundtrack creation activity.

5.3 The design project

5.3.1 Early form and system investigations

The metaphor I arrived at for the physical form and arrangement of the Sonic Blocks was building time, manipulable chunks of time in a physically compelling form. I did not want to attempt to represent sound as physical icons, with symbolic reference to the type of sound they contained. This would be difficult to synthesise physically into a collection of shapes that would or could be interpreted as characteristics for the sounds they embodied. How do you represent the genre of a sound as physical form without it being an unnecessary abstraction?

Therefore it was not desirable to reduce the sounds into a language of three dimensional icons that made reference to the sound type through form. Sounds are interpreted as a series of vibrations noticeable to the human ear in all of their complexity and beauty and whilst the sonic rendering and accuracy is important, for example through the quality of the amplification and speaker equipment, this is an issue that can be resolved technically. The form needs to maintain an appropriate abstract relationship with the sound it initiates.
The sounds as they appear on the Garageband interface are bands of colour with relatively arbitrary textual descriptions such as, 80s synth bass 07. Arbitrary language aside, these bands of colour are a successful way of representing and organizing the selected sounds for discussion and debate in relationship to each other. They represent the building blocks of the soundtrack and can be referred to physically by pointing at them. The Garageband GUI has strong spatial and organisational qualities that I chose to use in considering the arrangement and relationships within the Sonic Blocks.

Figure 18: Sketch showing early explorations into physical time-scales. This figure shows a rectangular timescale shape.

Figure 19: Sketch showing circular clock-face approach to a physical time-scale
The logic of board games was a subconscious direction, not really something at the forefront of my thinking but nevertheless present. Early attempts at a rectangular concept (shown at Figure 18 above) and a circular concept (shown at Figure 19) explore the timescale as a physical device with the sounds controlled and activated by the presence of the inserted blocks.

Figure 20: Controllers and GUI combinations. In this approach the controllers are coupled to a circular GUI. Each participant may have a controller that manipulates their respective sound.

These images above show early explorations in the representation and manipulation of the sounds. In the context of a digital system and tangible user
interaction, this playing would be tapping or manipulating an object that would in turn have a modulating effect on the resultant digital sound file. So technically a sound exists as a digital file and the physical actions on the device change a characteristic of the sound that is recognisable to the child using it.

**Figure 21:** Explorations of both percussive controllers, indicated here as concept 1 and physical timescales, concept 2

**Figure 22:** Explorations into the form of handheld percussive controllers

Figure 21 (above) outlines two broad conceptual directions, that frame all of the designing forthwith. They are concept 1, which features percussive controllers that respond to the activity observed with the handheld instruments in
the first observations, and concept 2, which responds to the placement and arranging of sounds as observed in the activity using Garageband. Figure 22 (above) explores the form and manipulation potential of an electronic drumskin type of controller.

![Figure 23: Further explorations into the percussive controllers mentioned at figure 21. The controllers are coupled to a tabletop GUI and a pegboard style physical user interface](image)

Figure 24 (below) arranges sounds as a constructed wall. One of the advantages conceptually with this approach is the division of time into two physical modules, a brick and a half brick. The smaller brick would be half the duration of the larger, which could encourage experimentation with time intervals within the soundtrack.
Figure 24: Explorations into stackable bricks as a means to represent sound files as two different units of time.

The theme of manipulable time is explored in Figure 25 (below). I wanted to explore softer geometries such as circles and swept surfaces that would afford holding and encourage touching, apart from providing a more dynamic aesthetic. The sketch shows a cotton spool type form that references the stackable plastic stools I spent my childhood playing with. These forms owe their modular logic to the work of Joe Colombo from the 1960s Italian design (Favata 1988). This concept was exploring a stackable metaphor that would encourage a vertical layering of sound whilst also allowing and a horizontal temporal sequencing.
Figure 25: Explorations into spool shaped controllers that afford stacking as a metaphor for layering sound files.

Figure 26: Explorations into modular controllers combined to represent an overall timescale.
The modular approach to physically organising sounds was my thinking as it developed in Figure 26 (above). Rows of these layers could be assembled to offer as many layers of sound as desired.

Figure 27: Early sketches of the Sonic Blocks as units of manipulable sound in time

Figure 27 (above) shows the refinement of the individual element of the modular approach and consequently presents the first representation of what was to become the final physical design for the project, the Sonic Block. This sketch shows the block as a base unit with a pluggable circular element that would have a unique sound file attached to it by electronic means. The aim of this pluggable element was for interchangeable sounds that could be attached and their volume increased via turning.
To appreciate the concept physically and spatially I made some quick mock-ups using pressed cardboard food serving trays, (Figure 28 above). I experimented with cutting circular openings into the top of these containers and inserting a modified polystyrene cup in this case to resemble a rotary switch that would serve to modulate the sound in some way, for example volume or pitch shift. These quick mockups enabled me to assemble a representation of the time block concept and were used to demonstrate my conceptual thinking to my supervisor and critical colleagues. Having a collection of electronic blocks was a tangible shift from the bands of colour that the Garageband GUI offered and afforded. They are a physically visible representation of the sound as a unit of time, and after a number of discussions it was considered a concept worthy of further design exploration.

5.3.2  The blocks of sound and time

Many ideas for the manipulation of the blocks emerged. They could be sequentially arranged in two axes, x and y as illustrated in Figure 29 (below) allowing a soundtrack to be built both as a single layer of temporal events, in
direction x, or a multiple layer of events or sounds, in direction y. Apart from the sequential arrangement of sound their manipulation was also considered. This image also shows three types of modules, indicated in this instance by colour. The red block controller has a raised soft button that can be tapped in a percussive way, the yellow block controller has a rotary volume switch and the silver grey controller is a repeat controller.

Figure 29: Computer model of early block configuration with different controller types indicated by colour.

The development of this system of controllers was to provide a physically explorative set of digital objects that afforded stacking in a logical order for sequential arrangement, for example the blocks could only be effectively placed on one side. It was physically obvious what was the base, and they nested neatly against one another. The other aspect this system offered was the availability of manipulable parameters such as volume and percussive modulations to specific block controllers. Manipulation and exploration is a desirable and stated design objective. Similarly, placement of each unit of time sequentially offers some equity amongst the group participating.

As a family of afforded manipulable objects the example at Figure 29 was a progression in the thinking. Consideration had not been given to the physical
semantics in this stage of the design. The block was a physical way of marking time. This raised the question, what were these blocks to be made of and how is each different controller represented as a meaningful statement of use?

5.3.3 Sonic Blocks - the beginnings

The earlier question on the finer points of representation and materiality needed resolution. On discussion with colleagues it was decided the control features for an effective activity, for example one that does not confuse the user, should not number more than three. The concept to date had a percussive controller, spatial sound controller, sound selector/volume controller and a repeat controller that cannot be manipulated. There were too many variables in the control of the sound as a successful mediator of a soundtrack making activity. A decision on the three key actions or manipulations needed further consideration. Reflecting on the first observations with Garageband, central to the activity was the ability to select sounds; this is what the Garageband GUI affords at its basic level. Therefore selection and activation was the first control attribute. The need to represent and control spatial sound feedback, given the open approaches offered by TUIs, was the next choice.

Finally it was decided to modulate the sound file in some way. Volume adjustment was chosen for its potential to create a dynamic in the narrative similar to the variation in a film score. The challenge then moved to how these controls were to be represented and what actions would they afford. The move away from the percussive controllers was a conscious one. The percussive controller was considered an instrument rather than sound selector which would introduce a complexity that could interrupt the soundtrack creation activity.
Making the decision on these three control features focused the design from both and interaction and technical design aspect. Being able to select, activate, spatially direct and adjust the volume of the sound files gave direction the physical design and affordances to consider. With this control framework in place, I was not convinced of the overall aesthetic of the blocks shown in Figure 29 and started again to consider the shape and semantics of the blocks. Figure 30 (above) shows an exploration of simpler forms. I had thoughts of Japanese architectural ornamentation that has an aesthetic discipline which ultimately leads to profound visual statements. A decision was made to use a hardwood for its grain and texture and decidedly un-technological materiality. This decision was partly influenced by the Montessori notion of working with natural materials and artefacts with children as a way of developing physical and spatial understandings (Montessori 1964). Timber has the compelling material affordance that encourages one to touch and grasp it, particularly when it presents itself as a block of the dimensions that fits comfortably within the human hand.

With the visual semantics resolved, the connection of the blocks to enable sound activation was the next challenge. Any electronic connection would
need to be robust considering the context of use. Attempts were made to try a mortice and tenon style positive connection so that in use it was obvious how the blocks connected, and as a mechanical support for any electronic connections needed.

The result of these aesthetic and interaction investigations was the sketch at Figure 31, in which the block was placed over a cylindrical spigot and tablet in a similar way that a ring is thrown in the game deck quoits, in which rings of rope are thrown over a short timber pin or pole (The Oxford English Dictionary, 1989).

![Figure 31: Explorations into a block over spigot type approach with tags representing different sound files](image)

This idea of block over pin developed by combining the two geometric elements into a cohesive whole. The pin became a rotary knob for the control of volume. The concept of block over pin was to suggest that layers of blocks, each with a sound, could be stacked on this pin making strong usage of the board game metaphor with which to build the layers of sound. However this was considered too much of an electronic challenge even considering the interesting interaction model it posed. It was decided to simplify this idea into two tags,
finger shaped in Figure 31 that then developed into triangular shapes in Figure 32 and

Figure 33 below. Sound files are embedded in these tags using Radio Frequency Identification (RFID) and are be magnetically placed on the top surface of the block. In this way there is an option of sounds and sound layers dependant where each tag is placed.

Figure 32: Computer visual of Sonic Blocks in timber with triangular tag recesses

Figure 33: Computer visual showing the triangular tag
Finally the blocks are coupled to a tablet that provides constraint for orientation and sequence in the constructed sound narrative. Five blocks were decided on each, with a 15 second sound file allowing for 75 seconds for the total soundtrack. The tablet controls the spatial direction of the sound and sequential order of the narrative; the sounds play starting with the left block through to the rightmost block. The electronic connections between the blocks and the tablets were not resolved at this stage.
5.3.4 Storyboarding and interaction sequences

Whilst developing the formal and physical characteristics of the Sonic Blocks, simple storyboards and interaction sequences were developed to test the potential use of the Sonic Blocks in an activity scenario. The two meta activities observed in the preliminary observations, creation and reflection, were used as frameworks upon which to direct the activities. Similarly the knowledge gained from the operative stages of negotiation and creation informed the realism of such a scenario. To give an overview of the social activity and the physical interaction that would occur, a chart was created (see Scenario Diagrams in the attached appendix). Reading this chart from left to right it starts with a description of the children’s activity that then describes the technological interaction with the blocks, with the last column describing the electronics connections and programming events. This chart enabled a clearer understanding of the concept in potential use. It was also valuable to help initial discussions about the electronics and programming that would take place in the development of the prototype. The Storyboard revealed the possible children’s activity and the interaction with the Blocks as a set of discrete events.

Similar techniques were used in another project in which I took part that involved a small multi-disciplinary group designing and developing tangible interaction devices for asynchronous playful communication amongst grandchildren and grandparents (Feltham, Vetere and Wensveen 2007). Experience from this project revealed that describing the interactions with a potential design concept in a temporal sequence allowed a focused discussion on the affordances, couplings and constraints inherent in the concept. It also informed discussions on the mappings between object and data and whether the
conceptual models, metaphors and design semantics would in fact be interpreted in the way the designer intended.

5.3.5 Interim evaluation of the Sonic Blocks

The Sonic Blocks were presented as a conceptual idea to the Graduate Research Conference (GRC)\textsuperscript{25} at RMIT University School of Architecture and Design in October 2006. The panel were satisfied with the concept and indicated the prototype should be developed to enable observation and evaluation to complete the research program. A presentation of the Sonic Blocks was conducted with the two teachers in charge of the Reggio Emilia program in which the research was directed. The teachers’ feedback indicated:

- that the Sonic Blocks are an interesting and engaging tool due to their physical novelty
- one of the teachers’ questioned the ongoing interest and how this might be sustained
- both teachers’ liked the fact that the feedback would be sound only as they felt that the children had too much of a visual focus on the screen with personal computers, whereas this would be an interesting alternative sensory feedback mode.

The teachers’ comments were generally favourable. The ongoing usage concern raised was not really a focus of this inquiry, as I was interested in the initial physical and exploratory nature of the Sonic Blocks.

\textsuperscript{25} The Graduate Research Conference is a twice yearly presentation of the graduate design projects within the School of Architecture and Design at RMIT. It is both a review of progress and dissemination of research projects within the school. Each presentation is open to the public.
Around this time in the development I became aware of the project Blockjam designed and developed by the Sony Computer Science labs (Newton Dunne et al. 2002).26

![Image of the Blockjam tangible interface with graphical symbols requiring interpretation. Image courtesy of (Newton Dunne et al. 2002).](image)

**Figure 36:** Image of the Blockjam tangible interface with graphical symbols requiring interpretation. Image courtesy of (Newton Dunne et al. 2002).

Becoming aware of Blockjam challenged me to think at a deeper level about the representational nature of the Sonic Blocks and my intentions for their interpretation, exploration and use. Blockjam functionally does what I was intending to do with the Sonic Blocks, except in a non linear fashion and over a network. It has a simplicity and intelligence as a system to create a physically enabled collaborative jam. My design development to this point was to offer a

26 Blockjam offered an interesting system of musical block controllers that magnetically attached to one another to created an assemblage of sound loops. These sound loops were multidirectional or non linear, that is they allowed sounds to be generated by the placing of the blocks in a number of directions. There are two types of blocks - the path block, shown with the + sign in figure 36 above, and the play blocks, shown with the directional indicators at the ends of the block sequences. Lastly there are three sound groups that are coded by colour that are selected and stored at the discretion of the user. These sound groups are dialed up by using a circular movement on the block surface. Blockjam is coupled to a visual GUI to allow remote collaboration over a network with another user with a similar system.
family of blocks that encouraged exploration and collaboration without the support of an accompanying visual GUI. As I was not intending any online or networked collaborations, a GUI was not really needed to support any feedback required with this type of collaboration. With careful reflection on the design direction, I uncovered my some of my earlier influences and these lay with the motor-sensory approach to affordance and action rather than the graphical and interpretive approaches developed with the screen based icons and metaphors.

In chapter two I discussed the position on direct and semantic ways of interacting from Djajadiningrat Wensveen et al (2004). These authors talk of the physical affordances designed products can have. They articulate two approaches to the meaning making of digital products. The first is what they term the semantic approach which is characterized by

using the knowledge and experience of the user, the product can communicate information using symbols and signs. (p.295)

The second is called the direct approach and it takes behaviour and action as its starting point.

Here, the basic idea is that meaning is created in the interaction. In this approach, respect for perceptual and bodily skills is highly important. What appeals to us in the direct approach is the sensory richness and action-potential of physical objects as carriers of meaning in interaction. (p. 295)

A way to define the approach of the Sonic Blocks, in comparison to Blockjam, is as a direct tangible from the above definition. Whereas Blockjam is a semantic tangible in that it relies on the meaning carried by the iconography of the LED display on its top face. This gives visual feedback on the state of the block functionally and what this function does in relation to the soundtrack or jam underway.
The Sonic Blocks have a different approach to representation. Each block has physical affordances that need to be explored to alter the sound characteristic. There is no graphical information on the type of sound being played, rather it forces the user to listen to the sound and make his/her own judgement on what it is or how it is to be categorised. The Sonic Blocks encourage certain actions with the forms that protrude beyond their top surfaces. These actions have resultant effects on the sounds that are played. The sound will be mediated by a spatial arrangement of speakers around the participants in the activity group. I argue therefore that the Sonic Blocks use a direct approach to interaction, as the physical actions help make the meaning in the engagement with the blocks and the soundtrack making activity.

5.4 Prototype and technological development

To start technologically it was decided to firstly design and develop the most effective means of connecting the tags to the blocks and blocks to the tablet to initiate the sound. This involved looking at the connection of one block to the tablet and exhausting the electronic possibilities for an effective and robust connection. I had a very broad conceptual understanding of how this might happen but not a sound electronic knowledge to realize this technical challenge. I consulted Professor Andrew Jennings from the Department of Electrical and Computer Engineering at RMIT University with the challenge of the electronics circuit for the Sonic Blocks concept.

5.4.1 The matrix of connections

After discussion with Andrew on creating a wireless means of activating the sounds, including Radio Frequency switching which creates a discrete signal frequency, I decided that analogue contacts would be the most reliable given the
many connections required. Wireless connection in the form of radio frequency is proven to create interference, therefore physical connection and voltage transfer was deemed the most effective and robust way of sending a signal. To describe the electronic features, each block has four functions. Three for sound control and one for visual feedback.

*Sound file types*

These are physically represented by the triangular tags that are placed at each of the triangular rebated corners of the timber block (figures 16 and 17). The proposition is to have these switchable via reed switches or similar means. When the tag is in place its magnet opens the electrical signal via the reed switch. The combinations for each block will be:

- Sound 1 = tag 1
- Sound 2 = tag 2
- Sound 1 and 2 = tag 1 and 2
- No sound = no tags on block.

*Sound direction*

The sound direction is indicated with the high pointed corner of the timber block. It makes a connection on the underside of the block in one of four quadrants.

*Volume control*

Each block is fitted with a potentiometer that enables real-time volume control. The connection for the volume control is on the underside of the block.

*Light feedback*

Each block will have an LED fitted inside that glows as the block is active or playing. This connection is made on the underside of the block.
The system works by the connection of tags to blocks and blocks to the tablet. No sound is played if either of these connections are unsuccessful. The blocks and tablet play from left to right and the sounds are initiated after a short delay, after block placement. Actually mapping out the number of contacts needed to be made at any one point in time for all of these functions resulted in the development of a matrix of connection points on both of the underside of the block and the top of the connection tablet.

![Underside of Block](image1) ![Topside of block](image2)

**Figure 37:** Connection points on the Sonic Blocks timber housing shown as small bullet shapes.

Figure 37 (above) shows 16 connection points on the underside of the Sonic Block and four on the topside. This matrix was based on using reed switches, which rely on a magnetic field to connect two fine copper reeds or wires to enable a connection. This voltage would be fed into an analogue to digital converter that would supply digital code to the digital music program Max MSP.\(^{27}\) Five per block are the optimum connections needed at any one time to control all of the variables for the Sonic Blocks.

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\(^{27}\) Max MSP is a digital sound synthesis programming software. © 1990 – 2005 Cycling ’74 / IRCAM all rights reserved.
Figure 38: A circuit diagram of the Sonic Blocks system designed and developed by Morgan McWaters.

5.4.2  The electronic circuit

The electronic circuit (figure above) housed in both the Sonic Blocks and their respective tablet was designed and developed by Morgan McWaters.28 Morgan took the connection matrix developed by Andrew Jennings and rationalised it to fit within the envelope of the Sonic Blocks to control the type, volume, direction and lighting variables I required. The circuit above is a simple

28 Morgan McWaters is an electronic musician and technologist who works within the School of Architecture and Design at RMIT as a research assistant and technical consultant.
voltage divider that uses a combination of resistors and potentiometers to vary the five volt input that provides specific data to identify and manipulate the sound files within Max MSP.

Figure 39: The electronic mockup to test the circuit design

To test this circuit design and a means of connecting the blocks to their tablet we created a quick mock-up. To describe the mock-up, denoted as surface A and B in the figure above, two surfaces were constructed rapidly in MDF timber with channels routed for the magnets and brass contacts. The magnets were obtained from a local electronics store and the brass contacts were fashioned out of a length of flat brass accessed at a modelling supplies store. The electronic componentry consisted of the MAKE\textsuperscript{29} analogue to digital converter, a rotary potentiometer and a trim potentiometer. This mock-up enabled us to determine

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\textsuperscript{29}The MAKE controller, © 2008 MakingThings LLC, is an analogue to digital converter accessed from www.teleo.com
the success of the circuit for generating a voltage which in turn was converted to
digital data to be read by Max MSP. It did this successfully enough. However
physically the magnets, battery probes and contact surfaces needed more
accuracy. Surface A needed to be held down on to surface B to make connection.
I was satisfied that in principle improvements could be made with more accurate
fabrication and assembly techniques.

Whilst the connections underneath the block could be refined there was
an issue with the selection of sounds within each block via the triangular tags.
The mock-up uncovered that the amount of voltage data being sent to the MAKE
controller was pushing Max MSP to its limit and that the Max patch would need
some refinement to handle this amount of data. The mock-up had only one
dedicated sound and not the switchable tag based system that was proposed with
the conceptual design. We concluded that spatial direction and sound activation
would work and the light feedback could be theoretically managed but needed
testing. However having a choice of sounds for each block would result in too
many packets of data for the MAKE Controller and Max MSP system to work.

5.4.3 Programming in Max MSP

Max MSP is an object oriented programming environment based on C++
and has a broad application base, but it is used extensively in music and video
design. It was chosen as the software to design the Sonic Blocks sound patches
because of its ability to create rapid prototypes with interactive sound that could
be evaluated and incrementally updated in a logical fashion. It also provides a
reliable connection with the MAKE controller hardware that was chosen as being
the best means to transfer the analogue voltage data from the blocks’ circuitry to
Max MSP. The final patch design by Jeffrey Hannam\footnote{Jeffrey Hannam is the production manager at the SIAL Sound Studios at RMIT University. Jeffrey’s research and technical focus is in spatial sound design.} (Figure 40 below), samples
packets of data from the Blocks every 250 milliseconds that in turn activates the sounds at their respective parameters.

Figure 40. Image showing section of Max MSP patch designed and developed by Jeffrey Hannam. The image shows the parameters used to drive three blocks on reception of data from the MAKE controller

5.4.4 Prototype Refinement

With the circuit, connections and programming resolved the next step was to combine the electronic circuitry within the block housing. The overall dimensions of the block as designed were to be adhered to as it was an optimum size for a child’s hand whilst containing a reasonably proportioned rotary volume knob. The refinement was therefore the task of fitting all of the componentry inside the overall block housing.

Apart from testing the basic circuit, the electronic mockup was a chance to experiment with the physical connections of the matrix. Earlier concepts for the matrix layout used magnetic reed switches to create the connection. Practically these were not suitable due to the size envelope that was available for the matrix at the underside of the block. Another complication was that the each reed switch would need a magnet, which would result in no fewer than 17 magnets placed in the connecting tablet. Apart from dimensional problems with this arrangement, for example magnets not being readily available in this size, the sheer number of
magnetic fields was deemed to create interference problems for the circuits housed in the blocks.

The solution was to therefore use small spring loaded connectors called battery probes. Battery probes are commonly used today in cordless phones for connections to the charging stations when the handset is not in use. The battery probes were sourced and used on the electronic mock-up and were successful enough to be considered for use on the final prototype.

![Figure 41: A sketch of the battery probe and its spring loaded contact point](image)

I discovered in constructing the electronic mock-up that as the battery probe had a pointed contact and given five of these points needed to make physical connection for the Block to successfully initiate the sound, the accuracy in positioning the battery probes and their corresponding contact plates was crucial. The mock-up informed me that accuracy was compromised by positioning the battery probes and making the contact plates by hand. I decided therefore to use acrylic for both the base plates of the Sonic Blocks and the tablet surface. These would be cut using Computer Numeric Control (CNC) for high levels of accuracy. Apart from the accuracy, using CNC enabled a mitre fit between the block base and the tablet for greater mechanical connection.
With the mechanical fit between the block base and the tablet resolved, the next challenge was fitting the potentiometer for volume, the trim potentiometer for the assigned block voltage and all of the associated wiring inside the timber block housing.
Figure 44: Sketch showing section through block housing showing critical dimensions for battery probe fitting

Figure 45: Detail sketch of the saddle to hold potentiometer in exact central location
Within the envelope of the block there were two critical dimensions, that of the battery probe and the height required to contain it (Figure 44 above) and the height of the main potentiometer to enable a comfortable distance for the rotary knob above the top surface of the block (Figure 45 above). These were resolved to accommodate all internal componentry whilst maintaining overall block dimensional integrity.

Figure 46: The complete block assembly with all dimensions, tolerances and fit resolved in 3D modeling software.

Figure 47: Exploded view showing the underside of the block and its connecting plate
5.4.5  *Prototype assembly*

With the critical dimensions resolved the components of the Sonic Blocks could be CNC cut and finished. The following sequence of images provide a visual record of the assembly process.

*Figure 48:* Image showing the electronic circuit and block base assembly

*Figure 49:* Image showing the block bases connected to tablet prior to fitting timber housing connection plates
**Figure 50:** Image showing the final matrix of connections as copper contacts housed into the tablet surface.

**Figure 51:** Image showing the wiring to the MAKE controllers. These convert the analogue signal from the circuitry within each block to a digital signal that can be processed by Max MSP.

**Figure 52:** The total electronic system being tested. Visual feedback via the GUI shown on the laptop confirms the connection has been made.
**Figure 53:** The test GUI on the laptop to give a visual indication of the connections. This GUI is for the operator and not the children using the blocks.

**Figure 54:** The main components before assembly.

**Figure 55:** The Sonic blocks and tablet as they were set up for the activity with the children. The tablet, consisting of the MAKE controller and associated wiring is housed in a black timber box.
5.5 Conclusion

The journey from initial idea to working prototype was a challenging one. Due to the technical limits, decisions were made that compromised the conceptual intention of the Sonic Blocks. However this is common in design prototyping. The most notable compromise was having to drop the sound selection tags from the block functionality, which resulted in each block only containing one sound in use. I made the decision to continue with this compromise as I considered the potential for exploration and physical interaction with the Sonic Blocks, the physical adjustments such as volume and spatial sound, provided the capability to not only sequence but physically alter the qualities of the sounds. Ultimately there were limits in this project such as time and budget that had an impact on what the blocks could do. However I was satisfied that in its context of use the system would gather some interesting findings on the nature of tangible interaction, and that this outweighed the blocks’ ability to enable a choice of sounds.
6 Second observations: The Sonic Blocks in use

6.1 Introduction

well you’re more interactive with them instead of just clicking

The Sonic Blocks were used in a particular way that contrasted significantly with the Garageband GUI. Being able to physically place, sequence and manipulate the sounds as embodied in the block artefacts resulted in actions and gestures replacing dialogue as the primary means of making a soundtrack.

The concluding chapter of this inquiry is in two parts. I have chosen to do this to enable the description of use and interpretations to be separated from the findings of the inquiry. The first part, sections 6.2 to 6.5, describes the activity and method for the observation program. It then gives a description of the modes of interaction designed to enable the use of the blocks’ as a soundtrack making device. The observation data is then explained and it reveals that the Sonic Blocks were used in an exploratory way motivated by the children’s curiosity for knowledge on how the system worked technologically. This chapter then interprets these explorations through the key concepts of this inquiry, namely action, representation and expression revealing the particular way in which the children acted upon, interpreted and expressed a soundtrack with the Sonic Blocks.

31 A response from one of the children when asked how the Sonic Blocks were different to the Garageband GUI.
The second part of the chapter concludes with what I have learnt about the Sonic Blocks as a way of embodying action and meaning, its limits as an expressive tool and a broader comment on the limits of TUIs. This conclusion also discusses mixing ethnography and design, revealing the challenges these two methods pose when combined without the inclusion of a social scientist or similar professional proficient in the analysis of qualitative data. Finally I conclude with what I see as the major challenge when designing TUIs. This challenge resides in the designer having a deep understanding of what is to be controlled and represented to enable the creation of appropriate artefacts and their couplings to digital data. Only when this is achieved can a TUI enable and support meaningful expressive activity.

6.2 Method and activity plan

6.2.1 The proposed soundtrack making activity

During the presentation of the Sonic Blocks to the teachers, discussed in section 5.3.5, I highlighted the physical and manipulable characteristics and the nature of the proposed building activity the children would have with the Sonic Blocks in creating the sound narrative. I also outlined the proposed order of activities as firstly, reading of a text that would then lead to the soundtrack building activity with the Sonic Blocks. The first observations illustrated that the children were adept at taking a narrative and conceptually translating it into a collection of temporal sound themes from the earlier activities with Garageband. In discussion the teachers agreed with this order of events.
6.2.2 Instruments and data collection

As with the first observations, the Sonic Blocks were immersed into the Reggio Emilia classroom with the data gathered being primarily unstructured (Atkinson and Hammersley 1994). The video footage, the bulk of the data collected, was transcribed through the contextual inquiry diagram after the fact. In this round of observations there was a separate session in which to ask semi-structured questions on the use of the Sonic Blocks to establish the children’s understandings of their actions and activity. In all, this method provided three sources of data (video, field notes and interview responses\textsuperscript{32}) on which to analyse the activity with the Sonic Blocks.

Finally the children were purposively sampled (Dixon et al. 1987) by the teachers. The group composition was different this time as the two girls Deborah and Zandra were not available. They were replaced by Sally\textsuperscript{33} and Nui who were considered by the teachers to be enthusiastic group contributors. It had been 14 months since the first observations so the children were now around 10 years of age and in grade 4 of the Reggio Emilia program\textsuperscript{34}.

6.3 The Sonic Blocks explained

The blocks were designed to physically afford the soundtrack making activity. Keyword tags on yellow post it notes were used to help guide the

\textsuperscript{32} The data collection instruments were video recordings of the children’s activity, my summary notes in a journal after the activity and informal interview data captured on audio tape.

\textsuperscript{33} Again the names have been changed to protect the identity of the children.

\textsuperscript{34} I questioned the teachers on their reasons for the considerable difference in lengths of the first to second observation activities. The first with Garageband went for approximately 45 minutes the second with the Sonic Blocks went for approximately 26 minutes. Their initial response was that the children might not have been as focussed with activity two due to the Christmas break looming, which typically caused distraction for classroom activities. The first observations were held in June (mid year) so there was not this distraction. As this inquiry is not explicitly comparing the results of Garageband to the Sonic Blocks but rather using the activity observed with Garageband to inspire and inform the design of the Sonic Blocks, I have not considered this factor in the findings or interpretations of the activity.
narrative. The children would be encouraged to write keywords on these post it notes and place them in the areas assigned (Figure 56). The post it notes are decisive physical representations of the soundtrack themes in sequence that aimed to direct the physical building activity and to prevent the diversion to keyword selection.  

The Max MSP patch was developed to enable two modes of operation. Audition mode, which consists of one block on the tablet, and sequence mode, more than one block on the tablet. Audition allows the sampling and adjustment of one sound (Figure 56 below).

![Diagram showing the tablet arrangement in audition mode with one block in position 1](image)

**Figure 56:** Diagram showing the tablet arrangement in audition mode with one block in position 1

Sequence mode is instigated when two or more blocks are placed on the tablet. The Max MSP patch operates as an event for 90 seconds, 15 seconds per block. Each block has its own distinct sound file, with a fifteen second delay between the last block and the first block. Therefore if three blocks are in positions 1, 2, and 3 (Figure 57 below), they play starting from left to right as three 15 second sound files followed by three 15 second sound gaps.

35 The children tended to get caught up in determining and agreeing on the keywords when using Garageband in the first observations. Whilst I accept that this is part of the creative process, I wanted to place the emphasis on not only the sequence of the sounds but their crafting and manipulation in an embodied and physical way.
The system enables the cycling between these two states, with the sequence mode intended to have a similar function to the playback mode in Garageband.

6.3.1 The feedback and sounds within the Sonic Blocks

The Sonic Blocks were developed and fabricated to be used in real time in the classroom. In sequence mode there was an intended visual feedback via a light below each block. This was designed to give an indication of the state of the system and sounds playing as the blocks were all identical. However due to the limits of Max MSP, we could not get the light feedback to work as the sound was played. Therefore when there was a sequence of blocks placed on the tablet you could not determine which block was playing from simply glancing at them. I made the decision to observe the blocks in use without this visual feedback, which in theory would seem difficult as it significantly reduced the coupling of the sound to the blocks. However I was interested in how the children might overcome this by making associations between the blocks and the sounds playing.
around them spatially; in effect they would have to create their own partial couplings.

6.3.2 The sounds embedded in the Sonic Blocks

I chose the five sounds for the Sonic Blocks without any narrative in mind. I also wanted to contrast significantly with the rock and roll sounds that made up the Garageband palette and chose an arbitrary collection from a sound library CD. I aimed at a diverse collection. There were three musical sounds, *vibraphone dreamy*, *indian flute* and *vibraphone accent* and two sounds from a soundscape type genre, *footsteps* and *electrical tone*. These sounds were to encourage the creation of a soundscape to be used as *treatments*36 for the narrative, rather than musical components to an ensemble, which is what Garageband fostered.

36 I borrow this term loosely from Brain Eno’s definition in which sound is applied as a treatment or collage, see http://en.wikipedia.org/wiki/Brian_Eno for a broad overview.
6.3.3 The layout of the total system in the classroom

The Sonic Blocks were placed in the school’s media room, which is separated from the main classroom activity space. The teachers suggested this space as it would comfortably house all of the equipment in a suitable spatial arrangement (Figure 58 above and Figure 59 below) to enable the children to move freely about the blocks and the tablet. It would also prevent interruption.
from children outside of the activity group, which was desirable considering the multitude of cables and equipment.

![Image: Sonic blocks setup](image)

**Figure 59:** The Sonic blocks as they were set up for the activity. Morgan McWaters is checking the system connections by viewing the Max MSP GUI

### 6.4 What the children did with the Sonic Blocks

Approximately 26 minutes of video data was gathered for the activity with the Sonic Blocks. Thirteen minutes was transcribed in detail as this was an adequate sample of the video footage to describe the activity and its patterns. The group was the same size and gender balance as with the first observations, two boys and two girls.

#### 6.4.1 Describing the activity with the Sonic Blocks

The group read a story and after an initial play period with the blocks we attempted to work with the story as a guide for the soundtrack creation. This first attempt at creating a soundtrack with the blocks was unsuccessful and involved
large levels of encouragement and coaxing from me, which ideally I did not want to occur. A decision was made to pick another story that the children were familiar with, as the children commented the first selected book was too hard to create a soundtrack to. The second text selected, The Two Bullies (Morimoto 1997) proved to be more successful as a narrative for a soundtrack. However the soundtrack making with this text was not an engaged activity compared to the earlier activity with Garageband, rather it was completed by the children more as an imposed requirement.\textsuperscript{37} The reality was that the children were less interested in making a soundtrack than in exploring the blocks as a physical set of actions and reactions. This physical exploration is the focus of my description in the remainder of this section.

6.4.2 Explorations with the Sonic Blocks

Initially there was a high level of curiosity from the two boys as they proceeded to place the blocks on the tablet and began to engage with these new physical devices. The first activity consisted of Dean explaining the function of the blocks to Ben by moving a block from location five to four. Dean was present in the testing of the system two weeks prior to the observation and therefore had some knowledge of how to activate the Blocks. This led to him taking an educating role in the early stages of the activity. This activity resulted in the boys each with a block in hand, Dean in location one and Ben in location five, adjusting the volume of their respective blocks in an arbitrary way without any noticeable consideration for the volume of the sounds being produced. At approximately one minute into the activity Ben gestures and suggests to Nui to try. With this encouragement Nui places a block on the tablet and adjusts the volume with considerably more care than the boys had shown. In adjusting the volume Nui

\textsuperscript{37} Of the total time spent there was approximately seven minutes of expressive soundtrack making activity compared to 19 minutes of exploratory activity.
turns to Sally and comments on the sound. This comment, undecipherable from
the tape, seemed to indicate an understanding of the coupling between block
placement and sound playback. The total activity observed cycled through these
stages of actions that were all directed at understanding the functions of the
blocks and their relationships to the tablet and resultant sound. The video data
indicated many interesting actions that could be discussed in a number of ways.

6.4.3 Types of exploratory activity

The explorations with the blocks fell into two broad categories. The first
was placement, which activated the sound, and the second was manipulation
which changed the characteristics of this sound. These two acts occurred in rapid
cycles and were repeated significantly throughout the observed activity.
Placement involved all of the actions that enabled a successful connection to play
a sound, from easing the block into its junction recess, which included the use of
magnets to ensure the connection was robust, to wiggling the blocks when they
did not play successfully. The children improved their placement technique over
time. This was indicated by both the improved accuracy of their fine motor
actions with the blocks and the sounds playing more regularly as the activity
progressed38. The observations indicated that the children gained a sense of when
the connection was successful due to the recognition of the sound feedback and
adjusting the blocks when there was no sound. The magnetic and mechanical
connection was understood through experiencing and feeling the haptic nature of
this connection. Through their use the children demonstrated the visual likeness
of block to junction recess and their actions also indicated an understanding of
the male/female connection. This connection could be felt inasmuch as it was

38In early attempts the children have difficulty in placing the blocks to activate the sound. This was due
to the block being slightly out of alignment with its corresponding contacts. As the activity progressed
the children realised through their trials and my advice that wiggling the blocks into position would
help initiate the sound.
seen and there were a number of instances of the children feeling and adjusting the fit between the block and the tablet, particularly when the sounds did not play.

*Manipulation* was every act that happened after the initial placement of a block. The children made conscious decisions to change the direction or volume of the sound playing. A common example was the children placing a block in position one, north east and then quickly rotating the block to south east (Figure 60 and Figure 61 below).

![Figure 60: Diagram showing a Sonic Block in position one north east rotation](image)

![Figure 61: Diagram showing Block rotated to position one south east](image)

The video footage revealed some interesting physical collaborations. There was an instance where both Dean and Ben both had their hands on one block. Dean was illustrating with action that the blocks can move in temporal sequence (position one to five) and rotating them within this position influences the direction of the sound (through one of the four speakers arranged). Ben was
physically experiencing the move and the resulting sound direction. These manipulations I define as being spatial and sequential.

Adjusting the volume is the last manipulation possible. It was intended to encourage crafting of the sounds in relation to one another, however the reality was quite different to this intention. The children in most cases turned the volume of each block to full as they wanted to hear the sound at its loudest and not arrange them dynamically for creative expression. Whilst not consciously an act of manipulating the sound dynamic, turning the volume control resulted in plenty of physical activity and this control was manipulated considerably both on and off the tablet. The boys tended to be quite haphazard in their use of the volume knob, just turning it because it was there to turn, whereas the girls turned the control with more precision and care, listening to the results of their actions but not really considering this volume in any sequential or compositional sense.

6.4.4 *Problems, solutions and other interesting explorations*

As I discussed earlier, there was difficulty initially in knowing which block was playing as the lights that were intended to indicate the active state of the blocks were not working. Interestingly the children overcame this by auditioning the block and placing it alongside or nearby the junction recess that they considered was suitable temporally in the context of the story (Figure 62 below).
These actions indicated a willingness by the children to adapt to the lack of feedback and use the physicality of the blocks to create arrangements that had a spatial and representational logic. Whilst the children overcame the sequencing feedback, not having this light working underneath an active block in a play sequence had an effect on the relationship the children could perceive between the blocks and the tablet and the state of the sound sequence. This was reinforced by the interview responses of the children who indicated that the block needed more description of the sound file it was playing.

There was an instance from the video footage where Ben turned a block upside down to reveal the acrylic base and battery probes and he touched a probe with his finger as it slightly protruded over the surface of the base. He was clarifying and exploring the electronic connections within the system and this indicated that his thinking was supported by the haptic engagement with the physicality of the blocks. There were also aspects of the design that were unintended but provided sensory affordances that warrant discussion. For
example the consistent physical feedback provided by the magnetic contacts on the underside of the blocks. These provided haptic control when placed as there was magnetic resistance as the block came within contact with the surface. The resistance ceased once the connection was made and a very slight clicking sound was made that was the result of the two surfaces coming together. This resistance was not consciously designed but rather a result of the materials and magnets I had used, and the observations indicated that the magnetic field controlled the act of connection. The haptically felt resistance provided a level of feedback that supported the visual association of the block to the tablet recess. The use of magnets was a technical decision, however the way they were used to control the connection was both an unexpected and interesting finding in the context of the affordances of the system.

6.4.5 Actions speak louder than words

The children acted with the blocks and through these actions they gained an understanding of the way the blocks initiated the sound through placement and controlled sequence, direction and volume. This observed activity started with simple placement actions and once the children had become confident in ways to place the blocks and initiate sound, the manipulations occurred with more conviction. The way the children learned how to operate the Sonic Blocks was through either their own actions or observing others’ actions. There were instances of dialogue to support these actions, but considerably less than the amount of dialogue that occurred through the activity with Garageband. The contextual inquiry diagrams39 from the first and second observations indicated that the prevailing mode of operation with Garageband was dialogue between the children with the actions often secondary responses. Contrastingly the activity with the Sonic Blocks was predominantly action, as comments were left to single

39 See the appendix for an example of the contextual inquiry diagrams
line questions verifying the operation of the system, if for example it stopped working. So action preceded dialogue; the thinking was through doing with comments and instructions following.

The way the children engaged with and learned to operate the Sonic Blocks was through action which lead to exploration with the Sonic Blocks as an engaged activity.

6.5 An interpretation of the actions, meanings and expression

The observations of the Sonic Blocks in use have indicated a different way of engaging with the activity of sequentially arranging sounds. One that is based on acting as thinking rather than interpreting graphical signs and responding. In this section I will discuss why I think the Sonic Blocks achieved this alternative approach to thinking through doing with digital sound data by interpreting the children’s activity. These interpretations will be based on the three research concepts I used to encapsulate my understanding of TUIs, namely action, representation and expression. These concepts will frame and focus the discussion. To support these interpretations I look to the responses from an interview conducted with the children the day after the activity and some interesting moments in the activity itself. See the appendix for selected transcript of the interview. I do this because I am interested in the meaning constructed by the children through acting with the Sonic Blocks.

The signs I refer to here are the icons on the Graphical User Interface and particularly the coloured bars in the Garageband timescale. These need to be visually interpreted as they have no physicality that might encourage play and exploration.
6.5.1  Design for action: reflections on the rationale for the functional form design

The conceptual model of building a soundtrack using the placement of construction blocks gave a clear functional representation of the five sounds and the ways they could be placed to complete the soundtrack as both a physical and sonic activity. This was evident in the observation data I collected. The children were able to both place and activate the Sonic Blocks, but also make higher level associations between the blocks’ sequential and spatial location and how this affected the resultant sounds.

In terms of what I term their sequential logic the Sonic Blocks are designed to be placed on the tablet in one of five locations. This placement is afforded by the blocks’ dimensionality and coupling to the tablet and its recesses that provide visual constraint and physical affordance. You can feel with reasonable accuracy if the block is in position, you have a choice of five positions that play in sequence from left to right. The spatial sound was represented via the arrow on the block surface and the subsequent mapping to the speaker it was pointing to. This information for use was visible through the arrow as a sign, accentuated by its three dimensional shape that rose from the surface of the block. This sign encouraged action and therefore I argue it is both a symbolic reference and an affordance. The volume control compositionally was arranged to have a diameter half the width and length of the overall block and therefore was perfectly visible in Norman’s terms (Norman 1988, p.4), it protruded from the block surface considerably. You could not help but act on it due to this visibility even if you did not initially understand the results of this action.

From an action and control position I aimed to design a system that consciously considers the physical form of the device, its constraints and couplings as a means of inviting action and control as meaningful to its use.
6.5.2 How the children acted with the functional form design

Through their actions and comments the children demonstrated a thorough understanding of the capabilities and functionalities of the Sonic Blocks. This understanding was gained through their physical experience and thinking with the blocks. The interview responses gave some interesting insights into what the children understood the blocks could do.

<table>
<thead>
<tr>
<th>Interview question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the blocks</td>
<td><strong>Ben</strong>, What you can produce sound with if you point at the speaker</td>
</tr>
<tr>
<td></td>
<td><strong>Dean</strong>, you put them on the pad to make sound</td>
</tr>
<tr>
<td></td>
<td><strong>Ben</strong>, you’ve got different blocks that make different sound waves</td>
</tr>
<tr>
<td>What did you do with the blocks.</td>
<td><strong>Dean</strong>, We put them on pads to work out the sounds, story</td>
</tr>
<tr>
<td></td>
<td><strong>Nui</strong>, We put them in order for the story</td>
</tr>
<tr>
<td>What are the different things that the blocks can do with the sounds they have.</td>
<td><strong>Ben</strong>, volume, sound waves, the magnet sticks to the sharp things and they make these sound waves through the cords, it’s like headphones but weirder.</td>
</tr>
</tbody>
</table>

Table 3: Selected responses to questions articulating what the children understood the Sonic Blocks to be.
This feedback indicates that the children have been able to give an accurate impression of the system and how it functions. I am satisfied that the main physical attributes of the Sonic Blocks invite sequential placement, spatial sound manipulation and volume adjustment. The system encouraged exploration through these manipulations, albeit in a basic sense.

<table>
<thead>
<tr>
<th>Interview question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can you describe how the blocks were different to the keyboard and screen</td>
<td><strong>Dean</strong>, Well you’re more interactive with them instead of just clicking.</td>
</tr>
<tr>
<td>What does that mean interactive?</td>
<td><strong>Dean</strong>, It means you’re using your body more</td>
</tr>
<tr>
<td></td>
<td><strong>Ben</strong>, you’re more active</td>
</tr>
</tbody>
</table>

**Table 4**: A definition and brief explanation of how the Sonic Blocks were more interactive than the keyboard and mouse acting indirectly on the GUI of the personal computer

The physical exploration was most engaging and compelling in audition mode. The comments above relate to the physical activity the children had when auditioning the blocks, they enjoyed these physical explorations as considerable play occurred through handling and manipulating the blocks. These manipulations were basic because they were concerned with getting the sounds to play and experimenting with direction and volume adjustments. However in sequence mode the system did not provide the right amount of feedback on the sound/block connection, reducing the ability to read the combinations of blocks as sounds in sequence. This had an effect on the soundtrack making as a refined and considered activity. I will discuss this in more detail in section 6.5.6.

The children did not only engaged with the Sonic Blocks through their affordances in purely a functional manner. They also made symbolic connection via the form, material and composition of the blocks and tablet. In the next
section I will discuss the representation and meaning that the blocks embodied in use.

6.5.3 **Representation: rationale for the symbolic form design**

The blocks were symbolic on a number of levels. I did not set out to design the Sonic Blocks considering the functional (affordances) and symbolic (semantic) nature of their form as separate elements. The blocks were considered with both of these factors in unison. However to faithfully give an account of the design intentions and the activity with the blocks, I have chosen to separate these elements. There will be some overlaps, as what is functionally afforded might also be symbolically represented. I accept that this separation is artificial, as action and meaning is intertwined but I consider it to be necessary to articulate two different approaches to the problem.

The Sonic Blocks were crafted using timber and therefore had a textual quality that is not common with electronic devices. The use of timber was a conscious decision to encourage touching, feeling and tactile interaction through the use of this textual quality. The Sonic Blocks were all exactly the same form, size and material. There were reasons why I resisted the desire to symbolically express the types of sounds they contained as characteristics of their form. The first reason was that I wanted the system to be interchangeable, that is the ability to change the sound of the blocks. And secondly, how do you represent a sound as a form to be meaningful for use in the types of playful and expressive activities with children I was seeking to foster?

The approach I took was to consider each sound on an abstract level as a unit of time. This approach was partly influenced by the coloured sound bars

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\[41\text{In fact every object in existence has values ascribed to it by virtue of what it is made of, how it is branded and the deeper socio-cultural associations made in use and consumption.}\]
within Garageband which marked time. The Sonic Blocks extended the unit of time in two ways. Firstly they were objects in the world, with all of the affordances objects offer, and not graphical representations on a screen. And secondly their capabilities (to sequence, change volume and spatially direct) were visible and not hidden under menu structures. These three capabilities of the Sonic Blocks whilst afforded physically also used symbols to present these qualities. The volume control has a small circular marker that indicates the volume level. This is a common means of representation on audio equipment and whilst this has shortcomings for an accurate measure of sound level, it did provide a sense of the sound. Spatial sound was indicated by the universally recognised symbol in the arrow. This arrow like ridge runs diagonally across the block surface rising to one corner (Figure 63 below). The three dimensional quality of this ridge can be seen from some distance and gives a highly visible sense of the sound direction.

Figure 63: An image showing the blocks as meaningful sound sequencing devices via the use of physical symbols

42 The volume could only be set real time when the system was in audition mode, ie one block placed at a time. Once another block was placed on the tablet the sound could not be adjusted from the initial placement volume. And secondly the only way to measure the volume accurately by sight was when the block was in the north east location with full volume being extreme right turn and no volume extreme left.
The sequential capability of the Sonic Blocks is managed spatially via the left to right order on the tablet. A block in position one plays first, second plays second and so on. The order of the sound sequence is mapped in a left to right fashion on the tablet and this calls on the spatial logic of game boards such as chess, where spatially organised constraints infer direction.

6.5.4 How the children interpreted the symbolic form design

The observations indicated the blocks were successful as playthings to be touched and felt. When informally questioned the children did not mention the textual quality of the timber used for the blocks. However I conclude that due to the amount of times the blocks were picked up, rubbed, tinkered with and explored, on and off the tablet, that the textual quality of the timber influenced these playful actions.

How the children responded to Sonic Blocks and their physical signs as representations of digital sounds was interesting. There was an instance in the video footage that had Ben placing his hand over the arrow in an attempt to stop its sound from playing. He seemed to be trying to block the sound, or he had the conception that wireless transmission created the sound, and was listening to hear if there was any sonic result of this action. Whilst this was incorrect technologically, it illustrated the effectiveness of the symbolic coupling between the arrow and the resultant sound which was an intended design feature. All of the children demonstrated through their actions and comments that they understood the coupling between the arrow and sound direction, even if not fully grasping the physics of the electronic connection\textsuperscript{43}.

\textsuperscript{43}There was an instance on the videotape that had Dean demonstrating the correct link between the arrow direction and sound feedback. This assisted the group’s understanding of this coupling.
<table>
<thead>
<tr>
<th>Interview question</th>
<th>Response</th>
</tr>
</thead>
</table>
| *Is it important to manipulate, change the volume or location of the sound like the blocks do. Because in Garageband you didn’t really do that you just seemed to make the sounds longer or shorter* | **Dean,** it just takes too long  
**Ben,** with Garageband you can make the sounds short or as long as you like and you can add other songs onto it.  
The Sonic Blocks are not like that, you’ve got to do one sound after the other instead of just having the same sound for a minute or less. With the sonic blocks you just have one 15 second sound after the other.  
Changing the length of the sound is good. |

*Table 5:* The children describe some advantages of the Garageband GUI and its virtual manipulation capabilities

Whilst the volume control as a representation of sound level was not articulated as a problem in the interview responses, the children turned the volume up to full and left it. There was no finessing of sound levels to emphasise particular parts of the narrative as was the intention. I cannot draw any meaningful conclusion to explain this lack of sound level finessing as there were some dynamic adjustments made when the children used the percussive instruments in the first observations. Dean commented on it *taking too long* to make the adjustments. My interpretation of this comment is that the volume needed to be a real time adjustment in both audition and sequence mode, not just the audition mode as was implemented\(^{44}\). This would allow immediate results. In summation the children understood the volume control and the circular notch in its surface as a measure of the volume level, but they did not use this control in an expressive way to place different emphasis on the stages of the narrative as I had hoped. The value is not an accurate measure of the volume.

\(^{44}\) The volume adjustment was intended in both modes but the Max MSP patch could not be configured to do so.
level but one that is established through use and knowledge of the system. So an understanding of the volume control requires the user to listen to the sound as it is sampled and make this connection himself in the audition mode. This may have created a difficulty in use that was not desirable.

The building of the soundtrack was successful using the timber blocks. The children demonstrated an understanding of each block embodying its own sound and the sequential capability of the blocks when arranged left to right. In the early stages of the activity Dean was captured on video sampling and naming each block, walking, strange sounds, strange things. Similarly Ben articulated that you’ve got different blocks that make different sound waves when interviewed. All of the children understood that the sounds play one after the other when two or more blocks were placed on the tablet and Dean articulated that the sound skips when you have no blocks in sequence.

However Ben laments the lack of ability to change the length of the sounds and overlap the sounds as was possible with Garageband (see interview responses above). This points to an interesting shortfall in the nature and limits of tangible interfaces like the Sonic Blocks which I will outline in the conclusion to this thesis.

6.5.5 The Sonic Blocks for expressing a soundtrack: rationale for the activity design

Once the children had read the story and arrived at a thematic and temporal structure, via the placement of post it notes, the Sonic Blocks were intended to be used cycling between audition and sequence mode. The aim of

\[45\] The Sonic Blocks rely on objects in the physical world to make discrete analogue contact to permit voltage transfer. It is this change in voltage that triggers the sound file and its parameters in Max MSP. At the time of the technological design we could see no other way of achieving this transfer in a robust manner.
6.5.6 How the children expressed the soundtrack

In use the responses were quite different to my aims and expectations. The children were not really interested in making a soundtrack, they wanted to play with this new collection of toys to discover their potential in a technological sense. There was genuine interest in the Sonic Blocks as a technological system, how it made the sounds, where the sounds came from and what the pointy bits were for, but there was no real considered engagement with the activity of making a soundtrack. The actual soundtrack making activity as a response to the narrative constituted less than a quarter of the video data gathered. It required considerable encouragement from me, and I would question the amount of activity that would have occurred without this encouragement. I found this quite frustrating initially but on asking the children how the Sonic Blocks were different to Garageband revealed why it was not an effective tool for making a soundtrack. The children indicated that having only five sounds limited their choice and that they would need to match the sounds to the narrative which suggested that they get selected by the children prior to the activity. They wanted more sound choices, some say in what these sounds were and the ability to layer sounds to construct a soundtrack.

Whilst the activity of making the soundtrack was disappointing, the ways the children explored the blocks as a technological system was interesting in itself. With all of their actions and manipulations they developed understandings of how an analogue signal can initiate and influence digital data through a physical connection. Their conception of this was interesting, for example their comments indicate that, the magnet sticks to the sharp things and they make
these sound waves through the cords, its like headphones but weirder. They also demonstrated an understanding of the physics of sound with comments like, you’ve got different blocks that make different sound waves. So whilst the Sonic Blocks did not foster expressive arrangement, as was intended, there was some interesting technological and even scientific learning through these exploratory actions.

Marshall Price et al (2003) articulate that there are exploratory tangibles and expressive tangibles. You act through an expressive tangible creating with it as an external representation of the thoughts you have and activity you do (p. 102). Exploratory tangibles encourage the user to focus on the way the system works, rather than reflecting on the history of their own interaction with it (p. 102). The Sonic Blocks were an exploratory tangible as the children spent the majority of the time placing the blocks on the tablet, rotating them to change their sound direction, turning the blocks upside down and feeling the contact probes and so forth. They were fascinated with how the system worked rather then expressing a soundtrack through their use.

When interviewed the children indicated that this activity was quite fun although they stated the fun would have increased if they had about six sounds per block. Gaver, Bowers et al. (2004, p.4) articulate that there are important factors to consider when designing for ludic (or playful) activity with digital technologies. These include:

Systems that promote ludic pursuits should provide resources for people to appropriate, rather than content for consumption or tools that structure the performance of defined tasks.

In asking the children to create a soundtrack with the Sonic Blocks, their curiosity was promoted through the novelty of the blocks as sound manipulation devices. But beyond these initial novel explorations there was little evidence of
appropriation of the Sonic Blocks as a resource to create a soundtrack in the sense that Gaver, Bowers et al (2004) might suggest. This was due to the limits of sound choices and the fixed time allocation of the sounds provided. The children therefore did not really appropriate the Sonic Blocks as a creative resource but rather consumed the sound samples without any real playful and creative composition.

6.6 Conclusion: the Sonic Blocks as a TUI

6.6.1 Action: the affordances and physicality of TUIs can support thinking through doing

well you’re more interactive with them instead of just clicking

This design research inquiry has shown that you can present non physical phenomena such as digital sound as a physical agent to be operated on in the world. There is enough evidence in the data collected in this inquiry to support this claim. The actions and comments by the children with and about the Sonic Blocks illustrate that they are objects to think with and that this thinking is not just an internal mental process, but one supported and, in some cases, initiated by action. Whilst the thinking was limited to the children’s explorations to develop their understandings of the systems workings - from the subtleties of feeling the block connect through magnetism to the spatial arrangement of an actual three dimensional objects - these sensory cues that were supported by the affordances and couplings of the Sonic Blocks to provide information for use that supported the thinking, exploration and discovery.
6.6.2  Meaning: semantics and aesthetics play a role in Tangible User Interaction

This design research has also shown that you can embed meaning via the form and material of physical objects to partially represent digital sounds, and for that matter digital data. The use of timber blocks and natural materials to support learning\footnote{Timber blocks as playthings have their origins in the work of Montessori and Froebel as both abstract and literal representations of ideas and concepts.} has emerged from constructivist theories of educational development. The Sonic Blocks were picked up and played with considerably and proved to be suitable representations of the functional sound manipulations through their unique embodied symbolic form that supported the children in making meaning. The children demonstrated an understanding of this embodied meaning through their successful sound manipulation activity. Finally the tablet was analogous to a board game in that it presented a spatial logic that was both visible and perceptible. I argue that, whilst not articulated explicitly by the children, the spatial layout contributed to the physical challenge and exploration through its constraints and logic. This was confirmed through the children’s actions and description of this logic.

6.6.3  Designing TUIs for Expression: failure of the Sonic Blocks to engage the children

This inquiry has shown that to design an expressive TUI is a challenge. The Sonic Blocks were designed based on the sequencing and arrangement activity evidenced with Garageband. But I did not really understand the strength of Garageband to cycle rapidly through these activities, that is to offer large amounts of sound choices and its ability to layer the sounds graphically and efficiently. These capabilities only became apparent, as valued by the children, when I questioned them after using the Sonic Blocks. These comments ultimately
indicate that Garageband is productive and compelling because its GUI, which supports being able to stretch time, drag and layer sound files on a screen.

I attempted to replicate the sequencing capability of this GUI as a physical device, but due to technological constraints was forced to simplify and ultimately compromise what I should have been amplifying and enriching. Therefore a compromise was made on the visual information to indicate the state of the system, in the form of lights showing which block was playing when, this resulted in presenting objects to be manipulated with reliance on their physical presence and their resultant sound feedback to indicate the state of the system. The children overcame the lack of feedback to some degree through their own spatial arranging off the tablet, however the engagement in an ongoing expressive sense was limited as the feedback was not as sophisticated as it was with Garageband. So effective TUIs for expressive soundtrack making activities need to exploit the abilities of visual feedback to be rapidly updated and economically presented, even if it is simple light sequences. This feedback needs to have a well conceived synergy with the objects of the system.

6.6.4 GUIs vs TUIs: the limits of the Sonic Blocks as an expressive TUI.

Garageband had more variety, you have a screen to look at instead of just blocks and you don’t have to move those, the blocks, with your hands only the mouse with one hand\textsuperscript{47}

The orientation towards the Sonic Blocks contrasted significantly with that of Garageband. Garageband mediated the activity via the graphical data on the computer screen, and comments were directed in a collaborative sense towards this visually managed resource that could be rapidly manipulated. These

\textsuperscript{47} Another comparison of Garagebands virtual functionality to the Sonic Blocks \textit{physical} functionality.
manipulations were crucial in terms of providing a compelling soundtrack sequencing activity.

As contrast The Sonic Blocks provided physical agents for each sound that were an engaging alternative from a spatial and motor sensory point of view that encouraged explorations into understanding sound making capabilities, rather than the sequencing and expression of a soundtrack. The Sonic Blocks were limited ultimately due to their lack of coupling to the sounds they were playing. This diminished their ability to be used as an expressive tangible.

6.6.5 Designers do design projects not gather ethnographic findings

This inquiry has given me an understanding of the role ethnographic methods can play in design projects and some of the pitfalls of doing so. I set out to gain a rich understanding of the actual nature of children’s exploratory and expressive usage with computers and hand held instruments and chose to do so by observing a small group. What I have found is that whilst collecting data is a relatively simple activity, particularly when it is collected via a video recorder, its transcription and analysis is a complex and challenging activity that clearly requires significant skill and experience to complete. Even if you manage to complete this transcription and develop findings through analysis, you may not have a compelling problem or opportunity to design for, but rather a set of problems that require an incremental re-design of existant technologies and not a leap forward in innovation. To look at a collection of findings and extract a design project of some depth and originality is an enormous challenge.

What I take from this inquiry is that there is clear value in ethnographic methods to provide a focus on a situation and develop a richer understanding and awareness to challenge any initial assumptions. Taking a list of factors to design for from publications and theoretical positions is often not enough. There is a
level of abstraction and interpretation in these formulated *rules* that can lack grounding and obscure the creative exploration which design activity requires. Designers need to have the right of refusal, or at least be aware but not constrained, as ethnographic findings can sometimes reveal what is already known and this knowledge can limit idea exploration. But designers should also have the good sense to be considerate of good findings that tell them something not known and give this knowledge due consideration within the design project.

To combine ethnography and design together there needs to be a designer, with all of the training in the creation and synthesis of ideas, and a social scientist or similar professional who has an appreciation for the craft of data collection and analysis. The project discussion then at the least can be created and developed with all of the necessary evaluations of the idea and concepts against the findings and constraints. If these individuals or groups develop a strong collaborative relationship the boundaries can become blurred and some interesting trans-disciplinary ideas can evolve.

### 6.6.6 Make good couplings: notes on making the digital physical

In this inquiry I have attempted to be faithful to children’s collaborative expression, but at the same time acknowledge that I am working in a new field that is relatively uncharted, namely Tangible User Interaction. So whilst I acknowledge the shortcomings of the personal computer interface for these type of activities I have resisted the desire to solve this problem and persisted in working within the domain of TUIs. My position is that in order to understand innovative ways of making computation expressive, a shift away from the screen and into the world of objects and actions is required. The criticism of the Graphical User Interface from the TUI community is that GUIs obscure all of the objects to act upon, as they are screen objects when they should be present in
the world as actual objects. However this inquiry has demonstrated that for expressive activities the visual capabilities of the GUI can be a powerful resource, and that not including any visual information can limit the level of engagement one has with a TUI. The value of the Garageband GUI for expressive activity is its lack of physicality, for its screen data can be moved and resized without any of the mechanical or electronic complexities of a TUI. But this lack of physicality can come at a perceptual cost to the user as this data requires the interpretation of signs and icons to be used effectively.

Through the design, implementation and observation of the Sonic Blocks I have discovered that using objects to represent and control digital information is a worthwhile pursuit that requires more research effort to gain deeper knowledge of their role in expressive and exploratory activities. I have also established from this inquiry that the design of meaningful TUIs requires a deep understanding of what is to be represented, what models exist to represent it (eg. visual GUIs) and how to effectively couple an object to non material information (eg. digital sound).

The challenge for design is striking an effective balance between the senses to be used as channels of action in the TUI. The physical, visual and sonic modes need to be suitably coupled to allow one to firstly be able to use the system and in time be expressive with it. If a TUI is suitably coupled to its multi-sensory feedback to encourage a cycle of activity on the system, new experiences occur that privilege direct action on objects as a way of thinking that can lead to exploration and expression.


8 Appendix

8.1 Supplementary documents to the study

- Contextual Inquiry Diagram example
- Field notes from all activities
- Interview questions and responses from the second observations.
- The scenario diagrams used to direct the design and programming of the Sonic Blocks.

A DVD containing the video footage used in the transcription and analysis for this inquiry can be obtained by emailing the author at frank.feltham@rmit.edu.au
<table>
<thead>
<tr>
<th>Time</th>
<th>Person</th>
<th>Quotes</th>
<th>Physical Gestures/Actions</th>
<th>Activities / Explanations</th>
<th>Roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:16</td>
<td>David</td>
<td>Walking</td>
<td>David then takes the block off the tablet and replaces it with a new block selection and then says...</td>
<td>David starting to identify and classify the sound types.</td>
<td></td>
</tr>
<tr>
<td>1:26</td>
<td>David</td>
<td>Strange Things</td>
<td>David takes the Strange Things: block off the tablet, replaces it and says...</td>
<td>Bean starting to demonstrate his conception of the sounds types to the others.</td>
<td></td>
</tr>
<tr>
<td>1:30</td>
<td>David</td>
<td>Strange Sounds</td>
<td>David repeats the Strange Sounds and says...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1:35</td>
<td>David</td>
<td>Strange Music</td>
<td>repeats above repeated action.</td>
<td>Bean verifying the sounds to David's classification earlier.</td>
<td></td>
</tr>
<tr>
<td>1:42</td>
<td>Bean</td>
<td>What is that sound?</td>
<td>Bean moves in to start controlling the block using picks first block up block on statement root second block up and sound, THIS IS THE SQUEAK SOUND that David related to earlier. He then uses the stick to tap on the block and leaves strange sound. In this sequence of events, sound to add to the sequence is the bleep sound, which is the last developed to rapidly after the cotton. The sound, he heard from the palm, was the sound he heard from previous activity and made relationships to other sounds.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Summary of field notes
First Observations,
Activity 1, Sound with Garageband, 19.7.05

Participants
Deborah 9 yrs
Zandra 9 yrs
Ben 9 yrs
Dean 9 yrs

Activity
Creating a soundtrack for the Story Cloudland by John Burningham.
Using the software Garageband on a Mac G3 computer.

Notes
The kids launched into the exercise and left me a little behind as - evidenced by the tape – they were really keen to get going. Once I advised them of how to sit they were off, and in fact Dean and Ben had already started playing such is the intuitive nature of the interface.

Generally the roles started with Dean operating the computer and Ben helping with Zandra and Deborah attending to the story and whether the sounds suited the particular theme of the page such as “Falling” and “Swimming”. Deborah was a consistent voice of reason at the start and toward the end Zandra seemed to become more engaged. It was a collaborative effort in that there were stages where the children agreed on sounds.

Probably the most profound observation for this research was the way the kids used gestures, made their own sounds and danced out the theme. Ben and Zandra were probably the best practitioners of this.

There was a displacement between the sound/gesture/movement and it being replicated and created on the computer.

For example Zandra and Dean might have been acting out sounds and Dean needed to find the sound in the palette of the program that best represented it.

Having said this the Computer monitor seemed quite a good central resource in terms of the graphic representation and names of the sounds to choose. For example the kids would point to the sound they think they would like and sample it, the control of the sound reviewed lay with the person with the mouse and keyboard so you could argue that the collaboration was limited here.

The building metaphor of the timescale helped with the concept of time for the kids. They could really understand what was where. It almost spatially represented the book in time. The kids could go back over the soundtrack and insert new sounds at any given point in time. The review feature was used consistently by the kids to see how it sounds and check the progress of the soundtrack in entirety. This was done a number of times during the video. I have used these moments to define the shift between creation and review.

Toward the end of the session the boys started getting distracted. Dean really lost interest and Ben subsequently took control of the computer when he was prompted to do so. The girls were committed to seeing the soundtrack related to the book and its themes and stages. They worked far more consistently on the task as they could see some sense of value in completing it.

Overall the engagement was quite remarkable it amounted to about 40 minutes of work. I will have to ask the teachers how this compares to other activities.
Summary of field notes
First Observations,
Activity 2, Sound using instruments, 2.8.05

**Participants**
Deborah  9yrs
Zandra  9yrs
Arnold 9yrs
Dean 9 yrs

**Instructors**
Lara Lubitz
Frank Feltham

**Activity.**
Creating a soundtrack for the Story Cloudland by John Burningham.
Using Instruments

**Notes**

The first activity was to read the Book. The girls took ownership of this activity with Zandra and Deborah taking turns.
I encouraged Arnold and Dean to Participate; only Arnold took up this offer.
This may have been due to the seating arrangements with the girls positioned directly around the book (see tape)

Generally the engagement was far different. The kids seemed to want instruction on what to do and the motivation was low compared to Garageband.
All of the children except for possibly Zandra didn't really understand the exercise.
Initially Dean wanted to jump on the computer and we had to tell him that this exercise was different to last time.

It seemed that the “Tools” (the instruments) weren't as good.
The kids would not experiment with the sounds of different instruments to match than narrative in the same way that they did with garageband.
They tended to make sounds of different tempo or loudness with the same instrument;
for example, Arnold tried to create sounds as diverse as swimming,
Falling and a thunderstorm with the one cymbal.
What I noticed was that Deborah collected the instruments as we progressed through the exercise.

It was almost as if the sound they made themselves had lesser value than the pre-recorded sounds in garageband.
And their also seemed to be concern with the quality of the sounds and the skill with which they made them. Anxiety over performance.

We felt we needed to introduce a narrator to the exercise to help with the composition.
Lara sat with the children and read the book and emphasised key words and themes for the children to create sounds to.
This helped with regaining focus as the children were tending to “run off with there instruments”
Summary of field notes
Second Observations,
Sound with the Sonic Blocks 19.12.06

Participants
Nui 10 yrs
Sally 10yrs
Ben 10 yrs
Dean 10 yrs

Activity
Creating a soundtrack using the Sonic Blocks

Notes
The children were unmotivated, Kerri had mentioned that it was the end of the year and that the kids were tired. The composition of the group had changed Zandra and Deborah was replaced by Sally and Nui. It seemed to me that the girls were not as willing to help the activity along in the same way that Zandra and Deborah had with the garageband exercise.

Generally the children found it difficult to get started with the activity as I had planned it. For example Read, create keywords, place and manipulate blocks in response.

We read “The Island” first but when the activity moved to the blocks the kids mentioned the story was not suited to the exercise, I had to coax them to consider the story and the “block” sounds as a way of working with the system.

Dean suggested that “The Bully” would be a better book for the exercise and so I read it to the group.

The kids seemed a little more enthusiastic to work with the blocks and “The Bully” as the Indian flute sound could be connected to the “oriental” feel of the story. Ben quite rapidly placed the blocks in an order that he felt satisfied the story and others contributed. It wasn’t in a true collaborative sense however as the Sally would move Ben’s blocks as he placed them in an independent action.

In the sequential mode it wasn’t clear as to what was playing, the LEDS I feel would have helped this.

Ben adopted an interesting strategy by playing and placing each block individually. This suggests that there was not a need for a visual readout in his case.
Informal Questions and Answers  
Second Observations,  
Sound with Sonic Blocks, 20.12.06

What are the blocks?

Ben, What you can produce sound with if you point at the speaker  
Dean, you put them on the pad to make sound.  
Ben, you've got different blocks that make different sound waves

What did you do with the blocks?

Dean, We put them on pads to work out the sounds, story  
Nui, We put them in order for the story

What are the different things that the blocks can do with the sounds they have.

Ben, volume, sound waves, the magnet sticks to the sharp things and they make these sound waves through the cords, it's like headphones but weirder.

What happened when you changed the position of the block on the tablet?

Sally, it made a different sound

Did the sound come from one direction?

The Boys, Four, different directions  
Dean, Four different speakers

What happens when you put 2 or more blocks on the tablet?

Ben, It plays one after the other and then replays,  
Dean, the sounds skip when there is no blocks

Do you think you can play with the blocks in a group?

Both Yes  
Ben but first we can get an idea of what book we can use to make the proper sounds.

Why did we have trouble with the island (the first text read)?

Ben, cause it didn’t match  
Sally, because it had more sound than the blocks

Can you do stories with the blocks like you did with Garageband.

Ben, No, cause Garageband has more different varieties of sounds
Can you describe how the blocks were different to the keyboard?

Dean, Well your more interactive with them instead of just clicking.

What does that mean interactive?

Dean, It means you’re using your body more
Ben, your more active

Was it good being able to move around?

Ben, No I would rather sit down and use the mouse

So the mouse was more precise.

Ben, Yeah, more advanced

Did you find that the blocks were good at representing the sound?

Sally and Dean, Yeah

You didn’t need a description of the sound like you have in garageband

Ben no we needed it a little bit.

What do the blocks need to make them more fun?

Add more sounds to them
Dean, Put another knob on the block to change the sounds
Ben, It would be good if you had about six sounds on the block

Any other comments.

Dean, It, sonic blocks, was quite fun, but garageband was a lot more fun.

In a couple of words why was garageband more fun?

Ben, garageband had more variety, you could have a screen to look at instead of just blocks and you don’t have to move those, the blocks, with your hands only the mouse with one hand

Is it important to manipulate, change the volume or location of the sound like the blocks do. Because in Garageband you didn’t really do that you just seemed to make the sounds longer or shorter

Dean, it just takes to long

Ben,
With Garageband you can make the sounds short or as long as you like and you can add other songs onto it, not like that, the Sonic Blocks, you’ve got to do one sound after the other instead of just having the same sound for a minute or less. With the sonic blocks you just have one 15 second sound after the other. Changing the length of the sound is good.

With the blocks being timber were they fun,

Dean and Ben
Yeah, if I was stuck with it in a room I would play with it and if we didn’t have Garageband we would play with it,
**Creation 1**

**Children's activity**
- Hanna, Alan, Grace and Robert sit down to re-read Cloudland. Their intention is to create a soundtrack to capture the 4K animation of a child falling from a mountain top into the clouds.

**Technological Interaction**
- Block is sitting still on the tablet ready to be manipulated.
- Block is placed on the tablet.
- Triangle piece is placed in a 1st slot. This gives the block a sound ID.
- Block is again placed on the tablet.
- Block in placed on the tablet.
- Triangle piece is placed in a 2nd slot. This gives the block 2nd layer to the sound.
- Sound stop.
- Sound stops.
- rotary potentiometer with physical connection between block and tablet at connector strip.
- The volume control (pot) is turned clockwise, sound level is increased realtime.

**Electronics/Programming**
- The only visual feedback is through a small light pulsing on the volume control. Sound and light plays through the designated speakers.
- After 2 second delay the sound plays through the designated speakers. The only visual feedback is through a small light pulsing on the volume control.
- Sound is selected in relationship to the top and slot. Triangle has RFID tag with RFID field in base of tablet.
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**Creation 2**

**Children's activity**
- The Children are divided into two groups, at their suggestion this is Robert and Ben; Hanna, Grace - annoyed at Robert and Ben’s lack of collaboration - ask them to re-read Cloudland.
- The boys agree to join the girls and after discussion they all agree that the key words to describe Cloudland are: falling, greeting, playing, dancing, partying.
- The girls decide that they will work with existing sound on the boys atmospheric sound set.
- The boys agree to join the girls and after discussion they all agree that the key words to describe Cloudland are: falling, greeting, playing, dancing, partying.

**Technological Interaction**
- In quick discussion the girls decide on a louder sound for falling.
- The girls decide that they will work with existing sound on the boys atmospheric sound set. Researchers types these keywords via laptop, these words are displayed on the control tablet readout.
- The girls decide that they will work with existing sound on the boys atmospheric sound set.
- The girls decide that they will work with existing sound on the boys atmospheric sound set.
- They then decide on changing its spatial location.
- Sound stops.

**Electronics/Programming**
- Sound stops.
- Sound stops.
- Sound stops.
- LED readout along the top of the tablet翡翠 paying sound.
- LED readout along the top of the tablet翡翠 paying sound.
- LED readout along the top of the tablet翡翠 paying sound.
- audio playback via laptop.
- Laptop cable connected to tablet. Laptop running Max/MSP has facility for typed input to this readout.
<table>
<thead>
<tr>
<th>Reflect 'n</th>
<th>Children's activity</th>
<th>Technological Interaction/Feedback</th>
<th>Electronics/Programming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Of the two sound palletes, Hanna and Grace have a musical/rythymic set and Robert and Ben have the atmospheric set. The only rule of collaboration is that the sound type can only be changed by the group that created it.</td>
<td>With both groups sounds complete, all lights on tablet, they are ready to start.</td>
<td>Speakers driven by Max/MSP accessed by laptop. Speakers are located around the children as they play with the system. LED light is housed on Vcontrol.</td>
<td></td>
</tr>
<tr>
<td>The Total soundtrack starts to play after researcher counts in.</td>
<td>Sound and lights stop when blocks are physically taken off the tablet.</td>
<td>Max MSP sound object volume increase. After one cycle through the soundtrack, the Total soundtrack lasts for 2 minutes. It is divided into 18 different sounds all linked to themes. Each sound lasts 7.8 seconds. The Total soundtrack lasted for 2 min 20 and had 18 different sounds all linked to themes. Which divided evenly into each sound lasted 7.8 seconds.</td>
<td></td>
</tr>
<tr>
<td>An argument occurs between the boys and their choice of sound.</td>
<td>Sound and lights stop when blocks are physically taken off the tablet.</td>
<td>Max MSP sound and light object turn off.</td>
<td></td>
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<td>Reflect 'n</td>
<td>Children's activity</td>
<td>Technological Interaction/Feedback</td>
<td>Electronics/Programming</td>
</tr>
<tr>
<td>The boys decide to change block 2 and 5.</td>
<td>Sound and lights stop when blocks are physically taken off the tablet.</td>
<td>Max MSP sound and light object turn off.</td>
<td></td>
</tr>
<tr>
<td>Block 2 and 5 have new sound types. They are placed on the tablet.</td>
<td>After 2 seconds, sound plays with light as sound passes through them.</td>
<td>Max MSP sound and light object turn on after 2 second delay.</td>
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<td>Reflect 'n</td>
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