Co-Construction Kits

the Transformative Potential of Interpersonal Connections for After-School Centres

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Abstract

The following thesis makes contributions to the design and educational use of tangible construction kits. It is shown that their transformative effect for young people in economically-disadvantaged communities is closely tied to kits, and their design, being embedded in a concept which places the communal nature of use at the centre. The approach enables young people to use the tools to strengthen social engagement and make investments their social environment.

A new kit - the fundakit - with a collaborative design concept addressing social relations was developed for the purpose. The transformative potential of this approach was tested in a comprehensive after-school centre in an economically-disadvantaged community in Portugal. Young people used the fundakit to co-construct fully usable and sustainable craft-tech interactive exhibits. The interactives were used by peers in the centre, and shared with others in the community, in settings such as a local school, home for the aged, shopping centre, and hospital. The study was conducted over a four-year period (2011-2015). Youth took between three months and two years to design their interactives.

Qualitative data was collected, and thick descriptions [Geertz, 1973] written up from the data. Thick descriptions were analysed and interpreted in the context of the corpus. Three interrelated study foci were foregrounded in the analysis: youth diversity, interpersonal connections, and transformative outcomes. Patterns in interpersonal engagements and arrangements that established opportunities to learn were surfaced. The results suggest that attention to interpersonal connections in tangible construction kits and related learning environments, creates special opportunities to support young people in economically-disadvantaged communities and change processes.
Zusammenfassung


Auf der Grundlage von 'thick descriptions' (Geertz, 1973) wurden im Rahmen der Arbeit Daten qualitativ erfasst und im Kontext des Materials interpretiert. Drei Schwerpunkte kristallisierten sich bei der Analyse heraus: Diversität der Jugendlichen, zwischenmenschliche Beziehungen und transformative Prozesse. Muster interpersoneller Verbindungen und sozialer Arrangements, die
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Co-Construction Kits
Chapter 1. Introduction

*Umntu ngumntu ngabantu* (a person is a person through other people).

isiXhosa proverb

How can young people living in economically-disadvantaged communities be empowered to make greater contributions to their communities? What kinds of tools, contexts, relationships and ideas can enable them to take on transformative roles? These are certainly not new questions, but they are gaining importance in an increasingly unequal world – see, for example, Oxfam’s *’An Economy for the 1%’* report [Oxfam Report]. Valuable work has already been achieved in this area, but much more is needed. I have identified two strands of work that have demonstrated concrete results, and have built on them to further explore transformative potential. The first of these are comprehensive after-school centres promoting youth development in economically-disadvantaged communities, and the second, tangible construction kits supporting learning through design explorations. My research efforts are focused on the ongoing shaping and intertwining of these tools and institutions, with a view towards contributing to a more equitable and just society.

Comprehensive after-school centres, which are also known as after-school programmes, after-schools, and after-school centres, are interruptive institutions where the cycle of social exclusion can be broken and youth development addressed over the long-term. They are generally located in economically-disadvantaged communities and aim to serve young people living in the immediate area. They are safe spaces which youth can walk to after school to meet up with friends, seek adult
guidance and support, explore new interests, and develop career dreams and plans over time. Unlike more targeted initiatives, such as community technology centres and youth sports programmes, comprehensive after-school centres offer kids a broad and varied programme. Variety in the activity programme helps to build diversity in the youth community, and this diversity is a powerful resource which centres can leverage for transformative ends.

Tangible construction kits are interruptive tools centres can use to aggregate and channel this diversity towards transformative ends. Kits enable novices to design new kinds of personally meaningful interactive objects and develop technological fluencies through the design process. They generally contain a collection of hardware components, some related design materials, and a programming environment, and are designed to scaffold user exploration and learning in a microworld. Most kits have been designed for designing the kinds of artefacts young people might want to invent for themselves. They could also be used by youth to invest in their after-school centres and the communities in which they are situated. For example, youth could combine skills and understanding to design new kinds of playful learning resources for the centre, build and share skills and understanding through the emerging design object, and take the completed object out into the community to promote the social inclusion of others.

Most kits have, however, been designed for individual connections. Resnick et al.’s landmark article on construction kits, *Pianos not Stereos – Creating Computational Construction Kits* [Resnick et al., 1996], proposes two types of connections as general design principles: personal connections – kits and activities should connect to users’ interests, passions and experiences, to allow them to draw on previous knowledge and connect new ideas to pre-existing intuitions; and epistemological connections – kits and activities should make certain ideas and ways of thinking salient, to enable users to connect to them in a natural way through the design process. Twenty
years on from the publication of 'Pianos not Stereos', many kits are much like pianos: ideal for individual users and for creating fugacious works. The focus has been on the individual designer, their relationship with the object under construction, and how the construction process helps to form internal models. Shareability has been deemed important because it establishes a context in which others can offer opinions, ask questions, give advice, etc., which promotes reflection and revision of internal models. There has, however, been comparatively little attention given to how the user connects with others through their 'public entity', and more importantly, how groups of users might co-construct a shared entity and benefit from each other's skills and perspectives in an ongoing way through the collaborative design process.

I perceive the need for a third connection type, *interpersonal connections* – kits and activities should facilitate connections in groups and support interactions with more skilled members in the *zone of proximal development (ZPD)* [Vygotsky, 1978], to enable users to participate in activities that would be difficult to attempt on their own, and to gradually adopt and transform tools. Communication and coordination with other members of a group stretches the understandings of participants, who strive to develop shared understanding to proceed with the shared endeavour [Rogoff, 1995, 1998, 2003]. This search for common ground, and the effort to extend it once found, involves adjustment and the growth of understanding. Ackermann has shown how the constructionist view (personal and epistemological connections) is not at odds with the socio-constructivist view (interpersonal connections), and how together they help to build a more comprehensive picture of learning and development. In her words: *people are good at using what they don't know as a lever to grow* (constructionist), and *'it takes a whole village to raise a child'* (socio-constructivist) [Ackermann, 2004]. Interpersonal connections could also provide a means for after-school centres to aggregate and channel youth diversity towards transformative ends more broadly in the community.
To gauge the transformative potential of interpersonal connections for comprehensive after-school centres, I have explored how tangible construction kits and the environments in which they are used can be further shaped to explicitly promote and support interpersonal connections. To this end, I have developed a co-construction kit and related design environment, and tested whether these facilitate interpersonal connections, and whether such connections enable centres to leverage diversity in their youth communities for transformative ends. My efforts were concentrated in three principle loci: within the individual, through mutual involvement in craft-tech design activities; within the institution, through the contribution of playful learning resources which help to make the environment more attractive and inclusive for youth; and within the broader community, through the sharing of these resources with others outside the centre to strengthen bonds and broaden access to new learning opportunities.

We designed a new co-construction kit – the fundakit – and related design concept – inclusive interactives – and formulated three guiding research questions:

- Did the design activity promote diverse participation?
- Did the kit and environment support interpersonal connections?
- Did interpersonal connections help advance the centre’s transformative agenda?

The fundakit is a co-construction kit for designing usable, computationally-enriched craft objects, implemented with wireless sensor networking (WSN) technologies. The kit is designed specifically for small groups of users and the design of multi-user projects. It contains a flexible number of physically discrete computational devices – network nodes with RFID capabilities and RFID tags – connected through wireless communication. The discrete nature of the devices enables group members to take temporary ownership of individual parts to implement changes for the project, and
wireless communication facilitates the integration of their efforts. These affordances also facilitate the design of projects for multiple users, who can take similar ownership of the completed project parts to use objects with others.

_Inclusive interactives_ are playful craft-tech interactive exhibits designed by groups in after-school centres, for after-school centres. They are modelled on Nina Simon's idea of the 'relational social object' [Simon, 2010], a museum exhibit which connects users and facilitates exchange. They are intended to be inclusive in two important ways: a.) the design process is planned to promote broad participation across the various interests and skills found in the comprehensive after-school centre, and b.) the making and ongoing use of completed interactives in and outside the centre should help to advance the institution's socially inclusive goals. _Inclusive interactives_ are designed with the types of crafting materials and tools typically found in comprehensive after-school centres, a limited number of novel crafting technologies, basic electronic components and tools, and the _fundakit_. They are designed to be fully usable, transportable, storable and sustainable.

The _fundakit_ and _inclusive interactive_ concept were explored in a four-year longitudinal study in a comprehensive after-school centre in Portugal (2011-2015). The study was framed as a centre activity with research intentions, and standard institutional procedures were followed. Youth chose to participate, and were free to continue participating for as long as they wished. They worked in small groups (3-5 members) to co-construct interactives for peers in the centre, and took these resources out into their community to share them with others. The duration of an interactive design process ranged from three months to two years. The kit design was iterated over the course of the study by observing the kinds of configurations that supported interpersonal connections, and the ways in which groups wanted to use the kit, and feeding these observations back into the design.
I used participant observation to gather various qualitative data, and 'thick description' accounts [Geertz, 1973] of four interactive design and use processes were written up from the data. A summary of each is presented, and analysed and interpreted in the context of the corpus. The analysis foregrounds the three interrelated study foci – youth diversity, interpersonal connections and transformative outcomes – and patterns occurring across processes are surfaced.

I now present two figures to help the reader picture how the hardware approach provides ways for small groups of youth to collaborate meaningfully around an emerging design object, and how these same affordances enable small groups of users to use interactives collaboratively. In both cases, multiple 'evenly-weighted' kit parts provide users with multiple points for engagement in the shared endeavour (design and use). Both interactives are described and analysed in Chapter five.

Figure 1: Collaborative Engagements in Design and Use
(left) The fundakit in use during the design of the A Batalha Ecológica interactive. The hardware approach has provided designers with multiple points for engagement in their shared endeavour. Youth are adapting the conductive layers of sensors to facilitate the passage of radio waves from RFID modules. (right) The A Casa das Palavras interactive designed with the fundakit being used by a group. The hardware approach has provided users with multiple points for engagement in their shared endeavour. Users are building words collaboratively with craft-tech letter cards.
Contributions emerging from the study relate to research and practice in the fields of social inclusion and learning technology design. For those working with youth in comprehensive after-school centres and other institutions with similarly broad-based developmental agendas, I provide descriptions of four collaborative technology design processes. The descriptions chronicle how heterogeneous groups of youth worked together over extended periods of time to design engaging new types of playful learning technologies for their centre – the inclusive interactivens. I also describe scenarios where youth shared these technologies with others outside of the centre, to show how technology design can empower young people act as change agents within their communities.

For researchers and designers in the learning technology field, I describe a new co-construction kit for designing usable craft-tech interactives, the fundakit. The kit is designed specifically for groups and the design of multi-user projects, and strongly informed by sociocultural perspectives on learning and development. I also describe a new sustainable model for designing tangible interfaces in under-resourced settings. The model enables reuse of core kit hardware and ongoing use of completed projects.

In the following chapter I introduce the foundational tools, objects and ideas underpinning the research study. In Chapters three and four I describe research design and the new co-construction kit we designed for the study. In Chapter five I present results from the four-year empirical study. The results include summaries of four thick descriptions of inclusive interactive design and use processes; analyses for youth diversity, interpersonal connections and transformative outcomes; and patterns in interpersonal engagements and arrangements across the four design and use processes that established opportunities to learn. Patterns are offered as insights with import for the design of transformative technology-based interventions in after-school centres.
Chapter 2. Foundational Tools, Objects and Ideas underpinning the Research Study

In this Chapter I provide the background to construction kits, relational social objects, and the 'homespun museum' concept that served as a starting point for the design of the study environment. Thereafter, I present the theoretical foundations for the study. They are centred on Rogoff's view that development is a process of people's changing participation in sociocultural activities of their communities. I begin with an outline of her transformation-of-participation perspective, then introduce the interpersonal plane of analysis she proposes for studying relationships between people as they go about participating in the sociocultural activities of their communities, and finally, present her guided participation concept which provides a perspective on how to look at interpersonal engagements and arrangements in activities to understand learning and development.

2.1 Construction Kits

The fundakit is a co-construction kit designed to support the collaborative design of usable craft-tech interactives – I use the term 'co-construction' rather than the standard 'construction' to emphasize my interest in nurturing and deepening interpersonal connections. I now provide a brief overview and history of construction kits, sketch out the idea of 'connections' in construction kit discourse, and reflect on issues of diversity and groups.

2.1.1 Overview and History

Construction kits (or computational construction kits) are systems for designing and creating things [Resnick & Silverman, 2005]. They can be purely software based, like Scratch [Scratch] and StarLogo [Resnick, 1997], or include a combination of software, hardware and related design materials [Eduwear][PicoCricket]. The latter type are generally known as 'tangible construction
kits' or simply 'tangibles'. A common thread running through almost all designs, be they software-based or tangibles, is the idea of 'learning through design': a process where users take charge of their own learning through the design of personally meaningful objects. Kits have been shown to be effective tools for engaging youth in design-based activities promoting technological fluencies [Kafai et al., 2007] and creative thinking [Resnick, 2006], and developments in the computational crafts area [Eisenberg et al., 2005] have helped broaden participation in these activities [Buechley et al., 2008][Rusk et al., 2008] and enabled youth to relate programming and technology to their lifeworlds [Katterfeldt et al., 2009]. Work with adults has shown how learning-through-design and acting in the local community can be productively combined to address rural development [Lyon, 2003][Mikhak et al., 2002].

Seymour Papert and colleagues at MIT pioneered work in the tangibles field in the 1980's and 90's with their LEGO/Logo and Cricket technologies [Blikstein, 2013][Martin et al., 2000], and Papert's constructionist learning theory, which informed work on these early designs, continues to influence developments in the field [Buechley et al., 2008][Resnick & Rosenbaum, 2013]. Constructionism builds on Piaget's constructivism, which posits that learning is an active process in which knowledge structures are built through ongoing internalisation of actions, by adding that the building and sharing of personally meaningful public entities provides an especially rich context for this learning. On the constructionist view, externalising ideas is as important as internalising actions [Ackermann, 2004]; the external object serves as an 'external shadow' of the designer's internal model, providing opportunities for reflection and revision [Resnick et al., 1996].

2.1.2 Kits and Connections

Resnick, Bruckman and Martin's landmark article, *Pianos not Stereos: Creating Computational Construction Kits* [Resnick et al., 1996], sketched out an early vision for construction kits, which,
as they put it, 'enable people to express themselves in increasingly ever-more complex ways, deepening their relationships with new domains of knowledge' [idem: 42]. In the article, the authors describe a theory of 'constructional design' which they use to guide the development of construction kits. They observe that constructional design is a form of metadesign, which involves the design of new tools and activities to support learners in their own design activities (designing for designers), and advance two general principles in the form of 'connections':

**Personal connections.** Construction kits and activities should connect to users' interests, passions and experiences. The point is not simply to make the activities more 'motivating'. When activities involve objects and actions that are familiar, users can draw on their previous knowledge, connecting ideas to pre-existing intuitions.

**Epistemological connections.** Construction kits and activities should connect to important domains of knowledge – and, more significantly, encourage new ways of thinking (and even new ways of thinking about thinking). A well-designed construction kit makes certain ideas and ways of thinking particularly salient, so that users are likely to connect with those ideas in a natural way in the process of designing and creating. [idem: 42]

They also state that 'constructional designers' should aim to create “spaces” dense with both types of connections, to enable learners to find areas that are both appealing and intellectually interesting. In keeping with constructionism's emphasis on 'the individual's conversation with their own representations, artifacts, or objects-to-think-with' [Ackermann, 2004: 20], what Crook describes as an orientation 'towards the needs of self-contained learners’ [Crook, 1996: 228], the focus is on the individual designer, the relationships they form with the objects under construction, and how these help to form internal models.
2.1.3 Kits and Diversity

Tangible construction kits have generally been designed around specific youth interests; often the kinds of things kids might want to invent for themselves. These include mobile robots, electronically-enhanced fashion, and interactive toys. Studies have found that some of these foci can strongly genderise participation in design activities – e.g. robotic competitions tend to attract mostly male users, while e-fashion design mostly female users [Turbak & Berg, 2002][Reichel et al., 2006][Buechley, 2008]. Other more gender-neutral foci, such as artistic creations integrating light, sound, music and motion, tend to promote more heterogeneous participation [Rusk et al., 2008]. Here designers have used themes that are open-ended enough to encourage a diverse range of projects, while specific enough to encourage workshop participants to share ideas and learn from each other. This 'multiple pathways' approach aims to leverage diversity for learning and development through the co-present authorship of separate objects, and their eventual juxtaposition in a shared exhibition environment. Rusk and colleagues propose four strategies for engaging a broad range of learners in robotics: (1) focus on themes, not just challenges; (2) combine art and engineering; (3) encourage storytelling; (4) exhibitions, rather than competitions [idem].

2.1.4 Kits and Groups

Tangible construction kits are regularly used by groups [Resnick & Silverman, 2005][Resnick, 2006][Rusk et al., 2008][Rusk et al., 2009], but there has been limited discussion about affordances that promote and support collaboration [Kafai & Vasudevan, 2015][Millner, 2010], and few explicit efforts to design for it. The Beatbug Network [Weinberg et al., 2002] and Quilt Snaps [Buechley et al., 2005] projects are notable exceptions, having been explicitly designed for interpersonal connections. In both, users coordinate efforts with their individual devices (hand-held percussive instruments and electronically-enhanced quilting patches) to produce shared creative works (compositions and quilts), and the use experience promotes thinking and acting at both individual
and group levels. I now offer summary descriptions of the Beatbug Network and Quilt Snaps projects to help the reader conceptualise the approach:

i. **Beatbug Network** – Beatbugs are hand-held percussive instruments that enable users to create, manipulate and share rhythmic motifs together. Multiple Beatbugs are connected up into local networks, allowing users to form 'large-scale collaborative compositions' by 'interdependently sharing and developing each other's motifs' [Weinberg, et al. 2002: 1]. A preliminary evaluation of the Beatbug Network revealed that the system supported conversations with and through objects. The authors observe that interpersonal interactions, such as making eye contact, looking, turning and pointing to coordinate musical events – a form of fun, collaborative, 'conducting' behaviour – and playful bodily interventions intended to surprise friends, emerged naturally through the shared compositions. They also share how participants, when asked about their learning experiences in comparison to traditional music classes, chose to emphasise the importance of communal music-making and peer-to-peer musical interaction.

ii. **Quilt Snaps** – Quilt Snaps is a fabric-based construction kit which consists of a collection of computationally enhanced quilting pieces or “patches” which kids can snap onto personal items such as backpacks and jackets or snap together to build up a variety of quilts with dynamic light flow patterns. Buechley et al. observe that the Quilt Snap 'quilting' allows for both individual activity (when users are decorating their individual patches with craft materials and electronic components), and collaborative work (when users combine their patches into a shared quilt with the dynamic light patterns). They note that while it is possible for users to interact with their individual patches, they obtain much more complex and interesting patterns by linking their patches together. In other words, much like the Beatbugs Network, the full creative potential of the work emerges through the combined and coordinated efforts of a group.
Researchers studying youth collaborative practices with kits not explicitly designed for groups have found that practice can be 'highly modularized', with youth taking on distinct roles and responsibilities within their groups, limiting their contributions to these areas, and rarely building and sharing ideas together [DuMont & Lee, 2012]. Also, youth often opt to participate in areas in which they are already comfortable, and avoid areas of discomfort (often programming) that could hold rich learning opportunities [Kafai & Vasudevan, 2015].

2.2 Relational Social Objects

_Inclusive interactives_ are playful craft-tech interactive exhibits designed by groups in after-school centres, for after-school centres. They are designed to connect users and facilitate exchange. Simon calls exhibits with these kinds of 'transactional' affordances _relational social objects_ [Simon, 2010]. I now provide a brief overview and history of relational social objects, grounding this overview in the pioneering work of Frank Oppenheimer. Following this I describe recent developments involving games, and calls for the democratisation of the design process.

2.2.1 Overview and History

Over the past forty years, interactive exhibits have helped transform museums from static collections into dynamic 'knowledge playgrounds' [Fröes & Walker, 2011]. These changes can be traced back to Frank Oppenheimer's pioneering work at the Exploratorium in the early 1970s [Cole, 2009]. Oppenheimer reframed the relationship with the museum visitor through a new form of exhibit, often designed rather than acquired, which required some form of physical engagement to 'create' the content. Increasingly youth go to museums to play with the exhibits, and many of these play experiences enable them to connect with others, share ideas about the content, and explore new ideas together. Simon [Simon, 2010] calls these kinds of exhibits relational social objects, because
of their ability to connect people and facilitate exchange – the museum exhibit as conduit. She views these interpersonal affordances as core criteria (along with artistic and historic significance) museums should be considering when planning their exhibitions.

Oppenheimer's work at the Exploratorium grew out of an earlier interest in designing experimental tools and contexts for the exploration of natural phenomena. Through this work he aimed to foster greater curiosity, awareness, and participation amongst young people. His 'Rationale for a Science Museum', the original proposal for the Exploratorium, provides a window into these concerns (it is worth keeping in mind that these words were written in 1968):

_There is an increasing need to develop public understanding of science and technology. The fruits of science and the products of technology continue to shape the nature of our society and influence events which have a world-wide significance. Yet the gulf between the daily lives and experience of most people and the complexity of science and technology is widening. Remarkably few individuals are familiar with the details of the industrial processes involved in their food, their medicine, their entertainment or their clothing. The phenomena of basic science which have become the raw material of invention are not easily accessible by the direct and unaided observation of nature yet they are natural phenomena which have, for one segment of society, become as intriguing and as beautiful as a butterfly or a flower._

_There have been many attempts to bridge the gap between the experts and the laymen. The attempts have involved books, magazines, articles, television programmes and general science courses in schools. But such attempts, although valuable, are at a disadvantage because they lack props; they require apparatus which people can see and handle and which display phenomena which people can turn on and off and vary at will. Explaining science and technology without props can resemble an attempt to tell what it is like to swim without ever letting a person near the water._ [Oppenheimer, 1968: 206]
The key word in the passage for the purposes of this text is 'props', which Oppenheimer describes as a form of tangible apparatus which renders intangible phenomena concrete, and enables users to manipulate the phenomena at will to better comprehend them. 'Props' were what would later become known as 'interactive exhibits', the playful scientific instruments that have become so popular amongst young users of today's museums. Interactive exhibits generally facilitate co-present exploration of a bounded physical microworld, and provide users with public feedback to allow them to develop and test hypotheses in a self-directed iterative manner. Oppenheimer envisaged multiple such props constituting a form of public 'laboratory' [idem], or 'woods of natural phenomena' [Cole, 2009: 148], in which young people could reconnect with the stuff of their surroundings in a fun and social way and build insights together. (His interest in visitor interaction was such that he chose not to put up signage for directions to the toilets.)

### 2.2.2 Social Objects and Games

Early interactive exhibits dealt primarily with natural phenomena, and did so through a blend of art and science. They were also often single entities, loosely modelled on the idea of a 'scientific instrument' or 'art object'. In recent years, content and approach to design have diversified as museums and other interpretive institutions have come to understand the potential of this new way of engaging publics and supporting social learning experiences. One trend is the use of games to promote interactions through the exhibition object [Beale, 2011][Jakobsson & Davidsson, 2012][Simon, 2010]. Games provide exhibition designers with ready-made cooperative structures and concepts they can design onto [Fröes & Walker, 2011]. To illustrate the growing richness of this approach, I now describe to two recent examples which take Oppenheimer's original idea of the public laboratory and imbue it with a distinctly playground character. The first was developed across a number of museums using state-of-the-art technology, the second distributed through a
single museum and created with traditional crafting technology such as sewing and cardboard cut-out models:

i. Internet Arm Wrestling – The internet arm wrestling exhibit was installed at six museums in the United States in 2004. It was designed to teach children about the next generation of networked hands-on applications. It used telehaptics – the ability to feel locally sensations applied at a distance – and consisted of a number of kiosks mounted at each museum. Each kiosk had a metal arm, which represented the remote opponent's arm, and a screen with video conferencing to allow opponents to see each other while wrestling. Users could wrestle someone in the same museum (at another kiosk) or another museum in the network. The metal arms exerted force on each player's arm equal to that applied by their remote opponent. While the exhibit was used by many individual users, it was also not uncommon for kids to gang together at one kiosk to take on a group of opponents at another site and communicate with them through facial expressions and physical gestures [Simon, 2010: 99]. The exhibit enabled users to create a unique distributed use experience for themselves – imagine taking on a group of kids in another part of the country and feeling their physical strength through the arm even though they are hundreds of kilometres away – that clearly demonstrated the core ideas underpinning telehaptics. Arm wrestling, in this case, provided a ready-made cooperative structure which facilitated youth cooperative engagement with the telehaptics topic.

ii. Porto Through the Game – The 'Porto Through the Game' exhibit was installed at the Casa do Infante Museum in Porto, Portugal. The designers aimed to help local kids learn about the city by allowing them to interact with a playful model. The model was a large floor-based puzzle, and each piece of the puzzle was a fabric cushion which represented a block in the city's historic centre. To assemble the puzzle, kids worked in small groups to find answers to questions written on flip-cards.
The answers were located throughout the museum and each card provided the general location of the answer in the museum. For each correct answer the group received a piece of the puzzle. The treasure hunt approach, a form of ‘guided discovery’, motivated kids to work together to find answers and build the model [Alexandre, 2011: 54]. Pieces were clipped onto a base mat with hook-and-loop fasteners, and youth collaborated on and around the surface to find the correct location and orientation for each piece. The size and unpretentious nature of the surface, coupled with youth familiarity with puzzles, paved the way for a very intuitive form of interaction with the exhibit. Once users had built the puzzle, they were required to create paper models of seven historic buildings located in the historic centre using cut-out templates, and place these in their appropriate locations on the map. The exhibit was a non-competitive game designed to foster teamwork and mutual support. Alexandre states that in initial testing in the museum, it was common for older kids to help and support younger peers [idem: 63]. The interactive exhibit was brought into physical existence through user collaboration, and the assembly and construction processes provided youth with ongoing opportunities to build and share knowledge through the emerging artefact. In this case, puzzles provided a ready-made cooperative structure which facilitated youth cooperative engagement with the layout of their city centre.

A number of common threads run through the two examples, surfacing how games can help both to promote and support interpersonal connections through social objects, and how museums can benefit from these interactions. Firstly, play worked as an aggregation tool, drawing different youth together and promoting interest in a shared endeavour. Secondly, multiple ‘game parts’ offered multiple points for concurrent engagement in the shared endeavour. And finally, game concepts provided users with familiar points of departure for engaging with the new topics, and game structures scaffolded cooperative engagement with these topics and the collaborative construction
of meaning. Fróes and Walker capture this potential in the following passage:

While museums and media, as well as play, all share a characteristic separation from the real world, when they 'play well together' they can lead to real gains, both cognitive and social. The very term 'visitor' implies passivity – someone who visits the museum and goes away. By contrast, a player is inherently active, and play enables museums to bridge their leisure and learning functions, to become knowledge playgrounds. [Fróes & Walker, 2011: 493]

2.2.3 Democratisation of Social Objects

Simon has described how the Boston Children's Museum went from being a museum about children and their families, to being a museum for them, and wonders what the museum would be like if it was made with them [Simon, 2010]. The with scenario imagined by Simon wouldn't have to conform to traditional museological models – she suggests it could look more like a coffee shop or a community art centre and function along the lines of a co-working space or sewing lounge. It could also be established in other settings frequented by youth on a regular basis, such as libraries and after-school centres. The making of social objects in such settings, for such settings, has the potential to extend learning opportunities upstream to the creative process, and establish rich learning trajectories from making through to use [Jakobsson & Davidsson, 2011]. Eisenberg and colleagues [Eisenberg et al., 2005] have envisaged such an informal learning space, 'infused' with museological ideas and practice, where users work with construction kits and digital fabrication devices to design their own 'personalised exhibits'. They call it the 'homespun museum', and foresee it taking root in schools and family homes. Their proposal is described further in the following section.
2.3 The Homespun Museum

The study environment was loosely based on Eisenberg et al.’s ‘homespun museum’ proposal. The homespun museum is a formal or informal learning space where youth make and use their own craft-tech interactive exhibits over time. I now outline the researchers' original vision and then reflect on how it could be extended to advance social inclusion.

2.3.1 Vision for a Homespun Museum

Eisenberg and colleagues have put forward a vision for a museological space that can be built up by kids at home or school [Eisenberg et al., 2005]. They call their DIY [Spencer, 2008] museological enterprise the 'homespun museum'. The museum is essentially a workshop in which users make and display their own 'personalised exhibits' over time. They observe that the increasing availability of 'accessible' digital fabrication devices and tangible construction kits allow users to re-imagine the room as a space for which they can design a new range of expressive and idiosyncratic educational objects. Such exhibits can be drawn up on a computer and 'printed out' on desktop devices such as milling machines, laser cutters and 3D printers – 'computationally-designed' exhibits – or be made from a range of other materials and have computation embedded inside them – 'computationally-enriched' exhibits. Fabrication and embedded technologies can also be combined to open up a range of other design and learning opportunities. The authors view the homespun museum as a way to revive the historic traditions of home crafting and home museums (cabinets of curiosities), and shift children away from passive consumer roles.

The homespun museum is manifest through practice rather than formal structure, and can therefore gain form in a variety of non-museological settings; the authors describe it as the 'diffusion of “museum values” into personal spaces' [Eisenberg et al., 2005: 19]. When manifest in the home,
the initiative would represent a return to an earlier tradition of domestic collections, known as ‘cabinets of curiosities’, the precursors of today's museums. There would however be an important difference between the original cabinets and their contemporary equivalents. The objects in the contemporary versions would be made by their owners, rather than purchased as they were previously, and as a result likely to hold greater emotional value. In the classroom, the initiative would be an extension of existing practice of classroom display, where teachers exhibit students' work to motivate the authors, show off examples of good practice, and improve the overall ambience of the learning environment. The new computational crafting tools would enable students and teachers to create and learn things that would have been a lot harder in the past; what Resnick refers to as 'design leverage' and 'conceptual leverage' [Resnick, 2006: 8].

2.3.2 Vision for an Inclusive Homespun Museum

The articulation of the homespun museum concept is specific enough to serve as a framework for the development of own implementations, and general enough to allow further creative development and localisations. For example, the researchers offer the terms 'computational crafts' and 'computational craftwork' to capture their vision for this approach to making own educational resources. The examples provided to illustrate the vision are mostly realised in the mind and 'made' by the computer. There is limited use of traditional 'hands-on' crafting materials and techniques, an area which is highly compatible with the proposed computational approach – something observed by the researchers themselves – and which could serve to significantly enrich maker learning trajectories, diversity of participation, and the overall exhibition environment. It could also make initiatives more sustainable by lowering material and making costs. The examples are also strongly connected to mathematics and science education, but other implementations could be focused on topics pertinent to the community or context in which the homespun initiative is seeded. For
example, it would be quite feasible to imagine implementations focused on local environmental issues, local languages (through storytelling), or health topics. Implementations also don’t have to be limited to schools and homes. It might be even more appropriate to explore contexts where youth spend significant amounts of their free time together, have a say in the shaping of the environment, and generally have limited access to state-of-the-art learning technologies. Comprehensive after-school centres are one of a number of institutions which fit this description, and they already offer youth access to computers and various creative activities. A homespun museum intervention in such contexts could serve as a low-cost, developmentally-rich way to introduce museological ideas and experiences into contexts with limited or no access to museums.

2.4 Development as Transformation of Participation in Sociocultural Activity

Barbara Rogoff’s sociocultural ideas underpin this study of the transformative potential of interpersonal connections through co-construction kits and in related design environments. I now outline her transformation-of-participation perspective, in which learning and development are viewed as changing participation in sociocultural activities. This is followed by a description of the interpersonal plane, which she proposes researchers foreground to study relationships between participants in sociocultural activities, and her corresponding guided participation concept, which provides a perspective on how to look at interpersonal engagements and arrangements in sociocultural activities to understand learning and development.

2.4.1 Transformation of Participation Perspective

In this study I adopt Rogoff’s ‘transformation of participation’ perspective [Rogoff, 1990, 1994, 1998], viewing human learning and development as a process of people’s changing participation in the sociocultural activities of their communities, which themselves change as a result of the
participation [Rogoff, 2003]. Rather than focusing on the acquisition of external models, the perspective emphasises the role of shared thinking, where development takes place through participation in shared endeavours in which the ‘individual is continually in the process of developing and using their understanding’ [Rogoff, 1998: 689]. Shared thinking can involve both agreement and disagreement, be intentional and accidental, be mutual and one-sided, and take place face-to-face and shoulder-to-shoulder. It can also be distal, and occur at different points in time. Cognition is viewed as collaborative, with people directly and indirectly involved in each other's thinking processes [idem]. Rogoff has offered the following description:

The view that development is a transformation of participation of people engaged in shared endeavours avoids the idea that the social world is external to the individual and that development consists of acquiring knowledge and skills. Rather, a person develops through participation in an activity, changing to be involved in the situation at hand in ways that contribute both to the ongoing event and to the person’s preparation for involvement in similar events. Instead of studying a person’s possession or acquisition of a capacity or a bit of knowledge, the focus is on people's active changes of understanding and involvement in dynamic activities in which they participate (Arievitch & van der veer, 1995; Gibson, 1979; Leont’ev, 1981; Pepper, 1942; Rogoff, 1990; Rogoff et al., 1994). Communication and coordination during participation in shared endeavours involve adjustments between participants (with varying, complementary, or even incompatible roles) to stretch their common understanding to fit with new perspectives in the shared endeavour. Such stretching to accomplish something together is development. As Wertsch and Stone (1979, p.21) put it, “the process is the product”. [Rogoff, 1998: 690] (emphasis from the author)

Transformation of participation in a collaborative craft-tech design activity could be manifest in various forms. It might involve respectful and constructive engagement in planning discussions and
gradual adoption of a shared activity repertoire [Wenger, 1999]. It could also include increasing participation in group endeavours such as research, project management and narration [Lave & Wenger, 1991]; the active use of concepts introduced at school or in the activity; and growing fluency with tools [Papert, 1996]. What is important is how people's roles and understanding change as the activity develops, how different activities relate to each other, and how people prepare now for what they expect in the future on the basis of their prior participation [Rogoff, 1998: 690].

2.4.2 Interpersonal Plane of Observation and Analysis

Rogoff's development-as-transformation-of-participation perspective is rooted in the sociohistorical theory of Lev Vygotsky and colleagues. Sociohistorical theory advocates that individual development must be understood in its social and cultural-historical context – i.e. Mind in Society [Vygotsky, 1978]. Vygotsky pictured development in four progressively expanding time frames that emphasise the interrelated roles of the individual and social world: at a genetic level in the form of species change; at a community-historical level in the form of tools and value systems; over individual lifetimes; and moment-to-moment learning in specific problem contexts. A core aspect of his theory is the idea that participation in cultural activities under the guidance of more skilled partners enables children to 'internalise' the community's tools for thinking. Efforts to understand development must therefore attend to 'the social roots of both the tools for thinking that children are learning to use and the social interactions that guide children in their use' [Rogoff, 1998: 682]. Leont'ev summed up Vygotsky's views on the relationship between the tools for thinking provided by a culture and development of individual thought processes as follows:

Vygotsky identified two main, interconnected features [of human productive activity] that are necessarily fundamental for psychology: its tool-like [“instrumental”] structure, and its inclusion in a system of interrelations with other people. It is these features that define the nature
of human psychological process. The tool mediates activity and thus connects humans not only with the world of objects but also with other people. Because of this, humans’ activity assimilates the experience of humankind. This means that humans’ mental processes (their “higher psychological functions”) acquire a structure necessarily tied to the sociohistorically formed means and methods transmitted to them by others in the process of cooperative labour and social interactions. But it is impossible to transmit the means and methods needed to carry out a process in any way other than in external form – in the form of an action or external speech. In other words, higher psychological processes unique to humans can be acquired only through interaction with others, that is, through interpsychological processes that only later will begin to be carried out independently by the individual. [Leont'ev, 1981:55]

Vygotsky developed the idea of the zone of proximal development, a region of sensitivity to learning in which children develop through their ongoing participation in problem-solving activities with the support of adults and more skilled peers. Vygotsky defined it as 'the distance between the actual development level as defined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or a collaboration with more capable peers' [Vygotsky, 1978:86]. The zone of proximal development defines those functions that are in the process of development, but have not yet matured – Vygotsky refers to them as the “buds” or “flowers” of development, which later become “fruits” of development [idem]. Rogoff observes that interactions in the zone of proximal development are 'the crucible of development and culture' [Rogoff, 1998:682], because they enable children to participate meaningfully in activities that would be impossible to attempt on their own, and cultural tools are passed on and adapted to complete the task at hand: 'people contribute to the creation of cultural processes and cultural processes contribute to the creation of people' [Rogoff, 2003:51]. The individual and cultural process are 'mutually constituting' [idem].
This understanding of development, as integrally bound up with and connected to cultural tools and others, led Vygotsky to search for a unit of analysis that preserved the inner workings and relationships of the whole. He argued that isolating the individual as the unit of analysis, broke down human functioning into elements that ceased to function as the large living unit did. He chose to focus on the unit of word meaning. Rogoff observes that Vygotsky's important contribution in this regard was the problematisation of the unit of analysis, which lead to further proposals. Bakhtin extended Vygotsky's focus on the word to a focus on dialogue, a unit which went further in preserving the interpersonal nature of human development, and Leont'ev extended it further by elaborating the concept of activity [Leont'ev, 1981][Rogoff, 1998].

Sociocultural theories, such as the transformation-of-participation perspective, have adopted the sociocultural activity as the unit of analysis, viewing individual, interpersonal, and cultural processes as mutually constituting [Rogoff, 2003]. Analysis may bring one into focus, but always with reference to the other two. Each is inherently involved in each other's definition. Rogoff observes that the challenge for researchers working with the sociocultural perspective, is to devise methods to study individual contributions in relation to participation in the sociocultural activity – i.e. not isolate the individual's contributions from the dynamic interpersonal and sociocultural elements [Rogoff:1998]. She proposes that the individual, interpersonal, and community/institutional developmental processes be viewed as different planes of observation and analysis, and that any one of them can be foregrounded for study while the other two are held in the background to inform the reading [Rogoff, 2003]. There are no boundaries between the three constituent parts of the unit, and it is incomplete to assume that development takes places in one and not in the others [Rogoff, 1995].
I chose to foreground the interpersonal plane for the study of the transformative potential of interpersonal connections in co-construction kits and related design environments, and used Rogoff's corresponding \textit{guided participation} concept to examine 'opportunities to learn'. Guided participation is described next.

\subsection*{2.4.3 Guided Participation}

Rogoff's \textit{guided participation} concept [Rogoff, 1990, 1995, 1998, 2003] 'provides a perspective on how to look at interpersonal engagements and arrangements as they fit in sociocultural processes, to understand learning and development' [Rogoff, 1995: 5]. It is a means for examining people's 'opportunities to learn' [Rogoff, 1998: 700]. It emphasises the identification of patterns in the organisation of sociocultural activities. Rogoff has proposed \textit{apprenticeship, guided participation,}\ and \textit{participatory appropriation,} as three 'inseparable' developmental processes that correspond to the three planes of sociocultural activity — \textit{community, interpersonal,} and \textit{personal} [Rogoff, 1995]. Summary descriptions of the three processes are now provided, followed by a more detailed description of \textit{guided participation} and its use in the study.

\textit{Apprenticeship} relates to the community plane of sociocultural activity. It extends the idea of craft apprenticeship to other culturally-organised activities where part of the purpose is the development of mature participation by less experienced people. Activities can include forms of work, recreation, family relations and schooling. The focus is on the specifics of the activity and its relation to other practices and institutions of the community in which it occurs. \textit{Guided participation} relates to the interpersonal plane of sociocultural activity. It refers to the processes and systems of involvement between people as they communicate and coordinate efforts while participating in the sociocultural activity. The “guidance” may come from materials, arrangements
and partners, while “participation” may take the form of observation or hands-on engagement. *Participatory observation* relates to the individual plane of sociocultural activity. It refers to how individuals change through their participation in the activities with more skilled peers and adults, and how in the process they become prepared for subsequent involvement in related activities.

Rogoff states that *guided participation* is not an operational definition that one can use to identify some interactions and arrangements and not others. Instead, it is meant to focus our attention on:

> the system of interpersonal engagements and arrangements that are involved in participation in activities (by promoting some sorts of involvement and restricting others), which is managed collaboratively by individuals and their social partners in face-to-face or other interaction, as well as in the adjustment of arrangements for each others’ and their own activities. [Rogoff, 1995: 5]

Two basic processes of *guided participation* appear to be common across cultures. Both involve children, adults and more skilled peers in the collaborative practice of: a.) 'building bridges from children's present understanding and skills to reach new understanding and skills'; and b.) 'arranging and structuring children's participation in activities, with dynamic shifts over development in children's responsibilities' [Rogoff, 1990: 8]. Rogoff refers to these two processes as the 'mutual bridging of meaning', and the 'mutual structuring of participation' [Rogoff, 2003: 285-287].

*Intersubjectivity* underlies the processes of *guided participation*, which Rogoff describes as the 'sharing of purpose and focus among individuals' [Rogoff, 1990: 9]; and Crook as 'shared understanding that is mutually recognised' [Crook, 1994: 80]. Intersubjectivity is built between people, and cannot be attributed to any one individual. It provides the grounds for communication, while supporting the extension of understanding to new information and activities: 'from *guided participation* involving shared understanding and problem solving, children appropriate an
increasingly advanced understanding of and skill in managing the intellectual problems of their community' [Rogoff, 1990: 8].

Guided participation is therefore an interpersonal process in which individuals manage their own roles and those of others – there is mutual involvement. Communication and coordination with others stretches the understanding of participants, who seek to establish common ground to enable them to proceed with the shared endeavour. This search for common ground, as well as efforts to extend it once found, involves adjustments and the growth of understanding [Rogoff, 1995]. Rogoff quotes Miller to explain how in the coordination of discourse, the product is jointly produced and individually appropriated:

although [a] joint argument will be mentally represented in individual minds, the process of construction proceeds by interlocking the cognitions of all the participants in such a way that a structural whole (the joint argument) can result. Thus each participant's thinking becomes more and more an integrative part of what everyone else thinks in the group, and therefore neither the meaning nor the mode of construction of each participant's cognition can be explained as isolated, individual mental entities. It is the mode of operation of this coordination device which explains the genesis of individual thoughts (in a collective argumentation). For example, if a participant of an argumentation changes his opinions, acquires some new information, or tries to resolve the contradiction between two different viewpoints and if it can be shown that these mental activities are linked up with the collective process of argumentation, then they are most probably not that subject's isolated mental activities. They are released, determined, or even made possible by the mode of operation of this coordination device, which in a sense surpasses the potentiality of individual subjects and represents a “reality sui generis,” a social reality. [Miller, 1987: 235, quoted in Rogoff, 1990: 196]
In the study, I focused on the co-construction kit and other pre-existing and introduced materials, as they were embedded in the system of interpersonal arrangements and engagements, in order to gauge their ability to support the 'interlocking' of cognitions and co-construction of a 'structural whole' (as described above by Miller): that is, a shared mental model of the design problem [Mohammed & Dumville, 2001][Mohammed et al., 2000]. In collaborative design projects, team members must build and maintain a common model of the design problem in order to use their knowledge and guide new information [Van den Bossche et al., 2011][Badke-Schaub et al., 2007]. Wood et al. describe shared mental models as the 'combination of individual team members' knowledge about the task being performed, tools available to execute that task, other team members' skills and abilities, and the procedures for interacting with other team members' [Wood et al., 2014: 211]. The models enable members to 'form accurate explanations and expectations for the task, and, in turn, coordinate their actions and adapt their behavior to demands of the task and other team members' [Cannon-Bowers et al., 1993: 226]. They increase the team's ability to share, process and utilise information [Mancuso et al., 2011]. The concept refers both to the 'multiple levels or sets of shared knowledge' and the 'synergistic functional aggregation of the team's mental functioning representing similarity, overlap, and complementarity' [Langan-Fox et al., 2004], and is thus closely aligned with the common ground concept (e.g. [Rogoff, 1995]) advanced by the learning sciences [Van den Bossche et al., 2011]. Shared mental models are, however, not only about establishing and maintaining mutual understanding; they also require mutual agreement [idem].

2.5 Insights from the Literature

I found that in keeping with constructionism's emphasis on the individual's conversation with their representations or 'objects-to-think-with' [Ackermann, 2004], the focus in construction kit design has been on the individual designer, the relationships they form with their objects under
construction, and how these help to form internal models – a focus on individual connections. Many authors have described scenarios where groups have used kits to design objects, but few have reflected on how kits designed for individual connections scale for groups, or detailed affordances that support co-construction and group collaboration patterns around them. The few researchers that have studied group use of kits designed for individual connections have described a 'modular' form of collaboration, with users taking on distinct roles and responsibilities within their groups, and often limiting their contributions to these areas. Users also often opt to participate in areas in which they are already comfortable and avoid unfamiliar areas which could hold rich learning opportunities. There therefore appears to be limited differentiation between individuals and groups in kit designs; the results from studies of groups using kits designed for individual connections suggest there is limited mobilisation of others for learning and development; and perhaps most importantly, opportunities to learn through mutual involvement in shared activities remain largely under-explored in kit designs.

The few kits that have been explicitly designed for groups have adopted a device collection approach. Group members take temporary ownership of individual 'evenly-weighted' devices (at a system level) and collaboratively co-construct shared creative works. The full creative potential of the work emerges through the group's combined and coordinated efforts with their individual devices. One can think of it as the physical digital equivalent of assembling a complex puzzle together, where each member of the group assumes responsibility for individual puzzle pieces, and works with the others to build out the bigger picture. This approach supports conversations with and through objects, or individual and interpersonal connections. Users reflecting on their learning experiences after using these designs highlighted communal making and peer-to-peer interaction as valuable. Work in this area has thus far been limited to music and e-textiles. It appears likely that other creative areas could hold similarly rich learning opportunities.
Rogoff’s transformation-of-participation perspective offers theoretical foundations for *interpersonal connections* in tangible co-construction kits. It emphasises the role of *shared thinking*, where development takes place through participation in shared endeavours in sociocultural activities, in which the individual is continually in the process of developing and using their understanding [Rogoff, 1998]. Communication and coordination during participation in shared endeavours involves adjustment between participants, who must stretch their shared understanding to fit with new perspectives in the shared endeavour, and this stretching to accomplish something together is development. Kits implementing the device collection approach provide multiple points for meaningful engagement in a shared endeavour, and group members must communicate and coordinate their efforts carefully with individual devices to achieve a collectively-valid end result. Communication and coordination with others in a group to create a shared work with multiple devices can serve as a mechanism for learning and development. Rogoff’s interpersonal plane of analysis can be foregrounded to study relationships between group members as they go about building and maintaining a *shared mental model* of their design problem in order to advance their shared endeavour, and her *guided participation* concept provides a perspective on how to look at interpersonal engagements and arrangements to understand learning and development.

Finally, I find a convergence in thinking in museological and learning technology fields around the democratisation of exhibit design. Researchers in the museological field working with sociocultural perspectives have identified a potentially rich learning trajectory, from making through to use of interactive exhibits, while others have argued strongly for the adoption of participatory design strategies involving children, and have offered visions for a more inclusive type of museum based on this approach. In the learning technology field, researchers working with construction kits and digital fabrication have shown how young people can use these technologies to design personalised
exhibits, and how making spaces can double up as exhibition spaces. Their ideas are similar to those advanced by the museological field, only offered from a learning technology perspective. This convergence in thinking points to a relatively new area of creative and developmental work that appears to be dense with learning opportunities. Relational social objects incorporating play would make a good starting point for an exploration of these opportunities. These exhibits are popular among young museum users and are designed to support interpersonal connections. Interpersonal connections could be extended upstream to the design phase through tools and environments, to establish a learning trajectory from making through to use, which would mobilise opportunities to learn through mutual engagement in interpersonal processes.
Chapter 3. Research Design

In this chapter I present the research design for the study. I begin with background about the context, first providing an overview of the comprehensive after-school model, then describing the Programa Escolhas after-school network in which I conducted the study, and finally highlighting the issue of variability across comprehensive after-school centres. Following this, I describe participation in the study, and the educational approach I used. The last two sections focus on methodology. In the first I present the methodology for the design of the kit, and in the second the methodology for the study of the kit and related social and cultural developments. The two were closely intertwined throughout the study. The approach was informed by Dourish's 'ethnographically grounded design' [Dourish, 2007: 14], which strives for an engagement between ethnography and design that goes beyond ethnographic enquiry or design practice, and results in a third 'project' [idem].

3.1 Context Background

I now provide background about the study context. I begin with a brief overview of comprehensive after-school centres to help readers understand the differences between these programmes and other more targeted initiatives such as community technology centres and youth sport programmes. This is followed by description of the comprehensive after-school network in which I conducted the four-year ethnographic study, the Programa Escolhas [Programa Escolhas] in Portugal. Finally, I foreground the issue of variability across after-school centres, and how differences in a number of key areas shape developmental outcomes.
3.1.1 Comprehensive After-School Centres

Comprehensive after-school centres, also known as afterschool centres, afterschools, and after-school programs, aim to support youth learning and development in socio-economically vulnerable communities during out-of-school hours [Hirsch et al., 2011]. Participation in and funding for these programmes has grown significantly in some countries in recent years. For example, in 2008 the Harvard Family Research Project estimated that there were about 6.5 million children and youth participating in after-school programmes in the USA [Harvard Family Research Project, 2008], and the 21st Century Community Learning Centers (21st CCLC) initiative, a federal funding source dedicated exclusively to after-school programmes, exceeded one billion US dollars as of 2008. The Boys & Girls Clubs of America grew from 1800 clubs in 1997 to 4000 in 2008 [Hirsch et al., 2011]. And the Programa Escolhas network in Portugal, in which I ran the study, grew from 50 centres serving 6000 children and youth in 2001, to 141 centres serving 69000 children and youth in 2014 [Relatório de Atividades do Programa Escolhas, 2014]. The model is being actively developed and evaluated in a number of other countries.

Hirsch et al. argue that it is easy understand the push for after-school programmes in the United States, especially when considering school-age adolescents in low-income urban communities. They sum up the challenges and opportunities for this demographic in the US, and how after-school centres are working with them:

*These young people need to cope with violence and poor schools on a daily basis. Job opportunities are often few and far between. Adult role models can be in short supply as the middle class has largely abandoned these neighbourhoods, many men are in prison, and parents often work shifts that leave little time for guidance and support. After-school programmes hope to step into these gaps and supplement what youth receive from family and school.*
Becoming an adolescent involves entering a period of increased susceptibility to emotional and behavioral problems as well as disconnection from school. But adolescence is not just a time of increased risk. Other hallmarks of adolescence — experimentation with possible identities, exploration of new roles, intimacy in relationships, and concern with the future — bring with them important opportunities for growth. Increasingly, researchers and practitioners who work with teens are doing so within the frame of “positive youth development.” This lens emphasizes the strengths that youth bring with them to the table, examining how contexts can support the development of characteristics such as character, confidence, connections, and competence.

Good after-school programs and the centers that are home to them can provide the nurturance and challenge that young people crave. The adult staff, often of the same race and ethnic background, can appreciate the youth’s life circumstances and provide mentoring, with plentiful amounts of warmth, encouragement, and guidance. Staff can demonstrate positive values in action, showing by example how acting responsibly elicits respect. Centers can offer challenging programmes and activities that promote learning and developmental growth as well as teach young people how to navigate dangerous situations. The safe environment of a high-quality center can shelter youth from violence, keep them out of trouble, and give them a chance to develop knowledge, skills, and attitudes that they need as a foundation for adult life. [Hirsch et al., 2011: 4]

Increasing investment in after-school programmes has been accompanied by parallel investments in research and evaluation studies and syntheses. The Harvard Family Research Project notes that: 'A decade of research and evaluation studies, as well as large-scale, rigorously conducted syntheses looking across many research and evaluation studies, confirms that children and youth who participate in after school programs can reap a host of positive benefits in a number of interrelated outcome areas —academic, social/emotional, prevention, and health and wellness' [Harvard Family Research Project, 2008: 2]. Academic outcomes include better attitudes toward school and higher
education aspirations; higher school attendance rates; less disciplinary action; lower drop-out rates; better performance in school; improved homework completion; and engagement in learning. Social/emotional outcomes include decreased behavioural problems; improved social and communication skills and/or relationships with others; increased self-confidence, self-esteem, and self-efficacy; lower levels of depression and anxiety; development of initiative; and improved feelings and attitudes towards self and school. Prevention outcomes include avoidance of drug and alcohol use; a decrease in delinquency and violent behaviour; increased knowledge of safe sex; avoidance of sexual activity; and reduction of juvenile crime. Health and wellness outcomes include increased physical activity; increased knowledge of nutrition and health practices; and improved body image [idem].

Durlak et al.'s meta-analysis of after-school programmes (ASPs) seeking to promote personal and social skills in children and adolescents found that:

*Current data indicate that ASPs had an overall positive and statistically significant impact on participating youth. Desirable changes occurred in three areas: feelings and attitudes, indicators of behavioral adjustment, and school performance. More specifically, there were significant increases in youths' self-perceptions, bonding to school, positive social behaviors, school grades, and achievement test scores. Significant reductions also appeared for problem behaviors.*

[Durlak et al., 2010: 302]

Lauer et al.'s meta-analysis found a positive effect on the achievements of 'academically at-risk students', with significant gains in reading and maths in elementary, middle and high school students [Lauer et al., 2006].
Centres are generally located within walking distance of youths’ homes, are safe spaces they can go to after-school and in the school holidays, and offer a range of adult-supported activities. Activities can include homework time, sports, games, recreational and study outings, performative arts, arts and crafts, seminars with guest speakers, computer access and training, and social work in the community. For the most part it is youth who choose to frequent these settings, and the activities in which they participate. Proximity, safety, inclusivity (diversity in the activity programme) and freedom of choice, make centres ideal settings for youth to try out new interests and explore them over time. Sustained participation in well-structured and well-implemented programmes can lead to the development of knowledge and skills that are often difficult to acquire at home or school, and the formulation of career dreams and plans. As such, centres can be interruptive institutions where the cycle of exclusion can be broken, and youth development addressed, over the long-term.

Youth-staff relations play a central role in the success of after-school programmes. In a four-year study in six urban after-school centres in the Boys and Girls Clubs of America, three quarters of youth reported that their club served as a 'second home', and the primary reason for this was the quality of relationships (rather than the physical characteristics of the site) [Hirsch, 2005]. Youth-staff ties, in the form of mentoring relationships, were identified as 'the heart and soul, the most fundamental strength' of the urban after-school programmes [idem: 131]. Ana (pseudonym), the longest-serving member of staff in the after-school centre in which I conducted the study, stated regularly that most youth regarded the centre community as their 'second family' (segunda familia). Ana's views were regularly confirmed through the support I observed youth offering to each other, and the emotional farewell parties arranged for youth re-emigrating with their families. Emotional ties in this context were between youth and staff, and amongst youth themselves, and cut across age-groups and gender.
3.1.2 The Programa Escolhas After-School Network

The principle research site in the study was a comprehensive after-school centre in the Programa Escolhas (PE) network in Portugal [Programa Escolhas]. The site was selected from an initial sample of four PE centres that participated in the first phase of the study. PE is an official governmental programme launched in 2001. Its mission is to promote the social inclusion of children and youth living in 'socio-economically vulnerable' contexts, with a view to achieving equality in opportunities and strengthening social cohesion [idem]. It falls under the auspices of the Presidency of the Council of Ministers (Presidência do Conselho de Ministros) and is integrated into the High Commission for Immigration and Intercultural Dialogue (Alto Comissariado para a Imigração e Diálogo Intercultural). At the start of the study (2011), PE had defined five strategic areas for intervention: i.) Inclusive Schooling and Informal Education; ii.) Professional Training and Employability; iii.) Civic and Community Participation; iv.) Digital Inclusion; v.) Entrepreneurship and Capacity Building for Youth. Centres were required to design their programmes around one or more of these strategic areas. Those that chose to intervene in the digital inclusion area, had to combine the intervention with one or more of the other four strategic areas; i.e. use digital inclusion as a means to address the other area/s. Centres had to have at least three local partners, which could include schools, associations and religious bodies (amongst others). The number of centres in the PE network grew during the four-year study period, from 134 in 2011 to 141 in 2015 [Relatório de Atividades do Programa Escolhas, 2014]. Centres were supported through three-year renewable funding cycles, known as gerações (generations).

Centres making interventions in the digital inclusion area were equipped with a Centro de Inclusão Digital (Digital Inclusion Centre) – known internally as a 'CID' (pronounced as 'sid'), which comprised roughly half a dozen personal computers connected to the internet, a multi-functional printer, a digital camera, and a video camera. PE also had agreements with a number of on-line
publishers and training initiatives, which provided free access to their materials and courses. CIDs were run by a dedicated staff member, who oversaw use, ran short training sessions with standard software packages (email, word processing, web browsing, etc.), promoted safe online practices, and provided technical and homework support. CIDs were required to be open for a minimum of thirty five hours per week. Kids generally used the computers to check and update social media, play games, watch videos, complete online learning tasks, and do homework. Older youth used the facilities to prepare CVs and seek employment opportunities. There was limited creative work and almost no computer programming.

3.1.3 After-School Centre Variability

All the centres in the Programa Escolhas network were required to implement the same basic institutional model [Despacho Normativo no. 27/2009], but were given the liberty to develop their own foci and design their activity programmes and spaces around them. I found significant variation across the four centres that participated in the first phase of the study, and this variation influenced the research activity outcomes. Hirsch et al. observed variation across centres in another comprehensive after-school network [Hirsch et al., 2011], and identified activity programmes, youth-staff relationships, and centre culture as variable factors which influence youth development. In another collaborative learning study in two settings in the Fifth Dimension after-school education programme [Cole & Distributive Literacy Consortium, 2006], researchers found 'cognitive success' was strongly influenced by the generation of a culture of collaborative learning, which in turn was influenced by the affinity between the internal culture of the Fifth Dimension programme and the larger cultural environment of the host institution – in their case an after-school centre and a library [Nicolopoulou & Cole, 1993]. The researchers note that the 'culture of the site, understood as a collective reality – as an activity system – is thus the key explanatory factor in accounting for the different patterns of generation and accumulation of knowledge bound up with a particular activity:
The same task-activity evolves differently and comes to be imbued with different meaning within two different sociocultural contexts’ [idem: 306]. Variation in centre culture, youth-staff relations, and activity programmes across the four Programa Escolhas centres also played a role in the variation of the research activity outcomes in phase one, as did the specific foci of each of the centres and staff's creative experience with digital media.

3.2 Participation

I now describe participation in the study. I begin with a summary description of the group of youth that participated in the research activity at the principle study site. I then outline measures I took to anonymise their participation, and explain decisions taken about the use of photography in the dissertation. Finally, I explain participation in the study, describing the framing of the research activity in the centre, parental consent, and youth understanding of the project.

3.2.1 Youth Participants

The target age-group for the study was 10-16 years. Youth participated voluntarily in the research activity, and were free to continue participating for as long as they chose. Gender composition fluctuated over the course of the four years: initially evenly balanced in the first phase (3 girls, 3 boys), then slanted in favour of the boys during the second phase (1 girl, 7 boys), and finally more evenly balanced during the third phase (6 girls, 9 boys). The greater presence of boys reflected a broader gender imbalance in the centre community for the chosen age-group – girls of this age were often tasked with home cleaning and looking after younger siblings. Participant numbers grew after each phase, suggesting a growing interest in the activity in the centre community. Also, a number of the younger children who used the interactives and assisted participants with their tests, indicated that they planned to join the activity when they were old enough. Ongoing participation in tests
over extended design periods was a form of *legitimate peripheral participation* [Lave & Wenger, 1991] – the younger children observed what their peers were doing, listened to their conversations, and revealed their growing understanding by acting in advance of the designers' instructions.

A total of seventeen youth participated in the study. Some youth participated for the full four years (three out of the three youth who were in positions to do so), while others participated for shorter periods, either because they entered the activity later, re-emigrated to another EU country with their family, drifted away from the centre, had an altercation with a peer, were taken out of the centre because of domestic issues, experienced incompatibility with their other timetables, moved to another neighbourhood, or chose not to participate further (two youth). The average duration of participation was twenty-seven months. Thirteen participants completed at least one interactive, with design periods ranging between three months and two years. Eight of the ten youth who were in positions to design a second interactive chose to do so.

Fifteen of the seventeen participants were of African origin. Some of these youth saw themselves as Portuguese kids with African roots, and others as Africans (Angolan, Cape Verdean, Guinean, etc.) growing up in Portugal. The children with no ties to Africa were from Portugal and Eastern Europe respectively. All youth spoke Portuguese, either as a first or second language. Portuguese was used as the language of instruction and conversation in the activity. The community was in a constant state of flux during the four-year study period, with families immigrating and re-emigrating each year. Youth were aware of my African origins, but chose to play them down, much like they played down their own woven identities.
3.2.2 Participant Privacy

Youth chose pseudonyms for themselves. I chose pseudonyms for staff and renamed the four centres that participated in the study. I also erased the principle centre's name and youths' names from all photos, and chose not to include any photographs of the exterior of the centre or the surrounding neighbourhood. I omitted personal details of youths' and staffs' lives when I thought they could be damaging in some way. I did however choose to include some personal details about youth and staff where I thought it was important for understanding issues raised through the study. I endeavour to do this in a way that captures the complexity of the situation without revealing much of the detail. I chose not to pixelate the faces of youth and staff in the photos, because I believe this information contributes to the overall reading of the ethnographic texts and findings.

3.2.3 Youth Participation

The staff member responsible for the digital inclusion programme informed youth about the activity shortly before the start of the study. Youth chose to participate, and were free to continue participating for as long as they wanted. The study was framed as a centre activity with research intentions, and ran for four years following standard institutional procedures. Staff were informed about the purpose of the study and consented on behalf of parents. They informed parents and liaised with them in an ongoing way about their children's participation. Youth were informed about the purpose of the study orally during the activity. They were also exposed directly to the research process through my open and transparent collection of different data. I encouraged active participation in this process – e.g. copying work-in-progress versions of programmes and project documents to my external storage devices at the end of sessions – to further promote understanding of what I was doing.
3.3 Educational Approach

I now describe the educational approach I adopted for the study. I used Rogoff's *community of learners* instructional model [Rogoff, 1994] in a learning environment based loosely on Eisenberg et al.'s *homespun museum* concept [Eisenberg et al., 2005]. Youth made and used *inclusive interactives* in groups in the 'homespun museum' environment over the four-year study period, and took them out into the community to share them with others. I begin with an overview of the *community of learners* model and then describe the *homespun museum* learning environment we established in the centre for the study. Finally, I present the *inclusive interactive* design concept we developed through the study.

3.3.1 Instructional Model

I used the *community of learners* instructional model [Rogoff, 1994][Rogoff et al., 2001] because of its fit with the theoretical perspective that learning is a process of transformation-of-participation in the sociocultural activities of a community [Rogoff 1998: 715]. Rogoff et al. describe the model as follows:

> both children and adults engage in learning activities in a collaborative way, with varying but coordinated responsibilities to foster children's learning. Adults are responsible for guiding the overall process and for supporting children's changing participation in their shared endeavours. Adults provide leadership and encourage children's leadership as well, and they learn from the activities in which they engage with the children. This perspective thus eliminates the dichotomy of adult-controlled learning versus children-controlled learning; it substitutes a quite different arrangement in which children and adults are partners rather than adversaries. The structure of the community is carried through the group's collaboration and can continue to function even in the short-term absence of any individual (including a teacher); people learn to fill in for others' complementary responsibilities.  [Rogoff, et al., 2001: 7]
The model also calls for adult facilitation of complex (rather than dyadic) interactions among group members, and the use of conversational instructional discourse embedded in youth inquiry [Rogoff, 1994]. I implemented the model by structuring the design process in ways that enabled youth to gradually scale up towards what they needed to know to implement their ideas, running sessions in an open dialogical manner so that youth felt comfortable expressing their ideas and building on and questioning those of others (peers and participant leaders), and offering and soliciting various forms of support to enable youth to work in a zone of proximal development [Vygotsky, 1978]. I also compared new problems to those which youth had seen previously, to help them to see them as versions of these 'solved' problems [Schön, 1984], and broke down large complex problems into collections of smaller runnable ones. I worked with youth to implement and test these smaller problems, and to connect them into a solution to the larger problem – helping them to solve the problem at hand and learn about techniques of abstraction and modularisation. The model allowed us to engage youth diversity, and to manage the often large gap between what youth knew coming into a design process and what they wanted to achieve by the end of it. The participants would have found it extremely difficult to 'tinker' [Resnick & Rosenbaum, 2013] their way towards solutions to the problems they had set for themselves.

3.3.2 Learning Environment

I arranged the environment for collaborative making and use, basing it loosely on Eisenberg et al.'s concept of the homespun museum [Eisenberg et al., 2005] – see section 2.3 for a detailed description. The centre's practice of making and exhibiting art and crafts in their multi-use area provided a ready-made context for the initiative. I situated the activity in this practice, by using much of the same infrastructure and adopting and adapting community routines, and worked with youth and staff to extended it into the 'computational crafts' [idem] domain. Their input, through
their ongoing participation, helped to guide it in directions that made sense for the community. I remained attentive to emerging patterns and trends in the centre throughout the study, and explored ways to integrate those I thought would benefit the activity in some way.

Youth were introduced to the *inclusive interactive* concept through use. In phase one, due to the lack of in-house examples, I presented two interactives designed outside the centre. One was narrated in Cape Verdean Creole, the second most commonly spoken language in the centre community. In-house examples were used in all subsequent introductory sessions. The examples, which were evidently handmade and strongly tied to the community in a number of ways, helped to illustrate what could be made and build motivation to make it. After using the interactives, we examined the underlying technology together, and drew connections between it and youths’ experiences with similar publicly-installed systems. Technologies used in the examples were explored further through a series of short group exercises. In later exercises, youth built simple playful versions of commercial devices (such as a light meter, burglar alarm, pedometer, remote control and RFID reader), and used them together to learn about materials, concepts and components they could use in their projects.

After completing the exercises, groups worked together to design their own *inclusive interactive*. Group size varied between three and six members, and in one case two groups of five members opted to combine forces to design an especially challenging piece of technology that was used in both of their projects. In phase one, youth self-organised into groups. In phases two and three, we discussed group composition with youth and worked with them to establish an even distribution of interests and skills. The structure of groups was cohesive but also flexible, which appeared to be the norm in the centre. Youth chose to solicit support from members of another group known to be skilled in an area they were finding challenging; asked members of another group to assist them
when they could see they had nothing to do in their own group; requested to participate in a particular stage of another group's project out of interest; and recruited members of other groups (and other kids not participating in the activity) to assist in tests. These informal inter-group engagements were encouraged. In some cases I actively promoted these collaborations to solve difficult design problems.

I iterated the approach to running the sessions over the course of the study, retaining elements that promoted interpersonal connections and discarding those that didn't. The final solution was used in workshops in phase three of the study. Depending on the tasks planned for the session, we either established a discussion area by placing chairs in a semi-circle in front of a projection wall and taping up large sheets of newsprint to list ideas, sketch diagrams, and record technical details, or set up dedicated work areas on the small table and chair sets dotted around the space. We used the discussion area for project planning and programming (when the centre's data projector was available). For the planning, I facilitated the overall discussion and youth took it in turns to stand up at the large sheets of newsprint and write up decisions and draw up ideas. The person doing the writing and drawing was encouraged to lead on specific points. Other members offered ideas and instructions from where they were seated. The collectively authored documents, which reflected the collaboration process through the different handwriting styles, generally remained taped to the walls for the duration of the implementation process for reference purposes. They helped establish a distinct activity identity in the region of the multi-use area we used for craft-tech design. For the programming, we projected the Scratch environment and talked to the image. One youth stood up at the projection to lead discussion and provide instructions for implementation, while another sat at the projector table to implement the group's decisions. I adopted a background facilitator role, posing questions, making suggestions, and offering clues and prompts. Youth rotated roles regularly to bring everyone into the process.
The dedicated work areas set up on the centre's small table and chair sets were appropriate for group and individual work. For group work, members generally sat around the round tables, facing in toward a shared work area and each other while working on similar or related tasks. This enabled them to observe each other's efforts and progress towards shared goals without breaking off from what they were doing. It also facilitated discussion and shared decision making. For the individually-orientated tasks, like soldering, heat-shrinking and hot gluing, youth generally laid out the tools and parts as they wanted them, and used the surface as they saw fit. They regularly paired up for these tasks, adopting asymmetrical roles which reflected their understanding of each other's abilities. When the centre's data projector wasn't available, youth set up a programming area on one of these table and chair sets. They huddled around the screen and rotated and shared the programmer role. For the audio recording, groups set up a makeshift studio in the staff kitchen, the only space in the centre with a certain amount of peace and quiet.

![Figure 2: Environment Arrangements](image)

(left) The activity discussion area, showing the projected image of the Scratch user interface, chairs positioned in a semi-circle, and project notes and diagrams taped to the wall. (right) One of the centre's table and chair sets that were dotted around the multi-use area. Youth set up dedicated work areas on them for sessions and tidied away afterwards.
When possible, sessions were run with the staff member responsible for the digital inclusion programme. We worked together to run sessions in an open dialogical manner, and encouraged groups to externalise their ideas regularly in tangible forms to promote the 'mutual bridging of meaning' and 'mutual structuring of participation' [Rogoff, 2003], and encourage reflection on the emerging shared mental model of the design problem. These intermediate social objects, which included maquettes, low-res prototypes, schematic diagrams, materials tests, etc., as well as our tools, materials and work-in-progress project parts, were stored in the funda activity cupboard between sessions, and retrieved at the start of a new session for further work.

Completed interactives were used with other members of the centre community in the same space. They were used like other play resources, with youth gathering around the shared interactive and alternating between active and passive user roles. These uses allowed peers to examine the activity and develop interest in their own time. The interactives were also taken out into the community and shared with others, in settings such as a local school, shopping mall, old-age home and hospital.

Figure 3: Funda Activity Cupboard
(left) A participant storing interactive parts inside the activity cupboard at the end of a session. (right) The funda activity cupboard, showing materials tests, materials, interactive parts, kits, tools and a mock-up.
3.3.3 Design Concept

In all three phases of the study, youth designed and used personalised exhibits which I call *inclusive interactives*. The *inclusive interactive* concept extends Simon's idea of the *relational social object* – a museum exhibit which invites interpersonal use and facilitates sharing and exchange [Simon, 2010] – by involving groups of youth in after-school centres in the design of their own craft-tech version of these objects for the setting and surrounding community. The content of the interactive is related to youths' interests and topics they deem important for their community, and structured around some form of game or playful challenge. The design process includes extended group work in various areas, including concept development, content research, interaction design, writing, drawing, craft construction, electronics, programming, project management, narration, and the recording and editing of audio content.

*Inclusive interactives* are designed with the types of crafting materials and tools typically found in after-school centres (recycled cardboard, alkaline glue, pencils, beads, cutting knives, scissors, etc.), a limited number of novel crafting technologies (sugru [Sugru], 3D printers, aluminium tape, anti-static foam, etc.), basic electronic components and tools, and the *fundakit*. They are designed to be fully usable, transportable, storable and sustainable. For the latter requirement, we developed a new interface model which supports reuse of core hardware and the ongoing use of designed objects. I call this model the *plug-and-play interface*, because hardware is temporarily embedded in a craft-tech tangible user interface (TUI) for use and removed afterwards for use in other projects. The craft-tech TUI can be built with a variety of materials and techniques. We used recycled cardboard as our principle material, because it was free, readily accessible, robust, and easy for youth to work by hand. Multiple cardboard layers were glued together to build up three-dimensional forms, and negative areas were cut away from forms by making incisions and peeling away unwanted layers. Youth made up their own sensor and switch cables to fit the unique requirements of their projects,
Figure 4: The Plug-and-Play Interface Model
(left) Members of a group temporarily embedding fundakit hardware inside a craft-tech TUI for use. The interface contains project-specific electronics. (right) The assembled device in use in the interactive. The user is rolling a virtual dice by pressing one of the three press-buttons embedded in the interface.

and embedded them in the interface form with hot glue. The multi-layered cardboard provided a robust surround for embedding sensors and switches, and cables were run and secured in internal channels. Cables are terminated in mini-jack plugs for plugging into the sensor ports on the fundakit hardware. Visible surfaces of the cardboard, cables, switches, etc. were covered with a variety of materials (coloured vinyl, sponge, sugru, beads, extruded PLA, etc.) to provide users with information, personalise aesthetics, and add body and protection to specific elements.

3.4 Methodology for the Design of the Co-Construction Kit

In this section (3.4) I describe the methodology for the design of the kit, and in the following section (3.5) I describe the methodology for the study of the kit and related social and cultural developments. There was interplay between the two methodologies throughout the course of the study. Ethnographic observations about the use of the kit and related social and cultural developments shaped the kit design, which was studied further to inform potential further iterations – what Dourish calls an 'ethnographically grounded design' [Dourish, 2007: 14]. A full technical
description of the final version of the co-construction kit is offered in Chapter four. This version
was used by all three groups in phase three (2013-2015), the final phase of the study. Two
interactives designed with this version are presented and analysed in Chapter five.

3.4.1 Co-Construction Kit Design

We designed a new co-construction kit for the study using wireless sensor networking (WSN)
technologies. The kit is called the fundakit. I iterated the design over the course of the study by
observing: i.) how youth wanted to use the tool, and ii.) the kinds of configurations that promoted
interpersonal connections; and feeding these observations back into the design. I began with the
simplest network, a single reader/node transmitting data to a host, and gradually increased the size
of the personal area network (PAN) to accommodate youth interest in physical 'ownership' and
playing together, while monitoring their ability to accommodate the changes. Dourish calls this
'engagement' of ethnographic enquiry and design practice an 'ethnographically grounded design'
[Dourish, 2007: 14]. RFID tags were included in each iteration of the kit, with the number of tags
ranging between six and twelve. The eventual solution was a flexibly-sized kit (from one to many
nodes), which could be adapted to specific group or project requirements. This final version of the
kit was used by all three groups in phase three of the study. I now offer a summary description of
the iteration process, followed by general observations.

Phase One

In phase one, youth were introduced to the kit through the use of two interactives designed by
others. One interactive was made up of twelve static tagged objects and a single mobile reader, and
the other three static tagged objects and a single mobile reader. In the use of both, youth improvised
their own social uses of the interactive to enable broad participation in the play act. In the use of
the former, youth shared the mobile reader device, passing it around the interactive to allow each
other to interact with the system while offering advice and commenting on decisions; in the use of
the latter, youth re-arranged the 'static' tagged objects on the table surface and interacted with them
to create their own little magic show. Passive users participated actively in the magic show,
shouting out guesses and roaring with laughter when the magic secret was revealed by the active
user. Youth were divided into small groups for the exercises (2-4 members), and each group was
given a kit with a single reader and four tags. Group members assumed responsibility for individual
craft parts associated with devices, worked together to author programmes, and took turns to
interact with the completed exercise projects.

Two groups of three youth designed inclusive interactives. One group's interactive included a
single mobile reader and twelve static tagged objects, the other two mobile readers and twelve static
tagged objects. In both cases members took temporary 'ownership' of individual devices and
associated craft parts to implement group decisions, and coordinated their actions carefully to
produce a collectively-valid result. The configuration with two readers allowed group members to
play against each other in the tests, which helped to externalise internal models, and promote
reflection and revision. In the use of the single-reader interactive, users took turns to play the game,
and passive users regularly adapted the game by discreetly removing a 'Clues' object when they
thought the active user was doing too well. These interventions were a form of participation in the
game. In the use of the latter interactive, two users played against each other, each with their own
reader. Youth devised a special version of their 'winner-stays-the-table' rule to build continuity
between games and make the interactive better suited to larger group use: the youth that won kept
their reader and played in the following round of the game, the youth that lost passed their reader to
the next user. Passive users rallied behind the challenger, offering them advice and support.
**Phase Two**

In the phase two exercises, youth worked in small groups (3-4 members) to design simple versions of commercial devices to explore technical concepts. In one exercise, groups shared access to a single reader to design a hand-held light meter. One youth assumed responsibility for the electronics work, and two youth programmed the device together afterwards. They then took it in turns to use the completed device, and there was little sharing or comparison of data. In another exercise each youth designed their own craft-tech force-sensitive resistor to create pedometers. They observed each other, offered support, and shared insights while designing their devices, and compared results from interactions and developed theories about them together.

Two groups (3 and 5 members) designed *inclusive interactivies*. I presented groups with a theme and a generalised starting point for designs, and they developed these further by adding their own ideas and project-specific components. The generalised starting point included three readers embedded in a single static object, and twelve mobile tagged objects. In both groups, members took temporary ownership of individual devices and associated craft parts, and coordinated efforts toward a collectively-valid result. The completion of the mobile devices and embedding of the readers in the static object effectively erased the earlier co-construction affordances, and youth acknowledged this by assigning members to new tasks while one youth continued to work on the static object. In both groups, youth coordinated efforts with the twelve mobile devices to test and debug their work. Coordination required involvement in others' thinking processes and the maintenance of shared understanding. The most common form of use of the completed interactivies was group use. Users assumed responsibility for individual devices and interacted cooperatively to play the games. Staff efforts to limit interaction to a single user frustrated youth, who made it apparent that they wanted to use the interactivies together.
Phase Three

There were two groups of newcomers and two groups of old-timers in phase three. The newcomer groups completed a multi-stage exercise and an interactive. The old-timers only designed interactives. The newcomer groups had three members. They used a three-reader-three-tag configuration of the kit to design an exercise project which enabled them to interact with each other to explore technical concepts. Each youth took ownership of a reader and a tag, and designed a mobile project identity around it. They invested personally in their objects, shared insights, learnt from each other's mistakes, and supported one another. Object relationships and collaboration patterns established through hardware were carried over into software. Each youth created their own virtual tag object in the *funda* project to represent their physical tagged object, and authored the scripts that handled tag events transmitted from their reader in the Scratch programme. While one youth programmed, the other members observed to learn from them, catch errors, and provide support. They interacted playfully and thoughtfully through the finished interactive to explore the exercise concepts together.

The *inclusive interactives* designed by the groups included a combination of six mobile readers and six mobile tagged objects; a combination of twelve mobile tagged objects, four readers embedded in two mobile objects, and six readers embedded in a static composite object; and a combination of two mobile readers, and six readers embedded in a static composite object. In each, youth took temporary ownership of devices and associated craft-tech parts and coordinated efforts toward a collectively valid result. They observed each other, offered support, and shared insights. They came together regularly to develop plans, assess progress, and solve problems, and worked together on challenging tasks. Designing objects containing multiple devices as loosely-coupled composites rather than single entities, enabled youth to maintain co-construction affordances through the design.
process. Object relationships and collaboration patterns formed through hardware were carried over into software. Youth rotated responsibility for handling events transmitted from readers, and coordinated efforts to implement other components in the programmes. They took temporary ownership of completed devices to test their interactives, and worked together to find and fix bugs. Users also took temporary ownership of the completed devices to use the interactives with others.

**General Observations**

I found that limiting access to the object under construction by limiting the number of devices in the kit constrained interpersonal connections; whereas promoting access to the object under construction by increasing the number of devices in the kit promoted interpersonal connections. Youth wanted to use tools together, and required physical access to do so in a meaningful manner. Meaningful participation helped to build a sense of common purpose, which promoted cooperation. Youth 'off-loaded' [Pea, 1993: 69] the extra cognitive load that came with additional devices into the environment, in the form of large public diagrams and technical notes taped to the walls, maquettes, low-res prototypes, and so forth, and engagements through these external resources promoted further 'interlocking' of cognitions [Miller, 1987]. Youth referenced them repeatedly to set up work-in-progress interactives, align perspectives during discussions, plan next steps, and to implement components collaboratively in their programmes. The largest project PAN explored in the study contained ten nodes. I also found that designing objects containing multiple devices as single uniform entities constrained social affordances after a certain point in the design process; whereas designing such objects as loosely-coupled composites enabled youth to maintain social affordances throughout the design process. This was more related to process design than technology design. It was addressed through workshop themes, and through timely interventions in the design process aimed at guiding group thinking towards composite solutions. Youth also expressed a clear interest
in using interactives together, and when interactives failed to meet these requirements, improvised their own solutions so that they did. These solutions generally involved devising ways to promote equitable access to the interaction event.

3.5 Methodology for the Study of the Kit and Social and Cultural Developments

I now present the methodology I used for the study of the kit and related social and cultural developments. I begin with a description of the process I used to select the study site and then outline the structure of the four-year study. Following this, I describe the ethnographic approach used in the study, the data collection process, and finally the data analysis.

3.5.1 Site Selection

I chose the study site with the support of the person overseeing PE's digital inclusion programme. He put out a call for participation to centres located in one of the network's three principle regions, to which we received 15 responses. We visited each of these centres together and I assembled a representative sample of four sites – referred to as Centres A, B, C & D in this document. Selection criteria included the focus of the centre, the centre's programme, the physical layout of the space, previous projects, the community in which the centre was situated, and the experience of the person overseeing the digital inclusion programme. The first phase of the study (April-June 2011) was run at all four sites simultaneously. The study site was selected from these four centres at the end of the phase. It was selected for the diversity in its activity programme and youth community. The activity programme included a strong emphasis on arts and crafts, computer use and training, sports, performative arts, games, homework support, and socially-inclusive work in the local community. The varied nature of the activity programme helped draw in youth with diverse backgrounds, interests and skills. Over 80% of youth were of African origin (Angola, Cape Verde, Guinea
Bissau and São Tomé and Principe), either having immigrated to Portugal, or having been born in Portugal to first generation immigrant parents. The centre community changed over the course of the four-year study, but this feature remained constant.

The centre was located in an economically-disadvantaged community on the outskirts of a medium-sized city. It occupied two different spaces during the course of the study, moving from the first to the second to increase its overall size and establish a dedicated office-kitchen space for staff. The two buildings were situated about five minutes walk apart. Both buildings were large apartment blocks, and both spaces occupied by the centre were on the ground floor with direct access from the street. Spatial usage was similar in both locations: the digital inclusion programme was run in a dedicated space (the CID), and all other indoor activities were run in a large open-plan multi-use area. The CID was laid out in classic laboratory fashion, with personal computers positioned alongside each other on low-cost office furniture. The space was cramped and undecorated. The multi-use area was laid out more organically, and the layout was often temporarily altered for specific activity requirements. It included a small library of books, a TV and DVD player, a collection of board and card games, cupboards stocked with arts and crafts supplies, a few donated toys, a social area with easy chairs, and multiple small table and chair sets. The table and chair sets were dotted around the space to create little work-play areas for groups of youth. The walls were painted with bright colours, and arts and craft work was displayed. These interventions, together with the stuff youth brought with them into the space (school bags, footballs, jackets, etc.), helped stamp a strong youth identity onto the space. The name of the centre has been altered to Centre D to protect participant privacy.
3.5.2 Study Structure

The study was run over a four-year period (2011-2015). It was framed as a centre activity with research intentions and structured in three project-based phases. In each phase I worked with youth and staff in a workshop setting to design a number of new inclusive interactives for the centre. The duration of the interactive design processes ranged from three months to two years. There were periods in the study when multiple workshops were run concurrently – phases one and three. There was always a break between phases to establish a coherent community cycle.

In phase one (2011) we ran the activity once a week for three months. Sessions were four hours long, and included regular breaks. Phases two (2012) and three (2012-2015) were run for six and thirty nine months respectively. In both, we ran the activity once a week during term time and twice a week over school holidays. Sessions were three hours long. In phases one and two there was a single activity group and newcomers were integrated into this group. In phase three we launched a second group to allow old-timers to keep raising the bar in their projects, and

Figure 5: Arts and Crafts Displayed in Centre D’s Multi-Use Area
(left) Collaboratively authored artwork celebrating International Day of Families (Dia das Famílias). (right) Paper star created by young boy. A staff member has hung it from one of the lighting units.
Figure 6: Study Phases

(above) The research study broken down into the three project-based phases, showing the four workshops run concurrently at four different centres during phase one (Centres A, B, C & D), the identification of Centre D as the principle study site during this phase (marked in yellow), and subsequent workshops run at Centre D in the following phases (also marked in yellow).
newcomers to start off at an appropriate level. I coordinated and ran the activity for the full study period. The staff member responsible for the digital inclusion programme assisted me when they could. They also ran sessions on their own to gain experience (<5%). Participants ran sessions themselves when neither of us was available, and reported back on developments afterwards (<2%).

3.5.3 Ethnographic Approach

There is a growing divergence in opinion about what constitutes ethnography in HCI, with views currently coalescing around two core positions. One can be characterised as the traditional 'positivist' [Rode, 2011] or 'empirical' [Crabtree et al., 2009] stance, and the other as an emerging 'contemporary' [Dourish, 2014] or 'critical' [Williams & Irani, 2010] stance. Dourish, who has been an important voice in the discussion, describes the changes in thinking that accompanied the computer's move from its traditional home in the workplace out into the wider world:

> Scholars working within HCI have increasingly recognized the relevance of the humanities for their work, and that interactive systems in contemporary society should be understood not simply as instrumental tools to be evaluated for their efficiency but as cultural objects to be understood in terms of the forms of expression and engagement that they engender. This position basically argues that if you restrict your vocabulary to bandwidth, storage, and encoding technologies, it's difficult to capture the essence of YouTube, and that menu layouts have little to do with people's attitudes towards Facebook. Ethnographic investigation implies more than simply a different way of getting at data, or a way of getting at it in a different setting (“in the world” rather than “in the lab”) but also signals, in this context, a shift in the objects or concerns of inquiry that asks what cultural work digital media and interactive systems do, how they fit in to broader patterns of practice and how the two co-evolve. This is not simply, then, using tools of anthropology to study interactive systems; it is also studying interactive systems anthropologically as sites of social and cultural production. [Dourish, 2014: 13]
The traditional stance views ethnography as 'equivalent to other empirical approaches in the HCI arsenal' [Dourish, 2006: 544], and is often associated with the requirements-gathering phase of the traditional software development model. Ethnography, 'an approach to social enquiry characterized by long-term immersive engagement with particular cultures in the effort to understand and explicate how they are experienced by their members' [Dourish, 2007: 4], is reduced to a 'toolkit of techniques for studying technology “in the wild”' (emphasis added) [Dourish, 2006: 542]. The ethnographer, in this view, is cast as a relatively unproblematic channel for the movement of data from the field to the design studio [Crabtree et al., 2009]: 'At work, designers, marketers, and developers are often entirely circumscribed by their work culture. At its best, ethnographic research in an industry context reconnects the workers with the world they inhabit and helps them imagine worlds they may have never seen …' [Salvador et al., 1999] (Quoted in Williams & Irani, 2010). Important theoretical debates that reshaped ethnography during the last quarter of the twentieth century are largely ignored; notably those around the production of ethnographic data through participation and engagement [DeWalt & DeWalt, 2011], and the 'poetics and politics' of ethnographic writing [Clifford & Marcus, 1986]. The stance emphasises empirical contributions, the “facts”; while the analytical component of ethnographic investigation is either marginalised or obscured [Dourish, 2006]. Scholars have referred to it as 'scenic fieldwork' [Button, 2000], and cautioned that it borders on a form of “tourist ethnography” [Sengers et al., 2006]. On the other hand, the emerging contemporary stance seeks 'to establish a deeper, more foundational connection between ethnography and design – to look for a connection at an analytic level rather than simply an empirical one' [Dourish, 2006: 548]. It takes its cue from anthropology's critical turn. Dourish calls it an 'ethnographically grounded design' [Dourish, 2007: 14] (e.g. Dourish & Bell, 2011). The approach strives for new ways of imagining the relationship between people and technology, through the rejection of traditional separations between designer and user, and technology and
practice. Williams and Irani ask if we could place the 'dichotomy between “design” and “use” into an ecology of practices: designing, crafting, making, appropriating, hacking, tinkering, borrowing, stealing, playing, perverting, rejecting, and so on?’ [Williams & Irani, 2010: 2728]. Research outcomes are not so much a list of requirements, as they are ‘corpus contributions’ [Dourish, 2014: 14] which surface 'phenomena of import to design' [Dourish, 2007: 13]. Contributions tend to open up design space rather than closing it down.

Given these divergent views and interpretations of ethnographic work, it is incumbent upon HCI researchers to elucidate their positions when employing these methods; i.e. whether they are simply using 'the tools of anthropology to study the interactive system' (‘methods as recipes' [Williams & Irani, 2010]), or also ‘studying the interactive system anthropologically as sites of social and cultural production' [Dourish, 2014: 13]. My work is firmly grounded in the latter 'contemporary' / 'critical' stance. I endeavoured to integrate the study into the institutional fabric of the centre, to allow for the 'intertwining' and 'co-constitution' of social and technological realms [Warschauer, 2003: 204-205]; I studied the kit and the design environment embedded in the after-school centre, as 'sites of social and cultural production' [Dourish, 2014: 13]; and I explored a polyphonic form of HCI ethnography informed by anthropology's critical turn. The approach is located and reflexive [Rode, 2011], positioning the researcher and participants squarely within the ethnographic frame. Thick description [Geertz, 1973] accounts of four interactive design and use processes were written up from collected data. The four documents describe the complex arrangements and engagements around the emerging design objects, as well as those between users of the completed interactive. Attempts are made to understand experiences in these interactions. Summaries of each are offered in Chapter five. The thick descriptions are analysed and interpreted in the context of the corpus, with analysis focusing on the three interrelated study foci: youth diversity, interpersonal
connections, and transformative outcomes. Findings, in the form of patterns across interactive design and use processes, are offered as insights with import for design – what Dourish calls ‘models for thinking’:

*Ethnography provides insight into the organization of social settings, but its goal is not simply to save the reader the trip; rather, it provides models for thinking about those settings and the work that goes on there. The value of ethnography, then, is in the models it provides and the ways of thinking it supports.* [Dourish, 2006: 549]

### 3.5.4 Data Collection

As a participant leader in an authentic *community of learners* [Rogoff, 1994], I used *participant observation* [DeWalt & DeWalt, 2011] to gather various qualitative data related to the use of the kit in the design environment and related social and cultural developments. I kept detailed field notes of activity sessions, and collected youth project plans, narrative scripts, audio recordings, drawings, maquettes, flow diagrams and materials tests, as well as materials I developed for sessions. I photographed sessions to document the development of interactives and participant interactions around them, saved copies of each group’s Scratch [Scratch] project after sessions in which they programmed, and was able to access the completed interactives stored in the centre for further analysis. Interviews were conducted with groups which felt comfortable about the interview process, as well as staff. Use of the completed interactives in and outside of the centre was studied in a similar manner.

I refrained from making written notes during sessions to maintain the focus on what we were doing together. I did, however, keep copious mental notes on the arrangements of the physical space, the arrangements of people within the space, the specific activities and movements of participants (youth and adults), interactions amongst participants and with the objects, words spoken, and
nonverbal interactions, including gestures and facial expressions. I photographed scenes regularly to create aide-memoires and recorded fleeting events for later analysis – it was often challenging to perform the participant leader and participant observer roles simultaneously, and photography provided me with a way to momentarily step out of my participant leader role to attend to events occurring away from the focus of my attention. I photographed from the first session, and continued to do so throughout the study. Youth quickly became used to the presence of my lens, and paid little attention to it after that. My photographic background (I have worked as a documentary photographer previously) facilitated the visual documentation process. It enabled me to sum up situations and work out appropriate positions to capture the maximum amount of relevant detail quickly, and to 'read' upcoming events that needed to be photographed from unfolding events. I also attended to events that were outside of the design environment but relevant to its functioning and role in the centre community, making mental notes and occasionally photographing things of special interest. I paid particular attention to how other older and younger kids in the centre related to what we were doing in the activity, what was taking place in other activities, changes in the physical layout of the space, emerging youth trends and interests, and the overall running of the centre. For the write up of a field note, I correlated all visual, written, programming and audio materials from the session to reconstruct the process and analyse events which had partially eluded me during the session, and then wrote up the note working from my own memory and the materials at hand. Field notes were written up within twenty-four hours of a session.

DeWalt and DeWalt view participant observation as a process of enculturation, where the researcher 'gradually absorbs the big picture and some of the details that lead to an understanding of people's daily lives, structure of events, social structure and expectations and values' [DeWalt & DeWalt, 2011: 80]. I participated in numerous events outside of the activity to build out this bigger picture.
These included football matches, card games, farewell parties for youth who were re-emigrating with their families, fund-raising concerts (as a spectator), and simply hanging out. I also adopted the centre practice of taking youth on an annual outing, which in our case included a visit to a museum and a picnic in a nearby park. These out-of-activity moments – conversations on the train ride into town, exchanges while making up the teams for a football match, saying goodbye to a close friend, UNO rule disputes, etc. – offered me another view of community culture. Insights emerged over time as I made connections and established patterns, and related them to events occurring in the activity. I wrote these down in my field diary as ‘thought inserts’ when they occurred to me.

I chose not to use video recording in sessions after an attempt to video a group discussion in phase one ended badly. Youth literally froze in front of the camera, and even the most extroverted kids said they had nothing to say or simply shook their heads. I also opted not to use questionnaires after a similar experience with the first questionnaire in phase one. Youth, who felt comfortable expressing their opinions to me, made no secret of the fact that they found questionnaires *uma grande chatice* (a big pain / waste of time). Finally, I also tried to start an online diary about the activity with youth and staff, so that they could develop a parallel set of ‘field notes’ from their perspectives. The staff member responsible for the digital inclusion programme led the process, working with youth to author entries collaboratively in a projected image at the end of sessions. Youth found the process extremely boring. They yawned, slouched in chairs and looked elsewhere. The staff member struggled repeatedly to secure their participation. We chose to abandon the idea after two frustrating attempts. The three failed data collection experiments had two things in common: i.) they were not used in any of the other centre activities; and ii.) they were not obviously related to what youth perceived as the purpose of the activity – designing playful learning resources
for themselves and their peers. Youths' early 'rejection' of these more formal methods, and enthusiastic and open participation in the research activity, helped to sharpen the methodological direction of the study through the first phase. Observation, writing, photography and materials storage became principle data collection methods after phase one.

Two group audio interviews were conducted with phase three participants. I also conducted an individual audio interview with the one remaining member of the O Quarto da Paula group in phase three (three years after the group had designed the interactive). All interviewees had participated in the activity for at least a year, greeted me with a handshake or kiss on the cheek when we met, addressed me by my first name, and understood the research intentions of my project. I asked them if they were prepared to speak to me about their experiences in the activity, and made it clear that I would not be offended if they refused. One group appeared to see it as an ethical responsibility, the other jumped at the opportunity enthusiastically. The individual girl also appeared to view it as the 'right thing to do'. The interviews were conducted on separate occasions. We sat around one of the centre's small tables and recorded the interview on my phone. The device was placed in the centre of the table and remained there unattended for the duration of the interview. Youths' consent appeared to have been influenced by their growing trust in me and greater maturity. Interviews were informal and conversational, much like our discussions in the activity sessions, and focused primarily on interpersonal connections and transformative outcomes for the centre.

3.5.5 Data Analysis

A representative sample of four interactives was selected for analysis using the following criteria: phase of the study in which the interactive was designed; design process duration; group gender; group size; participant experience in the activity; number of nodes in the project PAN (Personal
Figure 7: Study Breakdown

(above) Breakdown of the four-year study, showing the three project-based phases, the four centres participating in phase one, the selection of Centre D for the longitudinal study (marked in yellow), and the four inclusive interactives selected for analysis. The study sample includes interactives designed in all three phases, various group sizes, groups of girls and groups of boys, design durations that range from three months to two years, and various project PAN sizes.
Area Network); interface design; and interaction design. The eight criteria addressed representativity in participant groups, factors influencing the design processes, and design outcomes. The four interactives selected for study were designed in phase one – *O Quarto da Paula* (Paula’s Room), phase two – *A Casa das Palavras* (House of Words), and phase three – *Os Seis Amigos* (Six Friends) and *A Batalha Ecológica* (Ecological Battle). The *O Quarto da Paula* was designed by a group of three girls, the *A Casa das Palavras* by a group of three boys, and the *Os Seis Amigos* and *A Batalha Ecológica* by groups of three girls and five boys respectively. While the *Os Seis Amigos* group had three core members for the majority of the design process, there were also short periods when there were between four and six members in the group. The *A Batalha Ecológica* group collaborated with another group to design a shared reconfigurable hardware resource that was used in both their projects – the second group was made up of three boys and two girls. The *O Quarto da Paula* design process lasted three months, the *A Casa das Palavras* six months, and the *Os Seis Amigos* and *A Batalha Ecológica* one and two years respectively. Eight of the fourteen core members of the four groups were newcomers to the activity, and six were old-timers. Three of the six old-timers participated in all three phases of the study. Project PANs ranged in size (two, three, six and ten nodes), and all four interactives were made up of combinations of hand-held and static devices. The *O Quarto da Paula* and *A Casa das Palavras* interactives were tabletop designs, the *Os Seis Amigos* a distributed wearable, and the *Batalha Ecológica* a composite floor-based environment. Users read the one tabletop interface with hand-held devices, and positioned tagged objects in the other, interacted physically with one another through the distributed wearable, and moved about on the floor-based interface while reading tagged objects on it and rolling ‘rollables’ alongside it.

*Thick description* accounts [Geertz, 1973] focusing on design and use were written up from the data. Each thick description is a coherent and analysable package – what Geertz calls ‘an
inspectable form' [idem: 19] – which traces out the evolution of the interactive from early design discussions through to use in and outside of the centre. Behaviour is attended to with some exactness, 'because it is through the flow of behaviour – or, more precisely, social action – that cultural forms find their articulation' [idem: 17], and attempts are made to understand the experiences of participants. Attention to behaviour also provided a way to surface the roles of the kit and environment in social and cultural developments, and understand how social and cultural developments helped shape the technology and environment.

The thick descriptions were written up from my field notes and the extensive photographic record I built up through the study. Youths' work-in-progress and completed programmes, audio content, drawings, text documents and other developmental resources were also consulted, as were the developmental resources I designed for the study. The texts are my readings of the data, informed by extended periods of immersion in the culture of the setting and my research concerns. The thick descriptions are 'determined' in further ways common to most anthropological ethnographic writing:

*Ethnographic writing is determined in at least six ways: (1) contextually (it draws from and creates meaningful social milieux); (2) rhetorically (it uses and is used by expressive conventions); (3) institutionally (one writes within, and against, specific traditions, disciplines, audiences); (4) generically (an ethnography is usually distinguishable from a novel or travel account); (5) politically (the authority to represent cultural realities is unequally shared and at times contested); (6) historically (all the above conventions and constraints are changing). These determinations govern the inscription of coherent ethnographic fictions. [Clifford, 1986: 6]*

Youths' uneasiness about interviews and lack of interest in questionnaires and project diaries, made it challenging to integrate their voices into the planned polyphonic narrative. I attempted to mitigate these absences and silences through the inclusion of materials generated by them through
the design process, and photographs related to scenes described in the texts. In the photographs I endeavour to show the nature of the exchanges and engagements in the groups. I make no attempt to suppress first-hand experience, as is often the case in ethnographic writing, but rather place myself squarely within the ethnographic frame to show how youth, staff and I worked together as a community of learners to co-produce situated ethnographic knowledge. Tedlock calls this approach 'observation of participation' (rather than participant observation): 'both Self and Other are presented together within a single narrative ethnography, focused on the character and process of the ethnographic dialogue' [Tedlock, 1991: 69]. Despite aligning myself strongly with Tedlock's 'observation of participation' approach, I continue to use the term 'participant observation' because of its ongoing and common usage within anthropological and HCI communities, and because reflexivity is increasingly embraced by the numerous disciplinary traditions that work with ethnography [DeWalt & DeWalt, 2011][Lave, 2011][Rode, 2011].

The thick descriptions are analysed and interpreted in the context of the corpus. The analysis addresses the three interrelated research foci – youth diversity, interpersonal connections, and transformative outcomes – and strives to identify patterns in interpersonal engagements and arrangements across the four design and use processes that establish 'opportunities to learn' [Rogoff, 1998:700]. The patterns are offered as insights with import for the design of transformative technology-based activities in after-school centres. The full thick descriptions are not included in this document because of their length and concerns about youth and staff privacy.
Chapter 4. The Fundakit

The fundakit is a co-construction kit for designing usable computationally-enriched craft objects, implemented with wireless sensor networking (WSN) technologies. It is designed specifically for groups and the design of multi-user projects. It uses a device collection approach – e.g. [Buechley et al., 2005][Weinberg et al., 2002] – to explicitly frame design as a collaborative process, and to facilitate concurrent access to the object under construction. The kit contains a flexible number of physically discrete computational devices (network nodes with RFID capabilities and RFID tags) connected through wireless communication. The discrete nature of the devices allows group members to take temporary ownership of parts to implement changes for the project, and wireless communication facilitates the integration of their efforts. These features also facilitate the design of projects for multiple users, who can take similar ownership of the completed project parts to use objects with others. The size of a project PAN (Personal Area Network) is defined by project needs.

4.1 Hardware

The primary building blocks of the wireless sensor system are the funda readers. They constitute the nodes in each project PAN. A reader fits in the palm of a child's hand, runs on three AAA batteries, has an ID12 module for the radio frequency identification (RFID), an XBee module for the wireless communication, and three analogue/digital input ports for attaching sensors. Mini-jack sockets are used for the sensor ports to ensure robust connections which can withstand real use, and batteries can be recharged with a standard AA/AAA charger. The device can be customised into any number of more personalised forms by wrapping it in craft materials or embedding it in craft objects, and can be static or mobile. Multiple readers can be embedded in a single craft object to imbue it with greater functionality. Reader data is received on the host by a standard XBee-to-USB connector. The host runs the project software and performs all data processing.
Figure 8: Funda Reader Board Layout
(above) Component layout printed on the back of the reader PCB. The diagram indicates the orientation of batteries in the battery holders, component names, and the numbering of the three sensor ports. Sensor data is accessed in Scratch using the port and reader numbers (e.g. sensorN@readerN).

The other device type included in the kit is the RFID tag. Tags can be applied to or incorporated into objects to provide them with electronic identities, and do not have to be visible to communicate with the reader. Passive tags (the type included in the kit) have the added advantage of being powered by energy contained in the reader's requesting wave, so they do not require batteries. Readers read tags with the EM4001 or compatible format. Tags can be read through most materials, and the read range is ~12cm. Tags vary in both size and form, and are primarily designed to track and identify animate and inanimate objects in active use or movement. As such, they are usually designed with discrete, robust and combinatorial affordances, which are ideal for usable computational-crafts projects designed with the kinds of materials generally used in after-school crafting activities. Following Resnick and Silverman's dictum, 'make it as simple as possible – and maybe even simpler' [Resnick & Silverman, 2005: 3], I chose to limit the number of tags users could include in projects to twelve. This is implemented in the funda software. The hardware was developed with IXDS [IXDS], and based on an earlier kit developed by me [tagmat].
Figure 9: Fundakit Hardware
(left) The funda reader in a child's hand. The three sensor ports are situated on the left edge of the board, the RFID module centre right, and the ON/OFF switch on the right edge. The RFID module is protected by the battery holders, which surround it on three sides and stand slightly proud of the component. (right) The Os Seis Amigos interactive designed with the fundakit. The interactive is a game about six animals for six users. It is made up of six hand-held reader devices and six RFID ID badges. Each user receives a reader and badge associated with one of the animals.

4.2 Software

The fundakit software consists of the Scratch programming environment and the funda middleware application. Youth create projects with both for each interactive they design. The two projects are run in tandem on the host, which performs all data processing. The projects are normally given the same name to facilitate later identification. The file extensions make it easy to tell them apart: Scratch (.sb); funda (.ser). I now describe the Scratch programming language and environment and how youth access incoming data from funda in their projects, and then the funda middleware.

4.2.1 Scratch Programming Language

The fundakit is programmed with Scratch. Scratch is a visual programming language and environment which enables young people to learn computer programming through the design of personally meaningful media-rich projects. It builds on the constructionist ideas of Logo [Kafai &
Resnick, 1996)[Papert, 1980]. It is free, available in over fifty languages, has desktop and online versions, and runs on Linux, Mac and Windows [Scratch]. It was designed by the Lifelong Kindergarten Group at MIT and originally intended for use in after-school centres [Resnick et al., 2003]. It is currently widely in use, in both informal and formal learning contexts.

Users construct their programmes by snapping together brightly-coloured command blocks in a puzzle-like fashion, and block shapes prevent syntax errors. Scratch 1.4, the version used with the fundakit, has 125 commands. One can create a surprisingly diverse range of projects with this purposely limited command set. The language is object-based – sprites are objects that encapsulate state (variables) and behaviour (scripts) – but not object-orientated. Scratch is always 'live' [Maloney et al., 2010]. There is no compilation step or edit/run mode distinction; this 'helps users stay engaged in testing, debugging, and improving their projects' [idem: 4]. It also does not require users to create complete scripts before running projects. This enables them to iteratively develop their ideas through construct-run-reflect cycles. The environment provides visual feedback to show project execution.

The funda middleware implements Scratch's Remote Sensors Protocol [Remote Sensors Protocol]. The protocol is an experimental extension feature which allows for interaction between Scratch and other programmes. The feature is enabled by right-clicking on one of the light blue sensor blocks, and selecting the 'enable remote sensor connections' menu item. When enabled, Scratch listens for connections on TCP port 42001. Once a connection is established, messages can be sent in both directions over the socket connection. Each message consists of a four-byte size field, with the most significant byte first, followed by the actual message. The two principle message types are broadcast <string> and sensor-update <var-name_1> <var-value_1>. Broadcast messages sent to Scratch cause a broadcast to occur, and sensor-update messages update the values of virtual sensors
available in the sensor block drop-down menu. With the fundakit, tag read events are received as broadcast messages, and sensor data as sensor-update messages. Users handle the tag read events with Scratch's when I receive () block, and access remote sensor data through the () sensor value block. They combine these two 'funda-related' Scratch blocks with the other Scratch blocks in the normal manner to author their programmes.

![Scratch Blocks for Accessing funda Data](image)

**Figure 10: Scratch Blocks for Accessing funda Data**

(top left) Users right-click on the sensor () or () sensor value block to bring up and select the 'enable remote sensor connections' menu item. The funda middleware establishes a socket connection, and sends broadcast and sensor-update messages to Scratch over this connection. (bottom left) Tag read events are sent as broadcast messages, and handled with Scratch's when I receive () block. Messages are accessed through the block's drop-down menu (e.g. reader2@banana). (right) Sensor data are sent as sensor-update messages, and accessed through the drop-down menu in the () sensor value block (e.g. sensor1@reader2; sensor2@reader2; sensor3@reader2).

To illustrate how users combine the funda related blocks with Scratch’s other blocks to author their programmes, I now offer an example from the study. The example occurred during the design of the Os Seis Amigos interactive, a general knowledge game about six animals for six users – see section 5.3. Each user receives a reader device with a switch connected to the sensor 2 port and an RFID ID badge, and answers questions related to the animals by reading their own and the other players' badges. Users can repeat their questions by pressing their reader’s switch. The authors
wanted a collective interaction for starting/restarting the game, and opted for all six users pressing their 'repeat question' buttons at the same time. To implement their idea, they nested three if () blocks inside each other. In each they built a condition to test resistance values at sensor 2 on two of the readers. They used the () sensor value reporter block to access the sensor data, and combined them with boolean () equals () and () and () blocks to check for zero resistance on both circuits – i.e. both switches pressed. If the first condition evaluates to true, execution passes to the second if. If it too evaluates to true, execution passes to the third if. And if it also evaluates to true, a new game is created by invoking the scripts which rebuild the lists used in the game, output introductory audio, and choose the first player and first question and pose the question to the player. The nested if blocks are set within a forever loop so that users can start and restart the game from their readers at any time (after the green flag is clicked to run the programme).

![Figure 11: Example of the Combination of Scratch and funda Elements in Programmes](above) The start/restart script for the Os Seis Amigos interactive, a game about six animals for six users. The group combined () sensor value reporter blocks with boolean () equals () and () and () blocks to test if the six users were pressing their 'repeat question' buttons at the same time – the collective interaction required to start/restart the game.
4.2.2 Funda Middleware

Data from a *funda* project PAN is accessed via the serial port on the host. The data stream contains RX_16_RESPONSE (RX packet - 16bit - 0x81) and RX_16IO_RESPONSE (RX packet I/O data - 16bit - 0x83) XBee data frames. The frames must be isolated from the stream, identified in terms of their contents (sensor data or RFID data), and unpacked so that the various data can be used in Scratch. Sensor data packets must be checked, and individual samples extracted and associated with the sampled lines – the three sensor ports on the readers and an on-board battery voltage level reading. The RFID tag codes must be checked and isolated from the rest of the ID12 package (start and stop bytes and checksum). The source address and RSSI must be extracted from both types of packets, and the data (RSSI, samples and RFID) must be clearly associated with the node from which it was transmitted to enable easy identification in the programme. Scratch has no built-in features to do any of this. It knows nothing about *funda* or any other wireless sensor networks outside of the host.

From a design point of view, there were two obvious options. I could either extend the open-source Scratch Squeak Smalltalk code (Scratch 1.4 is implemented in Squeak Smalltalk), or develop a new external middleware application that performed these functions outside of Scratch and passed on the prepared data. The former approach, known as a Scratch Modification, was feasible, and other projects such as AR SPOT [AR SPOT] have successfully used it to add new features. The principle advantage of this approach is that everything happens within the Scratch development environment, using the same graphic language. New blocks are authored for the new functionality and used with existing Scratch blocks in programmes. The new edited version must, however, be named differently, and it is not supported by the original Scratch team. I chose not to follow this approach, because I wanted to continue to benefit from the ongoing work of the Scratch team, and
because the team had recently developed the Remote Sensor Protocol (Remote Sensor Protocol) (RSP) to support these types of initiatives. I pursued the middleware option instead.

The *funda* middleware unpacks incoming XBee data frames, reformats the tag and sensor data according to Scratch's Remote Sensors Protocol (Remote Sensors Protocol), and sends the messages to Scratch over the socket connection. Tag and sensor data is associated with the node from which it was transmitted in the message, to enable users to determine the origin of the sensor data and 'who' read the tag. Tag messages state the reader number and then a user-assigned name: *readerN*@$tag\_name$. Sensor messages state the sensor port number and then the reader number: *sensorN*@$readerN$. Users author their Scratch programmes to respond to this input. The RSSI (received signal strength indicator) and on-board battery voltage level measurement are also accessible through the drop-down menu in the () *sensor value* reporter block (see figure 10).

RFID tag codes are ten-digit hexadecimal numbers, which can be difficult to transcribe and identify correctly in programmes. The *funda* middleware records the tag code automatically when users add a tag to their project, and allows them to rename the tag with more user-friendly names which are normally related to their role in the project. For example, a tag representing a banana craft object in an interactive would likely be renamed 'banana' to make the connection explicit in the *funda* and Scratch projects. This eliminates transcription errors and makes the Scratch code more legible. It also makes it easier to express programming ideas in pseudocode. For example, a member of a group might express an idea in a discussion as follows: 'If reader so-and-so reads the banana, then we must ...'. Physical tags also have an external number to facilitate visual identification. These numbers are entered manually by users when a tag is added to a project. Virtual tags are represented visually in the GUI, and highlighted with a green border after a read event. The reader number, external tag number, tag code, and user-assigned name are also displayed.
The *funda* application is generally run in the background after users have created their projects. There is little need to refer back to it, other than to resolve misunderstandings about tags and/or rename them. The focus is primarily on the Scratch environment, and the development of the programme around the *funda* data. Users are encouraged to create their own data representation tools in Scratch to have ongoing and ready access to sensor data for thinking and debugging purposes. Designing the tools also helps to open up data representation and build a deeper sense of ownership of the design process. Groups represent a sensor's data by creating a new variable for the sensor and placing a *() sensor value* reporter block (with the sensor selected) in a *set () to ()* variable block (with the variable selected). The assembled *set () to ()* variable construct is placed within a forever loop and the variable set to visible to display the sensor values in its watcher on the Scratch stage. Battery voltage and RSSI can be represented in the same manner, or visualised graphically through personalised versions of the methods used on mobile phones (e.g. slices of pizza, apples on a tree, setting sun). Tags can also be visualised graphically.

![Data Representation Scripts for the 'A Batalha Ecológica' Craft-Tech Dice](image)

*Figure 12: Data Representation Scripts for the 'A Batalha Ecológica' Craft-Tech Dice (above) Data representation scripts for *dado um* (dice one) and *dado dois* (dice two). Variables have been created for the photoresistors set in the faces of the dice, and are grouped together to represent the dice in the programme. The variables are set to the sensor values with *() sensor value* reporter blocks. The variable block constructs are placed within forever loops to continually update the variables. Variables are set to visible to print out the data in the variable watchers on the Scratch stage.*
To illustrate how users rename tags with names related to their roles in the interactives, and how they work with this data in their Scratch programmes, I now offer an example from the study. The example occurred during the design of the *O Quarto da Paula* (Paula's Room) interactive, a treasure hunt game for two users – see section 5.1. The interactive comprises a tabletop textile interface representing Paula's room, and two reader devices, one for each user. Eleven objects are represented visually in the room, and each of these objects is represented electronically by an RFID tag concealed directly beneath it. The treasure is hidden 'under' one of these objects at the start of the game by the system, and users take it in turns to look for it with their readers. The system controls turn-taking and provides 'hot', 'warm' and 'cold' feedback. The first user to find the treasure wins the game. The kangaroo, the animal running the game, consoles the loser and tells them that the important thing is to participate, not win. The authors chose to name the tags after the objects they represented, and authored the tag event handler scripts to respond to this data. One of the objects in Paula's room was her bed. The group named the tag they associated with it *cama* ('bed' in Portuguese) – the hex code is 0415D763E5. They then dragged out two *when I receive ()* blocks.

*Figure 13: The 'Cama' (Bed) Craft-Tech Object in the 'O Quarto da Paula' Interactive* (left) Felt representation of the bed object bonded to the textile surface. (right) The digital representation of the *cama* object. The RFID tag is concealed beneath the felt representation during use to provide it with an electronic identity.
to respond to *cama* guesses transmitted from each of the readers, and selected the *funda* broadcast messages for the readers as the block arguments: *when I receive (reader102@cama)* and *when I receive (reader104@cama)*. Afterwards they built conditional constructs to check: a.) that the game was not busy processing a guess; b.) that it was indeed the user's turn to make a guess; c.) if the user had discovered the treasure; and d.) if they hadn't, which feedback ('hot', 'warm' or 'cold') to output to them. They connected the conditional constructs to the event handler blocks to create the two scripts responding to *cama* events. The two scripts are presented in figure 15. The interactive is described in section 5.1.

![Image](image.png)

**Figure 14: The 'Cama' (Bed) Virtual Tag in the 'O Quarto da Paula' funda Project**

(above) The *O Quarto da Paula* project after a *cama* event transmitted from reader #104. The virtual tag is highlighted, and the user-assigned name (*cama*), external number (10/8), hexadecimal code (0415D763E5) and reader number (104) are printed out.
Figure 15: The 'Cama' (Bed) Event Handler Scripts in the 'O Quarto da Paula' Scratch Programme

(above) Scripts responding to cama events from readers #102 and #104. The scripts check that the system isn’t processing another guess and that it is the user’s turn to make a guess, and then process the guess and provide output.
Chapter 5. Results from the Empirical Study

I now present the four interactives selected for description and analysis: the *O Quarto da Paula* (Paula's Room), *A Casa das Palavras* (House of Words), *Os Seis Amigos* (Six Friends), and *A Batalha Ecológica* (Ecological Battle). The *O Quarto da Paula* was designed over a three-month period in phase one (2011) by group of three girls; the *A Casa das Palavras* was designed over a six-month period in phase two (2012) by a group of three boys; the *Os Seis Amigos* was designed over a one-year period in phase three (2013-2015) by a group of three girls; and the *A Batalha Ecológica* was designed over a two-year period in phase three (2013-2015) by a group of five boys.

I apply the same lens to each of the interactives. I begin with a brief description and then summarise design and use in six sub-sections: concept; interface; content; programming; testing and debugging; use. After the design and use sub-sections, I pose and answer the three research questions:

- Did the design activity promote diverse participation?
- Did the kit and environment support interpersonal connections?
- Did interpersonal connections help advance the centre’s transformative agenda?

Finally, I surface patterns in interpersonal engagements and arrangements that established opportunities to learn. The patterns are offered as insights with import for the design of transformative technology-based initiatives in after-school centres.
5.1 Interactive #1: *O Quarto da Paula* (Paula’s Room)

5.1.1 Description

The *O Quarto da Paula* (Paula's Room) interactive is a treasure hunt for two users, designed by Jasmin, Lara and Patrícia (all names are pseudonyms chosen by youth). It was designed over a three-month period in phase one of the study (2011). The aim of the group was to teach peers that the important thing is to participate, not win.

The interactive is made up of a textile tangible user interface (TUI) with felt illustrations of eleven objects found in Paula’s room, and a kangaroo, the animal running the game. The kangaroo is positioned in the centre of the interface with the word 'START'. Each object represented on the TUI is associated with an RFID tag concealed directly beneath it. The interface is built up on a table or other similar flat surface, and users gather around it. The interactive can be used sitting or standing. There is no optimum viewing or using position – all users view a few objects well and the remainder in a variety of tilted or inverted positions. The interactive also includes two *funda* readers which represent the two players in the game, the *cavalo* (horse) and the *porco* (pig). The readers are housed in enclosures made from recycled padded envelope material and felt. Each enclosure has an image of the animal and their name on one side. Readers are inserted into the enclosures with the RFID module facing away from the image, and users are instructed to hold the device with the image facing toward them.

Users adopt one of the player animals and play as the animal in the game. They begin the game by reading the kangaroo object. This interaction invokes the start script, which plays the introductory
narrative, chooses the first player, and randomly assigns the treasure to one of the eleven objects in Paula's room. In the introduction, the kangaroo explains that she has hidden a bag of sweets under one of the objects in Paula's room, and asks users to help the horse and pig find it. Users take turns to look for the sweets by reading objects. After each guess, kangaroo provides ‘hot’, ‘warm’, or ‘cold’ feedback directed to the animal. The user who finds the sweets first wins the game. Kangaroo comforts the losing animal and tells them that the important thing is to participate, not win.

**Summary:**

Number of Authors: Three

Design Period: Phase One (2011)

Design Duration: Three months

Kit Configuration: Two node project PAN + twelve RFID tags
Figure 16: Designing the 'O Quarto da Paula' (Paula’s Room) Interactive
(left to right and top to bottom) Acting out an interaction idea in a preparatory sketch to think it through; proposing and discussing drawings for the interface; fine-tuning the interaction design and narrative with the completed interface; building the funda project; testing the funda project; the porco (pig) and cavalo (horse) readers in their craft enclosures.
5.1.2 Design and Use

Concept

Youth were introduced to the inclusive interactive concept through the use of interactives and short exercises, and then asked to design their own interactive for the centre. We informed them that they could work in textile or cardboard – the materials used in the examples – and encouraged them to think of their designs as contributions to the community.

The group quickly established that they were going to design a treasure hunt with textiles. Lara suggested that the objective of the game should be to teach users that ‘the important thing is to participate, not win’. Patrícia suggested that they situate the game in a little girl’s room, and, when the others responded positively to her idea, she began describing the contents of the room. The rest of the group joined in. While they were listing Paula’s different possessions – a desk, a bed, a TV, a computer, a cupboard, a chest of toys, etc. – Lara began sketching up the room on a sheet of paper. When the group had established an initial image of the room, they began discussing how the game would be played. Patrícia fired out ideas, and Lara worked them into a coherent form on a second page. She asked Patrícia questions about her ideas to get her to elucidate or add detail, built on her ideas with her own ideas, read what she had written back to the group, and refined parts she felt weren’t perfect. The end result was a detailed description of a hypothetical use scenario. In it, the group referred repeatedly to the three animals playing the game: the kangaroo, the figure running the game, and the two players, the cavalo (horse) and porco (pig). Lara placed a strong emphasis on structured turn-taking and fair-play. It was evident from the description that the group were planning a game for two users. To encourage them to ground their thinking in the technology, I suggested they use their sharpener and rubber to represent the two readers. Lara picked up the two objects, one in each hand, and began moving them around the drawing to act out different use
scenarios (figure 16). The positioning of the rubber and sharpener on the different objects in the sketch made ideas more public and concrete, and there was a marked increase in participation. Lara also used the improvised model to act out scenarios for herself, replaying them to recall them, or to think them through before discussing them with the others. When the group were happy with the description, Lara extracted the six principle rules governing play, and wrote them up on a separate page entitled 'Regras dos jogo' [sic] (Rules of the game). A girl who participated for the first session and then left the centre for personal reasons, observed the others in silence. The others tried to engage her. The group chose to hide the treasure under the carpet. When I informed them that it was possible to have the computer hide the treasure, and that it could hide it in a different location at the start of each game, they looked at me with disbelief and then squealed with excitement.

Interface

Each girl drew all eleven objects in the room. While they were drawing, I analysed Lara's sketch for the interface. It appeared that the A4 page had indirectly shaped the form of the interface. To open up the issue for further reflection, I told the group that there was no rule saying textile interfaces had to be square or rectangular, and that they could explore other forms if they wanted.

When the girls had finished drawing all the objects, they gathered around one of the round tables. Each girl stood with her drawings in hand, and began laying out some of her favourites as tentative proposals for inclusion (figure 16). Colleagues observed proposals from where they were standing, and began negotiating for their version if they thought it was better. The group gradually reached agreement on their own, and as they did, they adjusted the drawings immediately in front of them for optimal reading from their position. The cumulative effect of these individual actions was a plan for an interface with no privileged or optimal reading point. As the pattern became evident to
the group, they began adjusting drawings to establish a more pronounced form of radial symmetry. The outcome was a plan for a circular interface, following the basic shape of the table, which, like the table, was approachable and usable from all sides. The democratic design emerged organically through the democratically-structured design process. As per Lara’s original idea, the kangaroo was placed in the middle to mark the start point. Lara indicated that she would take responsibility for drawing the kangaroo.

At this point I thought it would be helpful to establish connections between the interface plan and the game plan, to check the two were aligning. I drew a circle on a page, and wrote numbers in the positions of the objects. I circled the number one to indicate the treasure location, and asked the group to provide feedback for the other ten objects. Up to that point, they had only mentioned *morno* (warm) to indicate close to the treasure, and *frio* (cold) to indicate far from the treasure. André (pseudonym), the staff member overseeing digital inclusion, asked why they weren’t using *quentes* (hot) to indicate very close. The girls liked his idea. We did some calculations and found that we could establish a neatly balanced feedback structure around the treasure: two *quentes* - one on either side of the treasure; four *mornos* - two on either side of the *quentes*; and the remaining four objects *frio*. I then explained how we could use random number selection to hide the treasure, and conditional statements to determine the feedback to provide to users after a guess.

After redrawing some of the objects that were deemed too small for the planned interface, the group relocated to the materials table with the final drawing selection. Lara again managed the process. She identified elements in a drawing that would be represented by a single colour, and then asked Patrícia and Jasmin to choose a colour for them. They looked through the piles of felt, chose a colour, and informed her of their decision. Lara labelled the elements in the drawing with the colour. She rarely commented on their decisions, and only intervened when she saw they were
having difficulty making a decision. The end result was a detailed implementation plan for the interface in twelve discrete parts.

We drew out the interface shape on a sheet of flannel, and André asked a local seamstress to hem it between sessions. At the start of the following session the group spread out their flannel base on a round table, and set up a second work area alongside it for the tracing, cutting and ironing work (we were using a heat-activated bonding agent to fix the felt illustrations to the flannel base). Each girl chose a drawing from the pile and began implementing it in felt. They worked on each other's objects, and often worked together on objects with lots of detail. The round tables provided ongoing opportunities for observing, sharing and socialising. When a girl had completed an object, she relocated to the interface table and reassembled it on the interface (figure 18). After they had completed all the representations, they discussed and refined positioning, and then ironed everything into place permanently.

**Content**

At the beginning of the following session the group spread out their textile interface on a table, and positioned the devices they planned to incorporate into it on it. They then proceeded to playfully enact a number of rounds of their game. They performed make-believe interactions with the off readers, and improvised feedback for them. Their play was spontaneous and light-hearted, but grounded in the rules. Afterwards they sat around the interface to script the narrative and fine-tune the interaction design (figure 16). Lara adopted the voice of the kangaroo in the introductory narrative, beginning with a personal introduction, then locating the game in Paula's room and explaining the objective, and finally concluding with the rules. Afterwards they worked on the feedback 'clues'. They spoke to and through the interface, using it to illustrate ideas to each other and establish feedback for a particular interaction.
The group recorded the narrative with André. Jasmin was unable to attend the session, and Lara was adamant that her voice did not sound good in recordings, which left Patrícia to do all the narrating. She looked pleased with the arrangements. André set up a makeshift studio in the CID, and took full responsibility for the recording and editing. Patrícia narrated the clues in a lively tone, and used the repetition of words to introduce a melodic quality, but found it difficult to narrate the longer introduction without mixing up words. After a number of unsuccessful attempts, André approached me about the issue. I explained that we could break the introduction into smaller parts, record each separately, and then simulate a single take with the programming. He and Patrícia then recorded the introduction sentence by sentence, which solved the problem.

**Programming**

The group spread out their textile interface on a table and placed tags on each of the object representations to establish physical tag-object mappings. They used consecutive numbering (from the tag's external number) around the perimeter of the interface – one to eleven – and placed the twelfth tag on the kangaroo. Lara then wrote up a mappings list, using the tag's external number as the object number. She also assigned the two readers to the two animal players, using the reader numbers as the animal numbers. She and Jasmin then proceeded to build the *funda* project. Jasmin clicked on the 'Add' (tag) button and read in the tag code with a *funda* reader. Lara inputted the tag's external number and user-assigned name through the keyboard (figure 16). Afterwards they tested their work by reading tags on the TUI and verifying output in the GUI, each taking responsibility for an interface while coordinating actions verbally (figure 16).

We worked together to author the Scratch project, using a conversational approach we would develop through the course of the study to mitigate the complexity of challenges youth set for
themselves. The approach was developed around Rogoff et al.'s 'community of learners' model, where adults are 'responsible for guiding the overall process and for supporting children's changing participation in their shared endeavours' [Rogoff et al., 2001: 7]. Conversations were structured around youths' rules and plans. We began by articulating a rule or rule element, then expressed it in pseudocode (natural language emphasising Scratch syntax and logic), and finally worked together to reformulate it in Scratch with the blocks. I withdrew from the process when I could see youth were able to work through a problem on their own. We began with the two 'start' event handler scripts, and then worked on the twenty two 'guess' event handler scripts. The craft objects and associated devices defined the structure for the programme and implementation method. Each object in the room was represented by a sprite, and the authors took turns to sketch their costumes and build the scripts in them. They used the temperature-proximity model I drew during the concept development stage, to plan the processing of a user guess, and then implemented their decisions. Lara lead, adapting the sketch for new object guesses, and assisting peers when she could see they were having difficulties thinking through scenarios. Each event handler tested for a number of conditions, often with sizeable conditional constructs (figure 15). Patrícia and Jasmin implemented a number of 'their' scripts, and then indicated that they were finding the process tedious. They tried to withdraw unnoticed. Lara was not happy with their behaviour, and reminded them that this was not how they had collaborated on the other components. She scolded them, and assumed responsibility for the last few scripts.

**Testing and Debugging**

The group tested their work by playing with the interactive. Jasmin was frustrated by Lara’s hundred percent win rate, until she realised that her friend was using her understanding of the software to make informed predictions about the location of the sweets. She reflected on her peer's
approach and adapted her model, which quickly evened things out. She used the strategy with devastating effect against other kids invited to play in the following round of tests. A bug in the code that controlled turn-taking was never detected, because the authors followed their own rules, and users attempted to abide by the rules outlined by the kangaroo in the introduction.

Use

The interactive was presented to the centre community at an open event at the end of phase one (figure 17). All three girls chose to wear something special for the occasion. They invited peers to gather around their interface and Patrícia explained the game. She oversaw use until every child had had a turn, after which youth took over and began applying a version of their winner-stays-on-the-table rule: if a user won they kept their reader, if they lost they gave their reader to the following user. The new rule built continuity between games and made the interactive better suited to larger groups. Those youth that weren't actively playing rallied behind the challenger, offering them advice and support while they waited for their turn. They also used the time to manage order in the player 'queue'. All this helped build an atmosphere of excitement and anticipation around the interactive. Importantly, there were no tantrums when users lost.

After the presentations, I left it up to the centre to explore their own uses of the interactive. Staff chose to use it in a variety of ways, both in and outside the centre. In the winter of 2013, they proposed youth present the interactive at a local old-age home Christmas party. The home provided us with a small square table for the interactive, with sides that were slightly less than the diameter of the interface. Youth quickly adapted the set-up, allowing the edges of the textile surface to drop over the sides, and placing the tags closer to the centre (figure 17). Having observed that residents were too frail to stand and use as they did, they positioned a few chairs around the interface. The two ladies that wanted to use the game informed us that they knew nothing about 'computer games'.

We explained that the interactive wasn’t a computer game in the traditional sense, and asked two youth to play a game to show them. The two youth sat at the table with the ladies and proceeded to play. The ladies smiled when the kangaroo announced the winner and consoled the loser, and then indicated they were ready to play. Each youth assisted one of the ladies, sometimes lifting their hand that was holding the reader and guiding it towards the object they wanted to read, and others, when the object was out of their reach, reading it for them. A form of intergenerational collaborative play evolved, with youth playing with their respective partners against each other.

5.1.3 Study Questions

i. Did the design activity promote diverse participation?

Observations

There was commonality and difference in the O Quarto da Paula group. All three members exhibited a clear interest in arts and crafts and playing games from the beginning of the design
process. They chose to draw up all eleven objects for Paula's room even when they knew only a few of their drawings would be used; discussed and handled the new textile materials with pleasure and excitement; pushed the materials to their representational limits in their own design; shared out the drawing of the Scratch sprite costumes carefully between them; and played the work-in-progress interactive enthusiastically at each stage of the design process.

Differences were also apparent. Patrícia and Jasmin were active participants in the centre's music and dance activities, and both played prominent roles in a public concert organized near the end of phase one. Patrícia was noticeably pleased when she was given the task of narrating all the group's audio content. Her narration style was expressive and authoritative, and likely informed by her experiences in the performative activities. Jasmin, who was unable to attend the recording session, expressed disappointment when she found out that Patrícia had completed the task without her. Lara showed no interest in such performative activities, but was learning to play a musical instrument outside the centre. She was adamant that her voice sounded bad in recordings – her reason for not narrating – and maintained this view for all three phases of the study.

Lara enjoyed planning and managing processes, and always assumed responsibility for these tasks in the group. Patrícia and Jasmin expressed no interest in her role, but did participate actively in the decision making. Lara was also an aspirant writer. She authored a number of illustrated short stories on her own at home after phase one. She explained in an interview in phase three that her co-authorship of the O Quarto da Paula story with Patrícia had given her the confidence to write her own stories.

Patrícia and Jasmin spent most of their allotted free time in the CID playing in their virtual dolls' houses (apartments), on a site where both had created accounts. They experimented with different
outfits, skin tones, hairstyles, make-up, etc., and spent hours redecorating their interiors. Lara stated many times that she didn't like computers, especially for creative work, but she was the one who appeared to enjoy reasoning her way through programming problems. Jasmin and Patrícia assumed more peripheral roles [Lave & Wenger, 1991] in the programming.

Conclusion

The design of playful craft-tech interactivities promoted diverse participation. The activity drew in youth with overlapping and different skills and interests. Areas of strong overlap included arts and crafts, and games. Areas of difference included performative arts, music, writing, planning and managing, and the use of computers. The combination of arts and crafts and games appears to be an effective way to promote diverse participation in design activities.

ii. Did the kit and environment support interpersonal connections?

Observations

The kit and environment played important roles in interpersonal connections from design through to use. Shared use of example interactivities in the introductory session, and co-construction of exercise projects with multiple devices, helped build shared understanding about the tools and the kinds of things that could be created with them. This was the common ground that enabled engagements around the shared design problem. The group were quick to establish their treasure hunt idea, because it was how they read the technology through the examples. The treasure hunt idea expanded common ground (all three girls were very familiar with treasure hunts) and located discussions in their lifeworlds. The group built out from this platform, grounding their thinking and discussions in the rules for treasure hunts and generating their own ideas from what they understood about the tools and things that could be designed with them. Multiple perspectives on the shared design problem (each individual had their own background knowledge, prior experiences,
expertise, aims, etc.) – 'cognitive diversity' [Badke-Schaub et al., 2007] – stimulated creative interactions. The girls queried each other's ideas, built on them, adapted them, and offered alternatives, and in so doing became involved in each other's thinking processes.

The interactive gained composite form around the multiple devices in the kit, and the external development process facilitated the 'mutual bridging of meanings' and 'mutual structuring of participation' [Rogoff, 2003]. The group listed the different hiding places they planned to associate with the RFID tags and spoke about two animals which would take turns to look for the treasure. Lara sketched up the first representation on a sheet of paper, basing it loosely on one of the examples they had used together, and the group imagined interaction scenarios in it. I suggested they use their rubber and sharpener to physically represent the two animals' (readers) movements in the game environment. Lara acted out their ideas with the two objects in the drawing, which made them more concrete and public. This helped to increase participation, and further 'interlock cognitions' [Miller, 1987]. Lara worked decisions into a description of a hypothetical use scenario, and then extracted six game rules from it. The rules, use scenario and drawing captured the group's shared understanding of what they planned to create together.

Multiple craft objects associated with multiple devices in the kit provided the group with multiple points for engagement in the shared implementation process. The girls decided that they would each draw all eleven objects and then choose the best. They gathered around one of the centre's round tables to make the selection, and each one positioned some of her favourites immediately in front of her as tentative proposals. Colleagues observed from where they were standing, and began negotiating for their version when they thought it was better. They negotiated across the table and on the shared surface, and adjusted drawings immediately in front of them for optimal reading from their position. The outcome of their combined actions was a plan for a circular interface, which
users could gather around and use from any point. They worked together to transform their drawings into plans for the felt implementations, labelling each element in a drawing with its colour, and each girl assumed responsibility for implementing a plan. They worked around one of the centre's round tables, observed each other, offered support and chatted. They worked on each other's objects, and together on objects with lots of detail. When they had completed the craft surface, they laid the RFID tags on the craft objects to establish the planned tag-object mappings in the physical world.

Co-construction of the concept and interface scaffolded software co-constructions up to a point. The group played the game with what they had; their rules and the interface. They performed make-believe interactions with the off readers and improvised feedback for them. Details and differences in understanding were discussed and resolved through the interface. Lara wrote up their ideas for the narrative in the script and Patrícia narrated it for the output. They carried relationships established between tags and craft objects over into their funda project, one girl reading in the tag codes with a reader while another entered user-defined data through the keyboard (name of the object, etc.). They then coordinated efforts verbally from the host and TUI to check their work. Finally, they carried relationships established between the different craft-tech objects over into the Scratch programme, using proximity to a point of interaction to calculate temperature-related feedback. Constrained access on the host focused the group's attention on individual problems, enabling us to leverage the combined understanding of the group to solve challenging parts. The programme was structured around the craft-tech objects, and the girls took turns to implement the tag event handler scripts for them. There were twenty two such event handlers, which each tested for multiple conditions, often with sizeable conditional constructs (figure 15). Patrícia and Jasmin indicated that they found the task tedious, and opted out after completing some of their scripts. Lara reminded them that it was not how they usually worked, and built the last scripts on her own.
Testing the completed interactive together helped to externalise internal models, which provided opportunities for comparison, reflection and refinement. Members took temporary ownership of individual devices and played against each other for the tests. They played with their model of what they had built together (which overlapped in most areas but not all). Some versions of the model proved more effective than others. The loser reflected on the winner's use and adapted their own. These adaptations helped to level out the playing field.

Users connected through the completed interactive. They gathered around the interface, faced inward towards each other and the unfolding interaction event, and alternated between active and passive user roles. Active users took temporary ownership of individual devices and played against each other, while passive users observed to learn how to play the game, see if they could detect how the system hid the treasure, devise their own playing strategies, offer support and commentary, and enjoy the social event. Multiple devices also enabled centre youth to team up with elderly folk in an old-age home and play against each other. They established playful inter-generational bonds through the game which were a new experience for young and old in the community.

Conclusion

Shared use of inclusive interactivies and co-construction of exercise projects with multiple devices helped to establish the common ground that enabled engagements around the shared design problem. The group negotiated and consolidated their developing shared mental model (e.g. [Mohammed & Dumville, 2001][Badke-Schaub et al., 2007]) of the design problem at each stage of the design process through their developing shared external model. The external model provided them with a common set of references and points for engagement, which supported the modification of perspectives to understand another member's perspective, and thereby the co-construction of the
internal model. The centre's respectful culture, common experiences in and outside the centre (e.g. crafting and treasure hunts), socialisation to interdependence – 'responsive coordination with the group' [Rogoff, 2003: 200], the round tables, the community of learners model [Rogoff, 1994], the inclusive interactive concept, and the use of a kit comprising multiple 'evenly-weighted' devices, all played a role in interpersonal connections. While it is important for the purposes of the study to single out the role of multiple devices in promoting and supporting co-construction (externally and internally), especially in building collective ownership and structuring the design process for co-construction, technology cannot be viewed in isolation. Rather, it was the ongoing interaction between factors related to the kit and environment, the centre, and its community, which helped to promote and support the interpersonal connections through the phase. The breakdown in interpersonal connections at the end of the programming stage appeared to be related to the extended and repetitive nature of the actual programming task.

Figure 18: Multiple Points for Engagement in the Shared Design Process – the 'O Quarto da Paula'
(Left) Group members assembling craft objects on the interface. Each girl has assumed responsibility for a craft object associated with a digital device. (Right) Discussing the association of digital devices with craft objects. The twelve RFID tags have been placed on the twelve completed craft objects for planning purposes.
The completed interactive comprising multiple craft-tech devices supported a variety of interpersonal connections through the object. These included group member involvement in each other's thinking during the tests, complex multidirectional shared engagements from active and passive user positions during use in the centre, and adult-child dyad constellations in an old-age home.

**iii. Did interpersonal connections help advance the centre's transformative agenda?**

*Observations*

Interpersonal connections promoted individual development within the group. Youth had to co-construct and maintain a *shared mental model* (e.g. [Mohammed & Dumville, 2001]) of their design problem to proceed with the shared endeavour, and involve participant-leaders in an ongoing way in the process. The model was built between individuals, and could not be attributed to any one of them alone. It involved communication and coordination, and involvement in each other's thinking processes – what Rogoff calls *shared thinking* [Rogoff, 1990, 1998]. Members were continually in the process of stretching their common understanding to fit with new perspectives in their shared endeavour, and using the understanding in context. Peers served as resources and challenges for each other. There was, however, a breakdown in interpersonal connections at the end of the programming, which limited opportunities to learn.

The stretching of common understanding was an ongoing process. For example, youth learnt about the multiple devices included in the kit while using example interactives together. They showed each other how to read tags, and realigned tags with craft objects when they were moved out of alignment through actions on the interface. They worked with this common understanding to develop their concept. They built on each other's ideas, proposed alternatives, queried what a peer
had said to get them to elucidate or add detail, and acted out ideas in a drawing to think them through together. They coordinated their contributions carefully so that the 'structural whole' (the shared mental model) could result [Miller, 1987], and each participant’s thinking became more and more an integrative part of what everyone else in the group thought. This became evident when I probed their planned temperature-proximity feedback model through my schematic diagram of their interface. They collectively offered feedback for my hypothetical interaction scenarios, and understood the value of André’s contribution (the 'hot' hiding positions) immediately, and incorporated it into their model. After I had shown them an approach for processing users’ guesses in the Scratch programme, they opted to use my schematic diagram to plan and implement each of the conditional constructs that controlled output to users. Lara circled the number of the hiding-place tag and marked the remaining tag numbers with the first letter of the feedback word as I had done in the concept development stage. The plan provided a clear roadmap for the implementation of a tag event handler script. The girls took it in turns to implement the event handler pairs for a hiding position, and Lara observed and offered support when it wasn’t her turn. She clarified points that I had explained to the group and caught errors. When they had completed the event handler pair for a hiding place, Lara rubbed out the letters and circle on the diagram, and the group repeated the process. As Rogoff has observed, the ongoing stretching of common understanding to accomplish something together is development, and later involvement in similar events reflect these changes [Rogoff, 1998: 689].

Jasmin, who re-emigrated with her family shortly after phase one, revealed changes during her participation in the testing and debugging. She was deeply frustrated by Lara’s unbroken winning streak until she worked out that Lara was using their shared mental model to narrow down the options and predict the location of the treasure. She adapted her approach and quickly levelled the
playing field. This cognitive stretching to understand Lara's perspective was only possible because they shared a mental model of the software – which overlapped in most areas but not all. Other youth who were not a part of the group, tried repeatedly to work out the 'secret' of how the system hid the treasure, but were unable to do so. These users included members of the other phase one group, who had also worked with Scratch to programme their interactive.

Patrícia's changes were evident midway through the design process, when she narrated the group's script for their audio output files. Her style was expressive and authoritative, and fitted well with the concept. Her use of example interactives and active participation in the design process helped her prepare for the role. In phase three she participated in the exercise stage of the newcomer group, and then left the activity because of a clash in time-tables. She was the only person in the new group with programming experience. She explained new concepts to peers in ways that they appeared to find easy to understand.

Lara went on to participate in phases two and three. She ramped up her project management in both phases to enable her colleagues to assume full responsibility for recording their audio content – which was significantly more ambitious than the phase one material – and mentored Luciana through phase three. The results of the mentorship were evident in the later stages of the phase, when the two girls regularly worked together as equals. In an interview near the end of phase three Lara revealed that her co-authorship of the narrative with Patrícia in phase one had given her the confidence to pursue her dream of becoming a writer, and that she had authored several illustrated children's stories at home afterwards. She chose to pursue the arts path in grade ten, the grade at which Portuguese kids must choose an area of specialisation. The course included multi-media and design components. She was the first child in the centre to choose this option.
Interpersonal connections also enabled the centre to effectively aggregate youth skills and interests in a design team in which the whole was more than the sum of its parts, which enabled youth to design an engaging new interactive learning resource for the institution. The interactive spoke to peers in 'voices' that were clearly from the community, and addressed an area of youth concern. Peers used the interactive repeatedly over the afternoon of the presentations, and during 'quiet' periods during the public presentations. The fact that they always chose to apply their winner-stays-on-the-table rule demonstrated how popular it was, and how it had been integrated into community culture. The fact that users never discovered the bug that would have allowed them to interact out of turn demonstrated how successfully the group had communicated their concerns to peers. The interactive represented a significant step in terms of youth participation in the ongoing development of their institution. Previous tangible contributions were mostly in the arts and crafts area, which helped to make the space more attractive and affirm youth identity and ownership. The interactive was the first craft-tech learning resource designed for youth, by youth. It showed how they could also become involved in the design of the things they used in the centre.

Playing the interactive together allowed youth to test out the activity and develop interest in their own time. It also helped build motivation to collaborate, and established a common set of references that could be used to solve other problems. Alex, Tomé and Luciana all used the interactive repeatedly during the centre presentations. They also took up strategic positions around the interface when they weren't using to follow others. Tomé, who was asked to leave the activity during the exercise stage because of his behaviour, announced that he would be participating in the following phase, even though none had been planned or announced. Alex, who chose not to participate in phase one, was one of the first youth to sign up for phase two. Luciana made an unannounced entry into one of the phase three advanced group sessions, and asked if she could join
the activity. The Os Seis Amigos group (section 5.3), who had all used the interactive on various occasions, used the interactive as a shared object-to-think-with [Papert, 1980] when they were thinking through steps while collectively authoring a large flow diagram for their programme. The common set of references helped to orientate shared thinking [Rogoff, 1998] around the problem. I used the interactive in a similar manner when I was trying to explain random mapping to the Batalha Ecológica group (section 5.4) in phase three. The common set of references enabled me to quickly unpack the technique, and the group went on to use it to solve their own design problem.

Interpersonal connections also enabled centre youth to engage with the broader community in new ways. Use in an old-age home demonstrated how the design of craft-tech interactives in after-school centres can enable youth to advance social inclusion and strengthen bonds in the community. Youth set up the interactive in the home and played a number of rounds with elderly folk who had not played 'computer games' before. Young and old, who normally would not have had the opportunity to play together, connected through the object. Youth showed the ladies how to play the game by playing with them, and assisted them with interactions they found difficult to make. The ladies became engaged in the game and were appreciative of youth efforts. Youth enjoyed playing with the ladies. It was a new experience for them, and one they said they wanted to repeat.

Conclusion

Interpersonal connections helped to advance the centre's transformative agenda at individual, institutional and community levels. At an individual level, there was evidence of transformation of participation [Rogoff, 1998, 2003] through mutual involvement [Rogoff, 1995] in co-construction activities. At the start of the phase, all participants stated that they had no previous experience in technology design, but that they used technology regularly for a variety of purposes. After co-
constructing the interactive, group members were able to manipulate a shared mental model of their software to gain 'unfair' advantage over peers in the game, explain programming concepts to newcomers in terms that they appeared to find easy to grasp, and effectively mentor younger peers into the design activity. One member was also able to build on her interest in the performative arts through the narration for the output, and the experience of authoring a story together helped to give another member the confidence to pursue her dream of becoming a writer. This member chose to follow the arts track when she reached grade ten. The arts track included multimedia and design components. Her participation in the activity could be read as a form of preparation for what she expected in the future on the basis of her prior participation in related activities. How people prepare now for what they expect later on the basis of prior participation, is one of the central questions raised by the transformation-of-participation view [Rogoff, 1998: 690].

At an institutional level, interpersonal connections enabled the centre to aggregate and channel youth diversity towards transformative ends. The group designed an engaging new learning resource for peers that would have been extremely difficult for any one youth or interest group to design on their own. Divergence of mental models at the beginning of the design task generated creativity, and convergence of mental models – toward the shared mental model – facilitated implementation. The interactive helped to make the space more convivial [Illich, 1973], by connecting youth in playful constellations, and demonstrating how they could further shape their environment to their tastes and needs. Playing with the new resource in and outside the centre enabled peers to test out the activity and develop interest in technology design in their own time. It also helped to build motivation to work together and establish a common set of resources – a shared repertoire [Wenger, 1999] – which we referenced to solve other design problems.
Finally, at a community level, interpersonal connections provided a way for youth to connect with others in their community and co-create an enjoyable social experience that promoted social inclusion and strengthened bonds between generations.
5.2 Interactive #2: *A Casa das Palavras* (House of Words)

5.2.1 Description

The *A Casa das Palavras* (House of Words) interactive is a three-letter word game for multiple users, designed by Superman, Alex and Tomé. It was designed over a six-month period in phase two (2012). The aim of the group was to help peers with their spelling and vocabulary.

The interactive is made up of a multi-layered cardboard TUI and twelve cardboard letter cards. Each card has a neodymium magnet and RFID tag embedded in the back, and a vinyl letter glued to the front. The TUI is designed in the shape of a house, and is made up of two interlocking forms which can be completely separated. The upper form has three recesses cut in the top surface for the letter cards. A ‘start’ press-button is set in the centre of the form, and a circuit with three reed switches embedded in the back. The reed switches are aligned with the magnets in the cards when cards are correctly placed in the recesses. Three correctly placed cards will close the circuit. Three *funda* readers are positioned in the base form, and the press-button and reed switch circuits are plugged into one of them (figure 19). The RFID modules on the readers are aligned with the tags in the cards when cards are correctly placed in the recesses. The upper form is placed over the base and locked into position for use.

Users press the start button to start or restart the game. The game has six levels, and users have two minutes at each level to build a specified number of words. The number of words increases from level to level, and words cannot be repeated at any time in the game. The first five levels are in Portuguese, and the final in English. Users are offered encouragement after completing a level, and then told how many words they have to build for the following level. Failure to complete a level
ends the game. The system can detect new words, repeat words, and ‘words’ not found in either of the languages. For new words the system plays back the word, for repeat words it informs users that the word is being repeated, and for words not found in either of the languages, users are told the word doesn't exist. Users that complete the game are congratulated. A short computer game tune is played immediately afterwards.

**Summary:**

Number of Authors: Three

Design Period: Phase Two (2012)

Design Duration: Six months

Kit Configuration: Three node project PAN + twelve RFID tags
Figure 19: Designing the ‘A Casa das Palavras’ (House of Words) Interactive
(left to right and top to bottom) Cutting out cardboard layers for the main interface form; collaboratively testing the reed switch circuit; programming together; plugging in the funda readers into the interface; testing the start button and start script together; building words collaboratively in the interface to test and debug the final version of the programme.
5.2.2 Design and Use

Concept

In this phase I provided a core concept and programme, and groups gradually shaped these into their own interactives by adding on their own ideas. In the introductory session I explained that we were going to design three-letter word games; that interactives would be made up of twelve letter cards and an interface for building the three-letter words; that the interface would contain a reader for each letter in the word and a reed switch circuit for detecting when a word was presented to the system; and that each letter card would contain an RFID tag for representing a letter, and a neodymium magnet for switching the reed switch circuit. The interface ideas were introduced through low-res prototypes, and the core programme components built together over a number of sessions. I encouraged groups to strive for designs that would motivate peers to build and share vocabulary and work on their spelling.

Youth planned their rules while working on their interfaces and core components for the programme. Bilingualism quickly emerged as a 'hot topic' in the two participant groups. Alex was the first to raise the idea. He asked if they were allowed to use English, a language everyone struggled with at school. His request set off an extended debate between groups about the use of the language. The other group wanted to offer English as an option to users through the interface, allowing them to play the same game in two different languages. The A Casa das Palavras group proposed to use it in the final level of a multi-levelled game. They explained that this would make the game especially hard to complete and would also encourage youth to work on their English.

Alex and Superman took responsibility for writing up the group's ideas for the project. André, the staff member responsible for digital inclusion, assisted them. He asked them questions, isolated
core ideas, and wrote down the ideas on a sheet of paper. He kept the outline simple: number of levels, number of words required to pass each level, time allotted for each level, languages for each level, and the rule that words could not be repeated at any point in the game. Afterwards, he drew up a flow diagram, showing decision points and user progress through the game. After consolidating their ideas in the document and diagram, he tasked them with writing up the game script. Alex's superior knowledge of Portuguese and the word processor placed him in a natural leadership position for this task. He led discussions, summarised ideas, showed Superman how to complete new tasks with the software, helped him with his Portuguese grammar (Superman was a second-language speaker from Cape Verde), and made a point of rotating responsibilities. The boys structured the document around the six game levels, detailing what happened at each level and the narrative that would accompany it. They showed the document to André afterwards. He made a few corrections to their Portuguese and worked with them to make the introduction more succinct. He also explained that there was no need to explain feedback to users. Youth grasped his point and adapted their document accordingly.

**Interface**

Superman and Alex looked through a number of the centre's games, and isolated one with playing cards which everyone felt were the right size and shape for their interactive. Tomé traced three card outlines across an A3 sheet of paper, and when he was done, he observed that the result resembled a house. The others liked his idea, and encouraged him to pursue it further. He drew up the remainder of his house with a ruler, and added some freehand lines to the roof area to indicate tiling. Alex then placed a *funda* reader inside each card outline, and the group proceeded to use them to explore hardware positioning and orientation inside the interface. After establishing a solution that met all their requirements, Tomé traced out the reader outlines to mark their positions, and cut the house from the page to create a template for the multiple cardboard layers.
They worked together to cut out the first cardboard layer. They cut simultaneously, each assuming responsibility for a side of the house. The size of the object made it difficult to access, but the three boys found a way. Alfonso, a youth who was technically part of the group, but who had not really participated since the start of the phase, expressed exasperation about the lack of a meaningful role for him and swapped groups. After cutting out the first layer together, each youth assumed responsibility for cutting out a layer and discussed changes with the others (figure 19). They regularly assembled the work-in-progress object to check their work, think through problems together, and plan next steps. Those who had finished their layers first began work on the cards. They shared insights with each other in a fluid and ongoing way. While Alex and Superman were working on the last of the cards, Tomé measured and soldered up the reed switch circuit. He took care to ensure the switches were positioned directly below magnets when cards were placed in the interface. After completing the circuit, he cut a channel for it in the back of the main form, and taped it temporarily into position. He then worked with Superman to test it. Superman authored a simple tester programme which enabled them to check if the circuit was closed when three cards were placed in the interface, and Tomé built words in the interface to test the circuit and cards. Superman observed Tomé’s interactions, and Tomé studied the Scratch programme (figure 19). The two boys discovered a minor hardware bug during the tests. They shared information about 'their' parts of the system to build a common and complete view, and used it to establish the cause and devise a solution.

After the tests, the group glued the cardboard layers together to create the main TUI form. This act effectively erased the earlier co-construction affordances. Youth acknowledged this by establishing a new set of tasks for Superman and Alex. Tomé continued work on the interface alone. He refined the internal recesses for the readers, set the 'start' press-button in the centre of the main interface
form, and secured the circuits with hot glue. When Superman and Alex saw he had finished the press-button, they proposed they use the interface to test the introductory audio segments they had recorded. Superman and Alex adapted an existing script for the purpose, and indicated to Tomé that he should press the 'start' button (figure 19). The introduction played back as the boys had planned. Over the following weeks, Tomé designed and implemented a cardboard locking mechanism to secure the two parts of the interface together for use. The locking mechanism was based on an idea originally advanced by the other group. They analysed Tomé's implementation of their idea carefully before implementing it on their own interface. After completing the interface, Tomé appeared to view his part as completed. We encouraged him to engage with the others in the programming, but his reply was always the same: I'm not good at those things (Não sou bom nessas coisas.). He spent the following sessions lounging in the easy chairs. At one point, after seeing how the other group were providing information to their users on the interface, he fetched the rolls of coloured vinyl from the activity cupboard and cut out the letters for the word 'START'. He applied the word to the area around the start button, and then proceeded to cut out a number of dots and apply these to the surface as well.

Content

Alex and Superman wrote up the initial Portuguese and English word lists. They showed the Portuguese list to André. He corrected some of their spelling, drew their attention to words that were not yet officially part of European Portuguese, and suggested a few new words. The boys listened carefully to his advice and adapted the list. They extended the list over subsequent sessions, working hard to identify all the Portuguese words that could be spelt with the twelve letters they had chosen for their game. They asked me to help them with the English list. Their initial list contained eight words. I worked with them to extend the list by adding some commonly
used verbs and nouns. I explained that I was limiting my suggestions in an attempt to make the game accessible to local youth. Both agreed that a simplified English list would be more effective than a definitive one. They took careful note of each word and its translation, and were especially pleased to learn the word 'cap'.

Superman, the old-timer in the group, lead the recording of the content. He and Alex sat side-by-side in front of the computer to complete the task. Superman controlled the software for the first few takes, and Alex did the narrating. This arrangement allowed Alex to observe the recording and editing processes, and learn the steps involved. From there on, they chose to rotate the narrator role and share control of the input devices. The editor interacted with the software through the mouse, controlling the various steps in the recording and editing processes, and the narrator entered the name for the new file through the keyboard. They coordinated their efforts carefully, observing each other's interactions and acting at appropriate points. André suggested they break up their introduction into a number of smaller segments, and simulate a single take with the programming.

*Programming*

The programming was completed in two distinct stages. In the first stage we built the common core for both groups' programmes. In the second, groups built and connected their own project-specific components to the common core to realise their ideas. In both stages we used the conversational approach from phase one (pg. 91-92). Superman's strong participation in the programming in phase one placed him in a natural leadership position for these tasks. He worked closely with Alex, who was the newcomer. Tomé only engaged in the programming when the group combined hardware and software to test components.
The common core was a scaled-down version of the basic functionality required for the three-letter word games. The programme was designed around three letters which could spell four Portuguese words. It read in the three letters presented by users in the interface, concatenated them into a word, and checked if the word was in a list of words that could be spelt with the three letters. If it found the word in the list, it played a sound file associated with the word, added the word to a list of used words, and deleted the word from the original word list. We built the programme component by component, and explored functionality at each stage through a simple prototype for the interface. In the second stage, we built the project-specific components and connected them up to the common core. We used the group's interface to think and play through new ideas, and referred to ideas embodied in it in our discussions. We also referred to the project script, and André's documents to bridge different perspectives [Rogoff, 2003] and plan next steps. Alex and Superman built on and responded to each other's ideas throughout our discussions.

The two boys worked together in Scratch. Superman generally assumed control of the mouse for the drag-and-drop programming, and Alex entered the numeric and string inserts in the block arguments through the keyboard. The prominent role of the mouse in drag-and-drop programming fitted well with Superman's leader position. Alex observed his interactions in the user interface intently, and asked him questions when he wanted to understand something (figure 19). They swapped roles for simple repetitive tasks, to allow Alex to gain experience with the Scratch construction process. This was Superman's idea. He observed Alex's interactions in the user interface, and provided support when he felt it was needed. They followed a similar approach for the funda project: Superman interacted with the funda GUI to create the new tag object, while Alex interacted with the interactive's TUI to make the tag code available to the software.
After testing the first full version of the programme, youth observed that it became sluggish after processing about a dozen words. They blamed the centre's computers, observing that versions running on my laptop for projection and discussion purposes ran much better. André and I conducted tests outside the sessions to ascertain the cause. We found that it was related to the operating system – the centre's computers were running Windows 7 and my laptop was running Ubuntu Linux – and the lengthy search and audio output scripts. André performed a dual-boot install (Windows-Ubuntu) on the centre's computers, and I studied ways to rework the Scratch code. I had chosen to use a limited number of well-defined and clearly related components in the common core to make the underlying mechanics of word search and audio output apparent. The approach had proved easy to follow – youth regularly demonstrated their understanding by explaining processes through the projection – but increased the number of steps for a result. Search could take up to 89 steps to produce a result, and output 88. Breaking down the lengthy processes into collections of shorter ones helped to solve the problem. The collections followed a similar overall approach, with a number of important differences. I explained the changes to youth and the concepts used to implement them, and then they worked alone to adapt their programme. They identified a component that required changes, studied the scaled-down example I had provided, read through what they had, and then discussed what needed to be changed and how it should be done. After settling on an approach, they implemented it together and then ran the code to check that it produced the desired result. When they discovered a bug in the output, they returned to the script, discussed the problem, and effected the agreed changes.

*Testing and Debugging*

The members of the group combined their work at various points to test it, each assuming responsibility for 'their' parts of the system and sharing information to enable the others to participate fully. When they had completed the software and hardware, Superman and Alex played
(from left to right and top to bottom) Alex removing a word from the interface; Superman positioning a word in the interface; both boys studying the code while Alex checks cards are correctly positioned in the interface; removing a word together; scrolling through the word lists to look for a bug; Alex positioning a word in the interface.
the interactive to test and debug their Scratch project. They prepared, built and removed words cooperatively, while observing changes in the graphic word lists and listening to audio output. Sometimes one boy removed the checked word from the interface while the other prepared the cards for a new word. Sometimes they worked together to remove the checked word and then build the new word in its place (figure 20). They switched back and forth between the two methods, always announcing new words that had come to mind to align intent, and observed each other's actions to coordinate efforts. When they detected a bug, they analysed the word lists and code together until they found the cause. Superman always corrected the code. Alex, who was the newcomer in the group, regularly spotted the problem before his more experienced peer, and explained the fix.

**Use**

The first use of the completed interactive was at the centre presentations. Staff organised it as a formal event to encourage youth to work on their presentation skills. The group stood at the head of a large table and presented their work to peers. Afterwards staff oversaw use, allowing each youth to use the interactive once. Passive users quickly began assisting the designated user, suggesting new words, passing them cards, and removing and placing cards in the interface with them. They also corrected and finished words the user was having difficulty spelling. When the word was played back by the system, the helper looked at the user and made a 'you-understand-now'-type gesture or expression. Some users with spelling difficulties were gradually edged out of the game as their peers built more and more words for them, often with the best intentions. Staff responded by enforcing single-user use. Youth attempted to abide by the new rules, but it was apparent that the rules did not fit with their reading of the interactive. They continued to whisper new words and slide cards nonchalantly across the table in the direction of the user, even after a number of staff outbursts about the matter.
After the presentations, I left it up to the centre to explore their own uses of the interactive. Staff chose to use it in their interventions in the local community, to engage young people and showcase the centre's work. The first such use took place at the local school's open day. The authors were adamant that they did not want to be associated with the activity at school, so we asked interns to build up the interactives and oversee use. Three broad types of use were observed on the day. The least observed was individual use. This type of use generally occurred when there were few other people in the room. The user observed others to learn how to use the interactive, and then used it themselves when it was free. Most of these users made it to the second or third level of the game and then ran out of time. The next most observed type was assisted use, usually a parent-child dyad. The child used the interactive while the parent observed their progress from a position nearby. When the child found it hard to think of new words, the adult stepped in and helped them, either by suggesting new words and assisting with spelling, or by building new words with them in the interface. Parents appeared to enjoy playing the interactive with their children, and often became equally engaged. Many perceived the pedagogic potential of the resource, and used it to teach their child new words. The third and most observed type of use was cumulative use. One or

![Figure 21: Using the 'A Casa das Palavras' (House of Words) Interactive.](left) Enforced single-user use during the centre presentations. (right) Multi-user use during the presentation at the local school open day.
two users began using the interactive, and were gradually joined by others through the course of the
game. The additional users were both known and unknown to the original users. Members of these
impromptu groups collaborated actively with one another, shouting out suggestions for new words,
responding to these suggestions, preparing new words outside of the interface, positioning cards in
the interface and removing them, and rubbing cards back and forth in the recesses to facilitate the
closure of the reed switch circuit. The smallest of these groups was made up of three members, the
largest seven. A number of these groups were able to complete the game.

5.2.3 Study Questions

i. Did the design activity promote diverse participation?

Observations

There was both commonality and difference in the A Casa das Palavras group. From the start, all
three boys exhibited a distinct interest in crafts, computers and games. They shared out their
construction work carefully, worked on each of the individual tasks when they could, reported their
achievements to one another, and always endeavoured to achieve the best overall result. All spoke
about what they were doing in hurried and excited tones. Their interest in computer games was
equally intense. They spent most of their allotted free time in the CID playing online games, and
kept each other informed about scores, powers, speeds, etc. They also played console games in the
centre, and organised to meet up at home to play there too. Board, card and other tangible games,
such three-in-a-row and table soccer, were also popular, and no boy ever tired of playing football
outside in the multi-sports arena. All used the interactives repeatedly at the phase one presentations,
and engaged in the animated group discussions around them.
Their experience with crafts and computers also differed. Tomé grew up in Cape Verde, in a context where it was common for children to make their own toys from packaging waste and other found materials. These early experiences appeared to have shaped his crafting skills, which were well above those of his peers. Superman, who was two years younger than Tomé, also grew up in Cape Verde. He too appeared to be familiar with making things, but not to the extent Tomé was. Alex, who was born in Angola and grew up mostly in Portugal, appeared to be the least familiar with craft construction, but was always keen to learn from his peers. In activity terms, Superman was the old-timer in the group. In phase one, he participated actively in all areas except narration, and took a special interest in the computational tasks. These experiences helped build understanding about the audio software, Scratch and fundakit, and placed him in a natural leadership position for the narrative recording and programming in phase two. Tomé found it hard to resist playing games when seated in front of a computer, and generally tried to avoid them in the activity to keep out of trouble. He also stated that he 'wasn't good with those things' (computers). Alex had been taught about the word processor at school, and was used to using it to author various kinds of documents. He knew nothing about the other computational tools we were using in the activity.

Youth also had their own interests. Tomé was passionate about electronics. He always set up the electronics area at the start of sessions and tidied away afterwards, and dispensed electronics advice and support to whoever he thought needed it. He also assumed full responsibility for all electronics tasks on the A Casa das Palavras. In a self-evaluation activity run by Ana after phase two, he stated that his biggest dream was to become an electrician. Alex was known as a 'bom aluno' (good student) in the centre, and planned to study law after school. He had a strong command of the Portuguese language, and often helped Superman with his spelling, grammar and pronunciation. Superman never articulated any firm career dreams or plans.
Conclusion

The design of playful craft-tech interactives promoted diverse participation. The activity drew in youth with overlapping interests in games, crafts and computers, but previous experience with craft and computers was extremely varied. Youth were also formulating their own career dreams and plans. One boy wanted to become a lawyer, another an electrician, and the third was not yet ready to express thoughts on the matter. The combination of crafts, computers and games appears to be a way to promote diverse participation in design activities.

ii. Did the kit and environment support interpersonal connections?

Observations

The kit and environment played important roles in interpersonal connections from design through to use, but there were also points where design decisions constrained interpersonal connections. Shared use of peer-designed interactives and co-construction of exercise projects with multiple devices, helped to build shared understanding about the kit and the kinds of things that could be designed with it. Exercises where the group shared access to a single device constrained access and promoted an asynchronous form of collaboration, in which members assumed responsibility for specific parts of the exercise and shared little about their work. Co-construction in these cases was primarily external, in the form of the exercise object. Further connections through use and analysis of the prototypes and common core programme I designed, helped to stretch shared understanding to key aspects of the design problem. The group built out from this platform, working with their shared repertoire of computer games. Common references, such as game challenges, levels, time limits, etc., served as a form of intersubjective scaffolding for shared thinking [Rogoff, 1998] around the design problem.
The interactive gained composite form around the multiple devices in the kit, and the external development process facilitated the 'mutual bridging of meanings' and 'mutual structuring of participation' [Rogoff, 2003]. André worked with Superman and Alex to formalise and detail their plans. They discussed how many words users would have to build with the tagged letter cards at each level in the game, how long they would have, and which languages would be used. André wrote up their decisions in a simple outline, and drew a high-level flow diagram to show user progress through a game. The outline and flow diagram captured the group's shared understanding of what they planned to create together. Superman and Alex wrote up the game script from the two documents. They structured it around the six game levels, listing possible scenarios for a level and writing the narrative for each. They consulted the outline and flow diagram to establish a task, discussed their ideas, and wrote up decisions. While one youth wrote, the other followed what they were writing on the screen, and drew their partner's attention to issues of concern. They rotated roles after completing a level. They adopted a similar approach for the narrative recording, with Superman first controlling the software while Alex narrated, so that Alex could follow his interactions and learn from him, and then sharing control of the software and rotating the narrator role.

Multiple craft parts associated with multiple devices in the kit provided the group with multiple points for engagement in the shared implementation process up to a point. Members cut out the first layer for the main interface form together, and then each youth took responsibility for a layer. They worked around one of the round tables, observing each other and discussing details. They periodically combined their layers to check progress on the overall task, think through problems and plan next steps. At these points, they built on and queried each other's ideas and offered alternative views, and in so doing became further involved in each other's thinking processes. When they had completed the layers, they followed a similar approach for the letter cards, each working on a card
and sharing insights in an ongoing way. While Superman and Alex were finishing the last of the cards, Tomé soldered up the reed switch circuit. He cut a channel in one of the layers, taped it temporarily into position, and then worked with Superman to test their work. Superman built a script which allowed them to check if the circuit was closed when three cards were placed in the interface. Tomé then proceeded to check the cards and the circuit. Superman studied Tomé's interaction with the tangible interface, and Tomé studied graphic output in Superman's programme. When they discovered a bug, they shared information about 'their' parts of the system to build common understanding, and then worked together to devise a solution. After completing the tests, they glued the layers together to create the main interface form. This act eliminated the earlier co-construction affordances. The group acknowledged this by establishing a new set of tasks for Superman and Alex, and agreeing that Tomé would complete the remaining interface tasks.

Co-construction of the concept and interface scaffolded two members' software co-constructions. Superman, Alex and I referred to ideas detailed in the various project documents and materialised in the interface, and developed solutions for the programming together. I withdrew when we could see youth were able to work through the problem on their own. Superman did the drag-and-drop work with the mouse and explained what he was doing to Alex. Alex followed his interactions, and entered numeric and string inserts in block arguments through the keyboard. They swapped roles for simple repetitive tasks to allow Alex to gain experience with Scratch construction. Superman followed Alex's interactions in the editor, and provided support when he felt it was necessary. They coordinated interactions through the graphic and tangible interfaces to build the funda project, Alex placing cards in the tangible interface to make tag codes available to the software, and Superman inputting user-defined data through the funda GUI. After discovering that the programme became sluggish, we reworked the larger scripts. I demonstrated an approach, and Superman and Alex implemented it. They studied my outline, reflected on what they had, discussed what they would
change and how, and then proceeded to adapt and test their version.

Superman and Alex played the near complete interactive together to test and debug the programme. They observed each other's moves and communicated ideas to coordinate interactions with the multiple tagged letter cards, and analysed programme output. When they detected a bug they inspected the code together to identify the cause and devise a solution. Groups of users communicated ideas and coordinated interactions to play the game together. They proposed new words out loud, offered feedback on proposals (if a word had been used or not, praise for a good idea, etc.), prepared cards outside the interface, explained word meanings, built up words together in the interface, and removed them afterwards. These interactions required and built *intersubjective understanding* [Crook, 1994]. Parents also supported children by offering new words, spelling them out loud, and explaining meanings, and in cases where adults enforced single user use, youth assisted peers who were having difficulty spelling words by correcting or finishing them for them.

*Conclusion*

Shared use of interactives in the centre, co-construction of exercise projects with multiple devices, and use and analysis of prototypes I developed, helped establish the common ground that enabled engagements around the shared design problem. The three boys negotiated and consolidated their developing shared mental model of the design project through their developing shared external model. This involved creative efforts to understand and contribute to the social activity – bridging between different ways of understanding a situation [Rogoff, 1995]. Gluing the interface parts into a single unitary form limited access, and forced youth to reconfigure the co-construction process as a dyad plus one. The group combined their work at various points and shared information about 'their' parts, but these more intermittent interpersonal connections were not sufficient to maintain a high degree of commonality in the developing shared mental model. Two distinct versions
emerged: the dyad version, which was detailed in areas in which Superman and Alex were continually in the process of stretching their common understanding to fit with new perspectives in their shared endeavour; and the individual version, which was detailed in areas in which Tomé engaged in ongoing conversation with his object-to-think-with [Ackermann, 2004]. Tomé’s avoidance of programming after completing the interface showed that interpersonal connections are also influenced by individual youth interests and past experiences.

The design process revealed that while respectful institutional culture, common experiences (e.g. gaming), socialisation to interdependence (e.g. [Rogoff, 1990]), round tables, the community of learners model, the inclusive interactive concept, and the use of a kit comprising multiple evenly-weighted devices all played a role in interpersonal connections, this did not lead to a high degree of commonality in the shared mental model. After a certain point the theme constrained access to the physical object, and thereby interpersonal connections. This points to the importance of structuring the design process for co-construction through themes which safeguard access to the physical

Figure 22: Multiple Points for Engagement in the Shared Design Process – the ‘A Casa das Palavras’
(left) Working on the craft-tech letter cards during the design of the interface. Each youth has assumed responsibility for one of the devices, and is implementing group decisions. (right) Testing the work-in-progress programme. Each youth has assumed responsibility for an interface and is coordinating their interactions with their partner.
object, and timely interventions that guide group thinking away from unitary forms that constrain access. It also appears that some youth have specific interests which drive interpersonal connections in some areas and limit them in others.

**iii. Did interpersonal connections help advance the centre's transformative agenda?**

**Observations**

Interpersonal connections promoted individual development within the group. Youth had to co-construct and maintain a *shared mental model* (e.g. [Mohammed & Dumville, 2001][Van den Bossche et al., 2011]) of their design problem to proceed with the shared endeavour, and involve participant-leaders in an ongoing way in the process. The model was built between individuals, and could not be attributed to any one of them alone. It involved communication and coordination, and involvement in each other's thinking processes – what Rogoff calls *shared thinking* [Rogoff, 1998]. Two members were continually in the process of stretching their common understanding to fit with new perspectives in their shared endeavour, and using this understanding in context. The third engaged with them up to the point where limited access constrained interpersonal connections, and then engaged in isolated conversation with his object-to-think-with. He re-connected with the others periodically to coordinate efforts towards the shared goal.

The stretching of common understanding was an ongoing process. For example, youth learnt about the ideas underpinning the theme by using and inspecting the prototypes, and working with me to build the common core for the programme. They used this shared understanding as a platform for the interface planning and concept sketching. They combined their ideas for the interface in a drawing, and explored reader positioning and orientation with three readers on the drawing. They pointed out limitations in each other's ideas, proposed alternatives, and returned to the prototype to
think through issues, always coordinating their contributions carefully so that the 'structural whole' (the shared mental model) could result [Miller, 1987]. They followed a similar approach for their multi-levelled, multi-lingual game concept. The result of their mutual engagements around the shared design problem became evident when Superman and Alex worked with André to detail their plans for the interactive. The boys explained their ideas to him and he developed them into a succinct game outline. He then authored a flow diagram from the outline. Superman and Alex worked with his high-level representations of their ideas to author the game script. After I had shown them an approach for managing multiple levels in the game, they chose to work with the documents to implement the approach, using them to orientate shared thinking [Rogoff, 1998] for each level. We reworked much of the first version of the programme after youth identified sluggish word processing. The two boys understood how the approach I proposed could dramatically reduce the number of steps for a result. They proceeded to break up and rework their large scripts into collections of smaller ones, and tested and iterated their results until they had fully resolved the problem. As Rogoff has observed, the ongoing stretching of common understanding to accomplish something together is development, and later involvement in similar events reflect these changes [Rogoff, 1998: 689].

Superman's changes surfaced at various points. In phase one, he followed André attentively when he was recording and editing the group's audio content. In the new phase André ran over the software with him, and tasked him with introducing the software to Alex. The two boys recorded and edited more than one hundred discrete files together. Superman also introduced Alex to Scratch programming through the phase. The results of the mentorship were evident during the testing and debugging, where Alex often found the bug before his more experienced peer and explained the fix. The reworking of the programme to resolve the sluggish word processing required an understanding
of the underlying mechanics of the word processing, and the new concepts introduced to address the problem. Superman led the process, and the boys implemented the changes together. In the final round of tests, he and Alex fluidly co-constructed Portuguese and English words which staff and I had shared for the content.

Tomé's changes were evident at the phase one presentations. He had been asked to leave the activity during the exercise stage of the earlier phase because of his behaviour. He arrived smartly dressed for the event and inspected his peers' work while they were setting up. He waited for an opportune moment, and then announced to everyone that he would be participating in the following phase – even though none had been announced. In phase two, he quickly established himself as the activity technician. He and I discussed hardware design issues in an ongoing way throughout the phase. He listened carefully to my ideas, and either developed them further or proposed well-thought-out alternatives. His contributions helped to define the plug-and-play interface model we developed through the study. He showed how the model could be generalised to other types of interfaces in the following phase through his work on the A Batalha Ecológica device collection (section 5.4).

Alex's changes were also evident at the phase one presentations. He had chosen not to participate in the earlier phase, but was an enthusiastic user of his peers' designs. When not using, he observed others to learn from them and to offer support. He sought out Superman for mentorship, and structured his participation in the hardware development so that he could learn from Tomé. Results from these ongoing engagements with more-skilled peers in a zone of proximal development [Vygotsky, 1978] were evident during the testing and debugging of the near complete interactive. He plugged the kit hardware into the interface for the tests and worked with Superman to identify
and fix bugs. He regularly found errors before Superman did and explained the fix. While conducting the final round of tests, he and Superman fluidly co-constructed words which staff and I had shared for the content. The two boys went on to mentor Bernardo and Tiago in phase three.

Interpersonal connections also enabled the centre to effectively aggregate youth skills and interests in a design team in which the whole was more than the sum of its parts, which enabled youth to design an engaging new interactive learning resource for the institution. The multi-lingual interactive was an important contribution, because everyone struggled with English at school, and the majority of youth either spoke Portuguese as a second language or were the first generation in their family to speak it as a first language. Peers used the resource together in a collaborative fashion, pushing each other to think of new words, sharing meanings, learning new words, and correcting each other's spelling. The fact that a number of groups were able to complete the challenging game showed that the authors had managed to excite interest in language.

Playing the interactive together allowed peers to test out the activity and develop interest in their own time. Raquel, Luciana and Mafalda were all active users at the presentations. They also took up strategic positions which enabled them to observe others when they weren't using. Raquel was one of the first youth to sign up for the beginner group launched in phase three; Mafalda asked her friends who were participating in the group to ask if she could join midway through the process; and Luciana, who also used and observed during the phase one presentations, finally made her request midway through phase three during an advanced group session. The plug-and-play interface model, developed through the combined efforts of both groups in this phase, was implemented on all subsequent interactives to enable reuse of core fundakit hardware and ongoing use of the interactives designed with it. Plugging and unplugging kit hardware became a standard step in all set-up processes after this phase.
Interpersonal connections also enabled members of the local community to engage in new forms of playful learning. A presentation at a local school open day surfaced a number of different examples. Some users observed others using the interactive to learn how to use it, and then used it themselves when it was free. Parent-child dyads explored a number of forms of guided use, ranging from verbal support to animated co-construction. And larger informal groups, in which members were both known and unknown to each other, improvised collaborative strategies in an ongoing, fluid way. These groups shared words and jokes with each other through the course of a game, and were generally deeply motivated to complete all the levels.

**Conclusion**

Interpersonal connections helped to advance the centre's transformative agenda at individual, institutional and community levels. At an individual level, there was evidence of *transformation of participation* [Rogoff, 1998, 2003] through *mutual involvement* [Rogoff, 1995] in co-construction activities. One member of the group had participated in the earlier phase, another had been asked to leave the activity early in that phase because of his behaviour, and the third had chosen not to participate. Both the boy who had been asked to leave the activity and the newcomer were active users at the phase one presentations. They connected with others through the interactives and co-created playful learning experiences. In the new phase, the old-timer mentored the newcomer, working closely with him during the programming and content recording to allow him to observe and take on simple tasks. Changes were evident in the later stages of the design process, where the two boys reworked the group's programme, using a number of new concepts to solve a sluggish word processing problem they had detected. They also used vocabulary built through the research process in the testing. The youth who was asked to leave the activity in the previous phase established himself as the activity technician. He also led the group's hardware efforts, and made important contributions to the design of the plug-and-play interface model.
At an institutional level, interpersonal connections helped the centre to aggregate and leverage youth interests and skills for the design of craft-tech learning resources and sustainable methods for designing these resources. Youth combined their different expertise to co-construct an engaging new language learning resource which would have been extremely difficult for any one youth to design on their own. Divergence of mental models at the beginning of the design process generated creativity, and convergence of mental models – towards the shared mental model – facilitated implementation. The interactive showed clearly how members of the community could design innovative and fun solutions to their own problems. Use of the interactive also allowed peers to try out the activity and develop interest in their own time. Three girls who were active users of the interactives at the phase two presentations joined the activity in phase three. They did so at different intervals, revealing that it often takes time for youth to develop the motivation and confidence to participate. Sustainable design methods developed through this phase were assimilated into a growing body of locally-generated knowledge – a shared activity repertoire [Wenger, 1999] – which informed the design of interactives in phase three.

Finally, at a community level, interpersonal connections provided a way for members of the broader community to connect and co-create a playful learning experience. They shared Portuguese and English vocabulary freely with one another during animated attempts to complete the game together, demonstrating the value of playful 'transactional' affordances [Simon, 2010] for community development.
5.3 Interactive #3: *Os Seis Amigos* (Six Friends)

5.3.1 Description

The *Os Seis Amigos* (Six Friends) interactive is a general knowledge game about six animals for six users, designed by Cassandra, Raquel and Carla. It was designed over a one-year period in phase three (2013-15). The aim of the group was to help peers learn more about the animals.

Each animal in the game is represented by a *funda* reader and an RFID ID badge. Readers are inserted in enclosures made from recycled drink cartons, and plugged into a single press-button circuit. ID badges are made from recycled cardboard, have an RFID tag embedded inside, and a drawing of the animal on either side. One side of the badge is marked green to indicate an IN state, the other red for OUT. Badges are attached to safety pins with Velcro stubs to facilitate the switching of visible sides. The game contains six questions about each animal. Questions cover a range of areas, including popular culture, science, language and history.

Users adopt animal identities by pinning a badge to an item of clothing with the IN side visible to the others. They stand in a circle with their associated readers, and start the game by pressing their press-buttons at the same time. The system randomly selects the first user and question, and poses the question to the user. The user answers by reading the badge of the animal they believe to be the answer. If the answer is correct they remain in the game, if not they are OUT. Eliminated users switch badges to the OUT side, but remain in the circle to enable others to answer questions through them. Play proceeds in this fashion, with player order predefined after the first user, and questions ordered randomly. The designated user always stands in the middle of the player circle. They can repeat their question by pressing the press-button on their reader. The game ends when there is only one user IN or when all thirty six questions have been posed, in which case it is a draw. The game
concludes with a short rap about the end of the game (performed by the girls), and the name they gave themselves, the fundagirls.

Summary:

Number of Authors: Three


Design Duration: One Year

Kit Configuration: Six node project PAN + six RFID tags
Figure 23: Designing the ‘Os Seis Amigos’ (Six Friends) Interactive
(left to right and top to bottom) Preparing a cable for soldering; working on the first version of the reader enclosure; observing the 3D printer printing a test for the press-button enclosure; beading the press-button cables; testing the start script by pressing all six press-buttons at the same time; the OUT sides of the six RFID ID badges.
5.3.2 Design and Use

Concept
The interactive is an extension of a preparatory exercise. In the exercise, youth were asked to adopt the identity of one of the animals in the Scratch sounds library, and work with the members of their group to create a project that enabled them to greet each other with appropriate calls. Each member designed their animal persona around a reader with a single-switch shield and an RFID ID badge, and interacted with the others to explore exercise topics.

In the first project session I explained to youth that we were going to extend the exercise into an interactive about six animals for six users. I taped several large sheets of newsprint to the wall for them to list and draw their ideas. The group first wrote up what they knew about the interactive, and then began discussing and adding their own ideas. They took it in turns to lead the discussion and write up decisions. They decided that each player would represent one of the animals through an RFID ID badge, that each player would have a reader, that players would answer questions about animals by reading badges with their readers, that the game would be played standing, that a player would be eliminated when they got a question wrong, and that the game would end when there was only one player left in the game or all the questions had been posed. They also decided that they would include six questions about each animal, and that the questions would be 'shuffled' at the beginning of the game (random ordering). Raquel suggested they use the single-switch shields to repeat questions. The others liked her idea.

In the following session the group discussed how the game would be played. Cassandra proposed that users stand in a circle facing each other, and that the player answering the question stand in the middle. She explained that this would make them the focus of attention, allow them to peruse the
different animals to make their decision, and make the others easy to reach for a read interaction. The group supported her proposal, so I encouraged her to draw it up. She sketched up a simple schematic diagram which captured the core ideas. Youth had a number of proposals for the player ordering. We implemented simple versions in Scratch, and played them to explore the ideas and make final decisions. They also discussed a number of scenarios for the elimination of users, often using playground games as starting points for own ideas. The challenge was to keep users in the game once they had been knocked out, so that others could keep answering through them. To make a suggestion, youth told everyone the game they were adapting, and then proceeded to act out their adaptation and explain how it could solve the problem. Group members built on each other's contributions in a hurried and excited manner. The final solution came from António, a boy who left the centre shortly after the concept stage. He suggested that the group turn the ID badges into a form of medal, and flip them around to show player state in the game. The idea was his, but it emerged through a rich and extended intersubjective process in which everyone participated.

**Interface**

The group adapted some of the badges from the exercises to meet the new requirements, and created new badges for the other animals. All badges had a drawing of the animal on either side, and an RFID tag embedded in the middle. One side was marked green to indicate IN and the other red to indicate OUT (figure 23). Each youth assumed responsibility for a badge, and worked on tasks they felt matched their abilities. Some drew up the new animals, while others traced existing drawings for the OUT sides. They sat around one of the round tables, each working on their own set of tasks. They discussed their work in a friendly and relaxed manner, observed each other, and regularly shared insights. Completed work was grouped together to keep track of overall progress. Cassandra led, allocating work and providing support when it was needed. She also conducted
research for the new animal drawings, and worked up the colour-coding solution for the IN and OUT sides. When youth had finished the drawings, we implemented the Velcro mechanism and glued everything into place.

The single-switch shields youth planned to use for repeating questions were appropriate for the once-off interactions in the exercise (figure 39), but not for ongoing use in and outside of the centre. I mocked up a number of enclosure ideas with drink cartons, and presented them to youth as starting points for discussion. We compared the mock-ups with the original shields – which were made from a strip of recycled cardboard and aluminium tape – and discussed what had changed and what had stayed the same, and why. Youth then proceeded to implement their own versions, each assuming responsibility for a reader and designing an enclosure for it (figure 23). They worked around a table, discussed ideas, shared insights, and supported each other in completing tasks. Raquel led the electronics work, and Cassandra assisted her (figure 23).

Each girl assumed responsibility for an enclosure for the tests. They moved around the space with their device while observing a projected image of the terminal to identify packets transmitted from their reader. They detected problems with the approach used for the switches, and the XBee signal, and agreed a redesign was required. In the second version, we replaced the aluminium tape switches with industrially produced press-buttons, designed and printed floral enclosures to protect the press-button contacts (figure 24), and embedded the press-button circuits in the drink carton enclosures with hot glue (figure 42). The girls chose to leave part of the press-button cable hanging free from one corner of the enclosure for aesthetic and functional reasons. This length was covered with colourful beads to add body to the cable and further personalise the designs (figure 23). We also cut away the areas of the enclosures that covered the XBee and RFID modules, and peeled off
the inner aluminium layer from the removed pieces to facilitate the passage of the radio waves through the material. The adapted pieces were fixed back into position with a custom-designed sticker, which showed an image of the animal associated with the reader, an RFID icon, and the reader’s number (for set-up purposes). The girls each assumed responsibility for an enclosure while working on the different tasks. They often built on each other's work, and appeared to view it as an act of friendship and solidarity. They also worked through problems together, and regularly offered each other moral support and encouragement. The electronics work was again led by Raquel, with Cassandra assisting her.

The design of the floral enclosures for the press-buttons surfaced an important facet of youth motivation. After the girls had settled on the floral theme, I tried to frame it as a symmetry problem. My efforts to make flowers perfectly symmetrical struck them as false, and likely driven by a school maths agenda. As a compromise, they each drew up one of their enclosure forms my way, in which we thought through angles and made calculations, etc., and the other in a looser,

![Figure 24: Floral Press-Button Enclosure – the ‘Os Seis Amigos’](image)
(left) The assembled enclosure with button inside. (right) The open enclosure showing the removed button cap and top section, and the button set in the base with hot glue.
more natural way. They viewed the internal recesses for the buttons differently. This for them was about the application of school maths to solve real world problems, and they were prepared to invest because of it. They made numerous calculations to ensure the buttons fitted perfectly inside (with a little bit of space for the hot glue), and the two parts snapped together. These calculations were their initiative, not mine.

Content

Youth researched their animals on the internet. They each assumed responsibility for an animal, and authored twelve questions in which the animal was the answer. While they were doing their research, we discussed ways to check the reliability of sources, as well as the identification, extraction and reformulation of pertinent information for questions. Paula (pseudonym), the new staff member overseeing the digital inclusion programme, regularly corrected youths' spelling, grammar and pronunciation, and probed and contributed to ideas they were developing. The process helped surface a number of new concepts, such as 'km/h', 'matriarchal', and 'on heat'. We discussed these thoroughly in the group to enable youth to use them in their questions. The strong research focus didn't appeal to everyone. Patrícia, who was a member of the O Quarto da Paula group in phase one, wanted to work with her existing knowledge and phrase the questions for a preschool user age. She left the activity shortly afterwards because of a clash in timetables, and the other members reworked her questions to bring them in line with the others. When youth had completed the questions, we transferred them to a single computer, and sat around it to make the final selection. We discussed what each youth had written, and chose questions we thought users would find interesting and challenging. Youth were encouraged to lead discussions for their animals. The final selection was a rich blend of information gleaned from popular culture sources (TV, cinema, etc.), the school curricula, the internet, and everyday life in the neighbourhood.
In the first recording session, I explained how to use the microphone and audio software. We conducted a few tests to enable youth to explore the tools and try out different narration styles. In the following session I asked the group to set up the equipment and conduct a test to confirm everything was working properly. They discovered a problem with the set up, and worked together to fix it. No one youth remembered all the steps. Rather, knowledge of the process resided in the group. Afterwards they huddled together around the computer and began recording the questions, animal by animal. Each youth assumed responsibility for an input device (microphone, mouse, keyboard), and roles were rotated after every two questions. They worked on their pronunciation throughout the recordings, and often asked Paula for her opinion. Carla refined the wording of some of the questions which she felt weren't perfect. Cassandra struggled to say some of the words in her questions, repeatedly transposing letters even when she acknowledged she knew otherwise. Carla worked with her, first saying the word and then asking her to say it, then repeating the word in a sentence and asking her to do the same, and finally supporting her in the recording. Cassandra persevered and eventually succeeded.

A youth who had recently joined the centre asked if he could join the activity near the end of the content recording. He and I discussed the challenges of joining a group process midway through, and agreed that he would participate in a trial session. His presence significantly altered the overall tone of the session. The girls, who were normally very open and forthcoming, became self-conscious about their contributions. There was little of the usual supportive and enthusiastic co-construction of ideas, and some members were uneasy about narrating. The boy made an important contribution to the project, narrating the animal names in a lively and expressive tone that users would later find very amusing, but his presence disrupted group dynamics. We reflected on the experience afterwards, and agreed that it would be better if he joined the following beginner group.
I broke down the programming task into a number of discrete runnable components with clear roles in the programme. We built the components one by one, and connected them up to the evolving system to test them. We continued to use the conversational approach developed through phases one and two (pg. 91-92), and programmed in a projected image of the Scratch user interface when the centre's projector was available. One youth stood up at the projected image to lead discussion while another sat at the projector table implementing the group's decisions with the keyboard and mouse. Those not involved in either of the tasks, observed interactions and provided support. Youth built on each other's contributions during the discussions and rotated roles regularly. Their knowledge of Scratch developed differently through the course of the programming, enabling them to fill in for each other in moments of uncertainty. If a completed component didn't produce the anticipated output during the tests, we worked our way back through the code to understand where we had gone wrong. Bugs provided a clear focus for our discussions, and an opportunity for youth to work with their shared understanding of what we had built together.

I encouraged the group to keep a visual record of our thinking and decisions, and provided a roll of newsprint and marker pens for this purpose. They collaboratively authored a large flow diagram for the programme, and kept a detailed record of all technical decisions. These included the numbers assigned to animals for the random selection, the numbers of the readers assigned to the animals (XBee 'MY' parameter in decimal), and the numbers of the questions pertaining to each of the animals. We also drew up numerous representations of hypothetical lists using the Scratch representational model, to understand how they were manipulated in the programme. The newsprint sheets were kept taped to the walls for the duration of the design process. We referred to them during our discussions, and to build components. The girls' shared vision was inscribed into
the flow diagram in statements such as: 'We announce the following question', 'We inform the players who is the winner', and 'We repeat the process' (own translations from original Portuguese).

For some components, youth worked together to develop a solution for one of the animals, and then took it in turns to implement their solution for each of the other animals. This enabled them to leverage the combined knowledge of the group to solve difficult problems, and then develop more personal relationships with the solutions through hands-on experience. An example occurred during the programming of the tag event handler scripts which responded to answer interactions. The first funda message, displayed in the first Scratch when I receive () block, helped youth to understand that they had to allocate readers to animals to determine who read the tag. After writing up the reader-animal list, Raquel led the construction of the conditional construct that checked if it was the user's turn to answer; Carla showed how we could use the question numbering to check if the user had answered correctly; Alex (a member of the A Batalha Ecológica group participating in the session) showed the others how to implement Carla's idea; and Raquel stepped in during Alex's explanation to show him how we could use the boolean () and () block to check if a value was greater than one number and less than another. After completing the basic outline for a tag event handler script, youth took turns to read the six tags with each of the readers – to make their funda messages available in the drop-down menu of the when I receive () block – and then began implementing the remaining thirty-five event handler scripts. They approached the task much like they had approached the funda messages, each assuming responsibility for handling the six tag events transmitted from a reader. While one youth implemented scripts, the others observed their interactions in the projection to ensure they were selecting the correct funda message in the when I receive () block, typing in the correct animal number in the conditional checks which confirmed that the user was allowed to answer a question (their turn in the game), and entering the correct question numbers in the conditional constructs for checking the answers.
After completing the core programme, the group improvised a shortened version of the game and played it with peers to test it. Paula observed the user group and made notes. After the tests she shared her observations, and suggested three ways in which the group could further improve their design. Two of her suggestions required small changes to existing components in the programme. We discussed the problem, and then the girls read through the code to identify the points at which they would implement the changes, and implemented them. The third suggestion, a time limit for answering questions, required significant changes across the programme. I sensed the task lay outside youths’ zone of proximal development [Vygotsky, 1978], and argued against including it. The girls were adamant that it was within their capabilities. As a compromise, we agreed to create two versions of the programme: one with a time limit and the other without. The girls' participation in the planning discussions for the time limit-version was minimal.

After completing the second version of the enclosures, the group returned to the programme to implement the two scripts responding to press-button events: the 'repeat question' script, and the 'start' script (figure 11). They worked together in the usual way to build the two scripts and then coordinated efforts with the multiple devices to test their work. For the repeat question script, Raquel and Carla coordinated interactions with the mouse and a repeat question button to find and fix a bug (figure 25). For the start script, Cassandra and Raquel coordinated interactions with the six press-buttons to play various combinations of playful sounds as tests (figure 23), and then swapped out the sound blocks for the actual code which ran at the start of a game. This coordinated form of interaction with the system was also used for the final programming tasks. One girl assumed responsibility for the mouse to do the drag-and-drop work, and another the keyboard for entering the numeric and string inserts in block arguments. They discussed tasks, made decisions, and observed each other's interactions in the GUI to coordinate their efforts. They also rotated responsibilities for tasks to bring everyone into the process.
Figure 25: Coordinating Interactions to Find and Fix a Bug – the ‘Os Seis Amigos’
(left) Raquel and Carla working together to find the bug. Raquel is checking incoming data values in the terminal with the mouse while Carla presses and releases one of the press-buttons to alter resistance values. (right) The first successful test of the debugged script. Carla is pressing the press-button to repeat the question.

Testing and Debugging

After completing the enclosures, the girls improvised a three-player version of their game. They pinned two ID badges to their jackets or tops, held a reader in each hand, and placed a chair in the middle of the space to mark the location of the player circle. The mood quickly turned competitive. They made suggestive gestures with their bodies to unsettle each other, and displayed signs of nervousness, excitement, disappointment, and irritation. After the first game, they put their readers on the chair, swapped ID badges, and then picked up the readers associated with the new badges and began another game (figure 26). After the third test, they placed all the readers and badges on the chair to take a break. As one girl was putting down one of her devices, the system responded, stating that it was an incorrect answer. To recreate the bug, they laid out the readers and badges in pairs in front of the host screen. Badges were placed with the IN sides facing upwards, and swiped over readers to answer questions. When an animal was knocked out of the game, the group turned the badge over to represent the OUT state. They shifted focus between their improvised TUI (which showed which animals were in and out of the game), and the player list in the Scratch editor
(which showed the number of players in the game and their player numbers), checking repeatedly that states matched. After completing the first game, Raquel demonstrated how it was possible for the winner to continue reading tags after the end of a game. We discussed the reasons for this and possible fixes. The girls chose the simple fix and implemented it.

After integrating the 'repeat question' script and 'start' script, the group tested the new version of the programme with some of the older girls and staff. The girls' African dance teacher was knocked out in the first round of questions. She expressed disappointment, and asked if there wasn't a way for her to rejoin the game. The game became animated when the older testers realised they were no match for the young authors. They adopted their animal personae and taunted the authors, discussed questions, queried answers, tried to assert their authority, crossed their arms to make it harder to read their badges, and finally, when all this failed to disturb the authors, accused them of cheating (in a friendly manner). I explained that the authors had learnt about the animals while

![Figure 26: Testing the Programme with the Completed Enclosures – the 'Os Seis Amigos'](image)

(left) Cassandra reading one of Raquel's badges. Raquel is playing as the cat and another animal (not visible). Cassandra is playing as the dog and another animal (not visible). (right) Carla playing as the cat and dog in the following test. Raquel is about to read one of her badges.
making the game. One of the older girls responded: 'Yes, they have done something worthwhile with their time'. The centre closed for the evening after the game, leaving the African dance teacher without an opportunity to play again. The group made a point of including her in the final round of tests run a few days later. During the tests, they shared their devices with her to keep her in the game. The act was spontaneous, and reflected the generous spirit in the group.

Use
After the group had completed the interactive, staff proposed they present it at a child-abuse awareness event and a local state hospital. The child-abuse awareness event was run in a multi-purpose room in a library. The interior space filled up quickly, and the noisy atmosphere made it difficult to hear questions. Youth encouraged users to use their repeat question buttons, but after outputting the questions twice, users were left with little time to reflect and answer – there was a thirty second time limit for answering questions. Many were knocked out in the first round, often after making a wild guess as they were about to run out of time. Most expressed frustration and didn't hang around to observe others. Numbers inside the space dropped in the afternoon, and some groups returned to try the interactive again. The quieter atmosphere proved more conducive, and many appeared to have a more rewarding use experience.

Cassandra and Luciana (a member of another group) were given the day off school to run the event in the hospital. The two girls chose to set up in the paediatric ward waiting room, and to use the version of the programme that did not have a time limit for answering questions. They adapted the game for the younger age-group, offering hints and asking questions which guided users towards the correct answers. When they observed a user was about to answer incorrectly, they stopped them, and posed additional questions to encourage them to reflect further. The new approach
made the game less competitive, and generally prevented users from being knocked out. Ending the
the game in a tie appeared to draw users closer together, and was often celebrated as a group
achievement. Other users and parents often offered additional hints, and the girls also solicited this
support from them. At times there were multiple forms of support on offer to a user. One such
moment occurred after a question related to the cat's field of view. A father who had heard the
question in an earlier game began meowing. Cassandra tried to represent the angle for the child by
spreading her arms. She explained how the gesture was related to the question. The child ignored
the father, and focused intently on Cassandra. Later in the day, the group was joined by a child with
physical disabilities. The disabilities only became evident after the boy made repeated requests to
sit down. The girls found some kiddies chairs, arranged them in a circle, and continued playing
seated until he left.

Announcements over the PA system regularly rendered questions inaudible. Users used their repeat
question buttons to repeat the question, and continued playing as normal. When a user was called
to their appointment, they passed their badge and reader to another kid or one of the girls, and this
person continued playing for them. Many kids came running back to the waiting room after their
appointment, eager to re-join the game. Their parents generally agreed to wait while they played
another game or two. Cassandra and Luciana took on badges and readers when there were less than
six users, and offered them to new kids entering the room. The girls asked the others to wait while
the new user pinned on their badge, and then introduced the child to the rules through playing the
game. The user group adapted naturally to these changes, appearing to view them as part of the
game.

The authors presented the interactive to the centre community shortly afterwards. Staff organised a
formal event, and brought in a home stereo to improve the audio quality. Cassandra and Raquel
gave a short introduction, and then called for three boy and three girl volunteers (Carla was unable to attend the event because she was preparing to re-emigrate). They followed the same approach for subsequent groups, until all youth who wanted to use the interactive had had a turn. A number of adolescent boys made it clear that they did not want to play the game. They appeared to be uneasy about being put on the spot in front of the others.

After the formal presentation, the authors continued playing with a group of young girls (figure 27). They adopted the supportive approach used in the hospital, offering clues and asking questions to help them discover the right answers. The younger users appeared to enjoy this less competitive version of the game, and continued playing with their older peers until closing time. They introduced a number of performative elements, bowing or curtsying when their animal’s name was announced as the next player, repeating the action when they reached the centre of the player circle, and dancing together in the circle while they were waiting for the designated user to make up their mind. They often repeated fully audible questions, apparently viewing the repeat question button as a playful feature. They listened carefully, reflected before making decisions, and followed peer interactions with interest. After a few rounds, they informed the authors that they no longer required support. Raquel and Cassandra knocked themselves out early in the following games, but remained in the player circle to oversee use and enable the girls to answer through their badges. Winners celebrated their wins with passion.
Figure 27: Using the 'Os Seis Amigos' (Six Friends) Interactive
(from left to right and top to bottom) Raquel and Cassandra introducing the interactive to a group of young girls in the centre after the formal presentations; reading an ID badge and listening to output; repeating a question; user interactions in the game; using body language to cast doubt on a peer's answer; celebrating a win.
5.3.3 Study Questions

i. Did the design activity promote diverse participation?

Observations

There was commonality and difference in the Os Seis Amigos group. All three members displayed an interest in arts and crafts, games, and dance. They invested personally in the artwork, worked painstakingly on the drink cartons to convert them into the reader enclosures (twice), reimagined flowers for the press-button enclosures, combined the beads in lively patterns on the press-button cables, and discussed outcomes in excited tones. They also contributed game ideas freely during the concept development stage, and shared the playground games that inspired them. In so doing, they revealed a vast shared repertoire of play. They were all also active members of the centre's African dance group.

Differences were also apparent. Cassandra had artistic ambitions. She had developed her own distinct drawing style and spoke authoritatively about colour and form. She led all visual tasks, and informed us that she planned to choose the ‘arts' path in grade ten, the grade at which youth specialise in the Portuguese schooling system. She was confident with representational tools but hesitant with electronics tools. This was the area in which Raquel asserted herself. She quickly grasped how to use the new tools during the exercise stage, and from then on ensured that it was always her who led electronics tasks. She developed her own little techniques and ways of doing things, and explained that in this way she resembled her mother, who also had her ways of doing things in the kitchen. She mentored Cassandra in the electronics tasks, and stated a number of times that she wished she could study electronics at school. She also fantasised about working in the field after school, and scolded a boy who drew her attention to gender stereotypes. Carla exerted a calm maternal presence in the group. She encouraged the others to contribute, reflect and persevere, and
regularly praised their work to build confidence and motivate. (Some youths' home lives were not stable, and this often influenced their general well-being.) She once shared how she had been known as a 'bom aluno' (good student) in Cape Verde, and how traumatic it had been for her when her results dropped after the move to Portugal. Her academic interests and abilities were evident in the activity, especially in the content-related tasks.

Cassandra and Raquel were enthusiastic about the new computational tools, and introduced their ICT teachers to them at school – in both cases the teachers chose to use the new tools in their classes (Scratch [Scratch] and Tinkercad [Tinkercad]). Carla often stated that she didn't like computers, but she was the one who regularly led discussion and thinking in the programming.

**Conclusion**

The design of playful craft-tech interactives promoted diverse participation. The activity drew in youth with a number of common and own interests. Common areas included arts and crafts, games, and African dance. Own areas included academic interests, a pronounced interest in art and design (with plans to specialise in the field), and electronics. The combination of arts and crafts and games appears to be a way to promote diverse participation in design activities.

**ii. Did the kit and environment support interpersonal connections?**

**Observations**

The kit and environment played important roles in interpersonal connections from design through to use, but there were also moments where interpersonal connections were strained. The regular presence of the activity in the main space, shared use of peer-designed interactives, and co-construction of exercises with multiple devices, helped to build shared understanding about the kit
and the kinds of things that could be designed with it. This was the common ground that enabled engagements around the shared design problem. The group built out from this platform, working with their shared repertoire of playground games. Multiple perspectives (each individual came to the process with their own background knowledge, prior experiences, expertise, aims, etc.) – ‘cognitive diversity’ [Badke-Schaub et al., 2007] – stimulated creative interactions in the group.

The interactive gained composite form around the multiple devices in the kit, and the external development process facilitated the ‘mutual bridging of meanings’ and ‘mutual structuring of participation’ [Rogoff, 2003]. The girls took turns to lead discussions, queried each other's statements, built on each other's ideas, and wrote up and drew up group decisions on large sheets of newsprint taped to the wall. They agreed that each animal would be represented by a reader and an RFID ID badge, that each user would take temporary ownership of a reader and a badge and play as an animal in the game, that users would stand in a circle to play, that the user answering a question would stand in the middle of the circle, and that users would interact with one another to answer questions. The emerging plan was clearly visible to all, and consulted regularly. Some ideas were run in Scratch (projected image), and others acted out physically in front of the group. Both approaches helped to make the ideas more public and concrete. The final project documents captured the group's shared understanding of what they planned to create together.

There were two points in the content research and recording where interpersonal connections were strained. The first occurred when youth were authoring the questions. One member wanted to work with what she already knew about her animal, and frame her questions for a pre-school age group. The approach was playful and creative, but wouldn't have taught centre youth anything new. Her approach differed significantly from that of the other members of the group, who were researching their animals on the internet, discussing findings with participant leaders, and framing
questions for peers. The girl left the activity shortly afterwards because of an incompatibility in timetables, and other members reworked her questions to bring them in line with the rest of the work. The second incident occurred during the recording of the questions, when a new boy in the centre participated in a trial session. He made an important contribution to the content, but his lively presence impacted negatively on group dynamics. We agreed that it would be better if he joined the following new group.

Multiple craft parts associated with multiple devices in the kit provided the group with multiple points for engagement in the shared implementation process. Each member took responsibility for an ID badge, and worked on tasks they felt matched their abilities. They worked around one of the round tables and grouped completed work in the centre to keep track of overall progress. They observed each other, discussed design decisions, and shared insights. Cassandra, the member with an expressed interest in art and design, led the process. They followed a similar approach for the first version of the reader enclosure. We first analysed my mock-ups to build common understanding and define the task, and then each girl worked on an enclosure. Raquel, the member with an expressed interest in electronics, led the process. Each member assumed responsibility for a device in the tests, and shared her findings with the others. Members attempted to reproduce problems with their devices to confirm them, and identify the cause. They worked together to establish the causes of two confirmed problems, and to devise solutions for them. The second version of the enclosure involved a range of different tasks. Members again took temporary ownership of individual devices to implement changes on them, and regularly built on each other's work. They discussed tasks, observed and supported each other, and appeared to view the act of building on each other's work as an act of friendship or solidarity.
Co-construction of the concept and interface scaffolded software co-constructions to a point. Youth 'off-loaded' [Pea, 1993] conceptual and related technical information into the environment on large sheets of newsprint taped to the walls. These included a flow diagram, the game rules, various technical lists, and drawings. We connected through them and a projected image of the Scratch user interface to plan and implement components in the programme. Our discussions were grounded in the game rules and game characters. At the beginning of a session we returned to completed software components and discussed how they worked together to plan new components, and in so doing each participants' thinking became more and more an integrative part of what everyone else in the group thought [Miller, 1987]. For some components, the group worked together to develop a solution for one of the animals, and then took turns to implement the solution for the remaining animals. Those not programming observed to ensure that the programmer was adapting the solution appropriately for the new animal. Completed software components were integrated into the emerging system for testing. If they did not produce the anticipated output in the tests, we worked our way back through the code to identify the bug and fix it. Communication and coordination of interactions with multiple devices to test components helped to 'interlock cognitions' [idem] further. An attempt to implement a late idea across components (rather than as a component itself, as we had done for the rest of the programme), did not promote the same levels of engagement.

The girls improvised various versions of their game to test their work. They connected through the interactive to co-create the game, and shared information with each other in an ongoing way. When they detected a bug in the completed project, they reconfigured the multiple devices to use them as a debugging tool. They collaboratively manipulated the devices to play the test and represent state, and compared physical and virtual state to track down the bug. They shared and rotated roles while fixing the bug. The girls also swapped devices during the tests to explore different roles, and shared their devices with a member of staff to enable her to participate for longer.
Users also connected through the interactive to co-create the game, and the authors often played
with them to teach them how to play. Users faced each other, interacted physically with one another
to answer questions, made suggestive gestures with their bodies to unsettle the current user, imitated
their animal calls, and improvised their own collective playing styles – such as dancing together in
the circle while waiting for a user to answer a question. The authors provided various forms of
support to younger users to scaffold their participation. Some adolescent boys in the centre
appeared to be uneasy about being put on the spot in front of peers, and opted not to play the game.
Users in a crowded public presentation found it difficult to hear questions, and often answered
arbitrarily to avoid being knocked out for passing the time limit. These users appeared to find the
use experience frustrating. The authors observed the problem, and chose to use the version of the
programme without a time limit in subsequent presentations.

**Conclusion**

The regular presence of the activity in the main space, shared use of peer-designed interactives, and
the co-construction of exercise projects with multiple devices, helped establish the common ground
that enabled engagements around the shared design problem – a ‘fusion’ of references which created
'a platform for subsequent joint action' [Rogoff, 1998: 686]. The group negotiated and consolidated
their developing shared mental model of the design problem at each stage of the design process
through the developing shared external model. Two developments in the shared external model in
this example helped to support the modification of perspectives to enable youth to understand things
from another member's perspective. Firstly, youth 'off-loaded' [Pea, 1993] plans and technical
information into the environment, in the form of notes and drawings on large sheets of newsprint
taped to the walls, and connected through these and a projected image of Scratch to develop their
ideas for the programming. The more public nature of these materials made it easier for members
to consult, refer to, and connect elements of the external model in the course of discussions. Secondly, the use of a device collection theme, to promote similar access to the shared external model through the design process, enabled youth to implement group decisions concurrently on like parts. It also enabled them to take temporary ownership of like parts to test the object together. Similarities in access and task, as well as proximity to each other while working on a task, enabled members to hold parallel 'conversations' with the object [Ackermann, 2004], in which issues surfaced were likely to be familiar to the others, and to converse with the others about these issues through their parts of the object.

There were also moments when interpersonal connections were strained. Patrícia's 'storybook' approach for the animal questions was out of step with the approach adopted by the other members, and she appeared resistant to change. Incompatibility of interests can therefore be viewed as a potential impediment to interpersonal connections. This type of individual stance was, however, rare in the centre, because most youth were socialised to interdependence – 'responsive coordination with the group' [Rogoff, 2003: 200] – and endeavoured to fit in rather than stand out (see also [Markus & Kitayama, 1991, 2003, 2010]). The new boy's participation in the trial session revealed how youth develop ways of thinking and acting together which are particular to the group and activity, and how the group culture was challenging for others to see and adopt. In this specific case, it also appeared easy to perturb. Finally, the group's limited participation in the planning of the time limit code – which was implemented across components, rather than as a component, because of its late integration into the plan – showed how abstraction and modularisation can serve as an effective way to involve novices in ambitious programming tasks, and highlighted the importance of managing this view for youth.
iii. Did interpersonal connections help advance the centre’s transformative agenda?

Observations

Interpersonal connections promoted individual development within the group. Youth had to co-construct and maintain a shared mental model (e.g. [Mohammed & Dumville, 2001][Van den Bossche et al., 2011]) of their design problem to proceed with the shared endeavour, and involve participant-leaders in an ongoing way in the process. The model was built between individuals, and could not be attributed to any one of them alone. It involved communication and coordination, and involvement in each other’s thinking processes – what Rogoff calls shared thinking [Rogoff, 1998]. Core members were continually in the process of stretching their common understanding to fit with new perspectives in their shared endeavour, and using the understanding in context.

The stretching of common understanding was an ongoing process. For example, youth learnt about the multiple devices in the kit during the animal identities exercise. They designed their identity
around their reader and tag, built the event handler scripts for their tag in the shared programme, and interacted with one another to greet each other and explore exercise topics. I proposed they extend the exercise into an interactive about six animals for six users. The group worked with common understanding built through the exercise to develop their concept. They continued the associations between reader, tag, animal and user, and worked up their own set of rules. They built on each other's ideas, queried them, asked each other to elucidate, and proposed alternatives. They also ran ideas in Scratch to explore them and make decisions, and acted out ideas for each other to make them easier to understand. Members took it in turns to lead the group discussions and to write up decisions. They coordinated their contributions throughout so that the 'structural whole' (the shared mental model) could result [Miller, 1987]. The results of their mutual engagements around the shared design problem became evident when they authored a large flow diagram. Their deliberations about what would happen at each step were clearly informed by what Crook calls a 'backlog of “common knowledge”' [Crook, 1994: 114]. I based my plan for the programme on ideas detailed in their notes and flow diagram. I broke it up into a number of runnable components with clear roles. We worked together to build each of the components, grounding our discussions in the game rules and thinking with Scratch and the other public materials, and connected completed components up to the emerging system for testing. Youths' understanding developed differently through the process, enabling them to step in for each other regularly. While playing the completed interactive to test it, they discovered a bug related to the completion of a game. They laid out the devices in front of the host screen in a manner that represented state at the start of a game, and played the game to advance through it. Changes in state were represented physically with the devices, and compared with Scratch state representations to identify the bug. We then discussed ways to fix the bug, and the girls implemented their preferred solution together. As Rogoff has observed, the ongoing stretching of common understanding to accomplish something together is development, and later involvement in similar events reflect these changes [Rogoff, 1998].
Raquel's changes surfaced at various points. She was the one who suggested using the single-switch shields to repeat questions. She had grasped how switch events could represent user decisions while working on the animal identities exercise, and used the new understanding to address a perceived user need. She took an immediate interest in electronics, and quickly developed her own ways of performing particular tasks. She mentored Cassandra through the phase, first learning how to do things herself, and then teaching her peer through paired implementation. She expressed interest in taking an electrician course a number of times, and fantasised about one day becoming an electrician. After the study she played a leading role in a new community radio project. Her involvement was primarily in technical areas.

Cassandra's changes were brought into focus during the presentation in the paediatric ward waiting room. At one point she wanted to offer support to one of the users, but couldn't remember what the correct answer was. She asked the group to hold on, and ran over to the host. She consulted the variable watcher which held the number of the most recent question, scrolled through the code to the thirty-six answer processing scripts and identified the first one in which the variable value fell within the parameters set in the 'correct answer' conditional construct, and then consulted the *funda* message in the broadcast block to see which tag event it was handling. Her method for establishing the correct answer was directly informed by her understanding of how the programme processed user guesses. She told us that she planned to choose the arts track in grade ten, which included specialisations in multi-media and design.

Carla's changes became apparent when we were working on the script which checked for the end of a game. I began the discussion by asking the group how the game ended. Carla explained the two ways in which one could end a game. I asked how we could express them in Scratch. She began
thinking aloud in Scratch, starting her sentences with 'if', and exploring a number of conditions. She eventually settled on 'if the questions list is equal to zero', and smiled proudly. I showed her how we could use an 'or' block to check for both conditions. She quickly saw how she could formulate a similar expression with the players list, and gave instructions to the peer doing the programming. In both cases she was building boolean conditions with Scratch's list blocks to check for the end of a game. The approach required understanding of the boolean blocks and how we were using lists in the programme. She re-emigrated shortly after the group completed the interactive, making it difficult to observe further changes.

Interpersonal connections also enabled the centre to effectively aggregate youth skills and interests in a design team in which the whole was more than the sum of its parts, which enabled youth to design an engaging new interactive resource for the institution. Young girls were especially keen to use the interactive. The authors played with them to scaffold their participation. They offered clues, posed questions, and intervened when they could see one of the girls was about to answer incorrectly. The young girls learnt most of the answers through this more supportive version of the game, and went on to play without the support. Older girls and female staff were also drawn to the game. They expressed indignation when they realised they were no match for the younger authors, but acknowledged the group's achievements in various ways. A staff member who disputed one of the answers later informed me that the girls had been correct and that she had made a mistake. She had researched the topic further after the game. One of the older girls asked me if we were going to 'do more inventing' the next time she saw me in the centre. Her use experience appeared to have broadened her understanding of what could take place in the centre. A number of adolescent boys appeared uneasy about using the interactive in front of peers.
There were no further opportunities for participation in the activity, so it was difficult to gauge how use influenced interest in craft-tech design. A number of the younger users did, however, participate enthusiastically in the testing of the A Batalha Ecológica, which took another year to complete, and were active users at its presentation. Technical insights generated through the Os Seis Amigos design process were assimilated into our growing shared activity repertoire. For example, the A Batalha Ecológica group later experienced problems with their RFID signals after embedding the readers inside the FSRs. I explained how the Os Seis Amigos group had encountered a similar problem with the aluminium layer in their ice tea cartons, and showed them the solution developed to fix it. The boys examined the enclosures carefully, and developed a solution based on their approach (figure 30). The Os Seis Amigos enclosures also provided a clear example of how the plug-and-play interface model could be implemented on handheld devices.

Interpersonal connections also enabled the centre to explore new forms of inclusive work in the broader community. Youth temporarily transformed the paediatric ward waiting room of a large state hospital into an informal museological space through their supportive presentation of the interactive. Children and parents from different walks of life connected with youth through the interactive, and shared knowledge and ideas. The learning experience was valued by both the children and their parents. Kids often came running back to the waiting room after their appointments, eager to re-join the game. Parents generally consented to another round or two, apparently perceiving value in the game. A presentation at a child-abuse awareness event proved more challenging because of the larger number of people in the space, inadequate output devices (standard PC speakers), and the use of a time limit for answering questions. Youth addressed these problems themselves in subsequent presentations.
Conclusion

Interpersonal connections helped to advance the centre's transformative agenda at individual, institutional and community levels. On an individual level, there was evidence of transformation of participation [Rogoff, 1998, 2003] through mutual involvement [Rogoff, 1995] in co-construction activities. All three girls had used peer-designed inter actives previously, but none had designed any themselves. By the end of the year-long co-construction process, group members were able to mentor a peer in simple electronics tasks, work with the game rules to implement conditional constructs in the programme, and manipulate the shared mental model of the software to solve use-related problems. One member expressed interest in taking an electrician course, and fantasised about working in the field after school. She assumed a leading technical role in a community radio station launched after the study. Another member informed us of her plans to specialise in art and design in her final three years of school. Both girls' participation in the activity could be read as a form of preparation for what they anticipated later on the basis of their prior participation in related activities. How people prepare now for what they expect later on the basis of their prior
participation, is one of the central questions raised by the transformation-of-participation view [Rogoff, 1998: 690]. The design of the interactive also enabled the girls to take on new roles in the centre community. They played the interactive with younger peers and used the play experience to teach them about the animals in the game. This playful form of peer instruction was not observed previously.

At an institutional level, interpersonal connections enabled the centre to aggregate and leverage youth diversity. The group combined their different skills and interests to design an engaging new learning resource which would have been extremely difficult for any one member to design on their own. Divergence of mental models at the beginning of the design process generated creativity, and convergence of mental models – towards the shared mental model – facilitated implementation. The resource supported playful learning through mutual involvement in shared activities, and social interaction as an 'integrated multiparty group' [Rogoff, 2003: 144] – the preferred form of social interaction in the centre. The interactive was especially popular amongst female users of all ages. It demonstrated clearly how members could design their own technologies which reflected and built on their cultural heritage (clapping games, beading, etc.), and personal interests (hamsters, horses, fashion accessories, etc.). Young users expressed their growing interest in technology design by later volunteering to participate in another group's tests, and studying their design when they had it open to plug in the hardware. New technical solutions were assimilated into a growing body of locally-developed design knowledge – our shared activity repertoire [Wenger, 1999] – which informed the design of interactives in phase three.

At a community level, interpersonal connections provided a way for young and old to co-create playful learning experiences in settings such as a library and a hospital. Groups varied in size and comprised active and passive users. Users, who often didn't know each other, interacted freely,
shared ideas, supported one another, and reflected on the contents. The device collection theme enabled the authors to develop a special scaffolded version of the game for younger users. They played with the younger kids as fellow users, and helped them to think through the questions by offering various kinds of support. One presentation highlighted the limitations of working with standard PC equipment in crowded public presentations. Users were barely able to hear output, and as a result struggled to make informed decisions. The presentation also pointed to potential drawbacks of time limits in interactives, which in some instances appear to constrain interpersonal connections.
5.4 Interactive #4: *A Batalha Ecológica* (Ecological Battle)

5.4.1 Description

The *A Batalha Ecológica* interactive is a game for two teams (4-6 users), designed by Superman, Alex, Tomé, Tiago and Bernardo. It was designed over a two-year period in phase three (2013-15). The aim of the group was to teach peers about recycling.

The interactive is made up of a floor-based playing environment comprising eighteen foot-sized force-sensitive resistors (FSR), two craft-tech dice, and twelve tagged PLA geometric forms. The playing environment is built up with modules, each of which is made of three detachable FSRs. A reader is embedded in the middle FSR, and all three sensors are plugged into it. The middle FSRs are marked as the recycling containers. Photoresistors are embedded in the dice’s six faces, and plugged into two readers housed inside. Each team receives six geometric forms (the same forms for both teams, but numbered differently) and a dice. The software is run across two computers. One computer runs the dice system, waiting for input from users requesting a roll event, then calculating a result and outputting it to users; the other runs the main system which controls the game and establishes the overall winners.

Users start the game by standing on the four corner FSRs of the playing environment, and then move from their side towards their opponents’. They move FSR by FSR, working together to complete three different types of colour-coded challenges. For blue FSRs, users answer a multiple-choice trick question (*adivinha*) by moving to a yellow or green neighbour. For green FSRs, both teams cover the photoresistors embedded in faces one and six of their dice to request a roll event from the dice system, and then, upon a signal from the system, roll their craft-tech dice. The winners enter the result of the roll into the main system by standing on the first three FSRs of their
side of the playing environment. For yellow FSRs, users either complete a secret combination by pacing out a colour code in the environment, or engage in an ecological battle with the other team. For the ecological battles, the system randomly maps six recyclable objects to the six tagged geometric forms, and then asks teams to recycle an object in a randomly selected materials container (blue, green or yellow). The first group to reach their opponents’ side wins. The game ends with a short rap recorded by the authors, followed by a two-minute long Afro-House clip (long enough to dance to).

Summary:

Number of Authors: Five
Design Duration: Two Years
Kit Configuration: Ten node project PAN + twelve RFID tags
Figure 30: Designing the ‘A Batalha Ecológica’ (Ecological Battle) Interactive
(left to right and top to bottom) Creating a maquette for the dice; programming together; adapting the conductive layers of the FSRs for the RFID signal; testing the start script with the start interaction; unplugging readers from the dice after playing a test; ‘holding’ an idea in the maquette for the interface while a peer implements it in the programme.
5.4.2 Design and Use

*Concept*

Superman and Alex led the concept development process. They began with an internet search for inspiration. We discussed their findings, as well their early ideas for an interactive. The group then proceeded to develop their ideas further with pencil and paper, sketching up simple representations of the envisioned playing environment to communicate thoughts to each other and think through issues. When they had established a basic plan, they designed a maquette for the playing environment, and played out ideas in it to develop them further. André, the staff member responsible for digital inclusion, also enacted scenarios in the maquette to probe their thinking and encourage them to reflect further (figure 31). Afterwards the group authored a four-page ‘guião’ (project plan), in which they described the rules for the game, the role of the computer, how users interacted with the system, the hardware required for the project, the colour-coding of the different positions in the playing environment, and what happened in each of the colour-coded challenges. For the colour-coded challenges, they included example scenarios. The document focused on what they viewed as ‘unknowns’ in the project – their ideas. When I queried how they would implement them, they provided broad confident descriptions of how they planned to use FSRs like the ones they had designed and used in a phase two exercise, as well as kit technology, to realise their ideas.

Two of the colour-coded challenges involved athletic activities in and around the playing environment. I warned the group that craft-tech FSRs were unlikely to withstand ongoing athletic use, and encouraged them to rethink their plans. They redesigned the two challenges as more thoughtful tasks which did not encourage running. I also urged them to adopt a modular approach for the playing environment to facilitate storage. They proposed to design it in six distinct modules, which could be butted up against each other on the floor for use, and stacked on top of one another.
(left) André, the staff member responsible for the digital inclusion programme, acting out hypothetical scenarios in the playing environment maquette to test the group’s ideas. Alex is responding. (right) Maquettes for the dice showing different solutions for the sponge covering. Youth played with the maquettes to make final decisions.

for storage. Each module was made up of three physically-connected FSRs, which were plugged into a funda reader embedded in a dedicated enclosure. The modular solution was based on a design developed by the other group in the workshop, the Funda Glória group. They were also planning a floor-based playing environment made up of foot-sized FSRs, and wanted a flexible solution that would allow them to build up their playing ‘path’ in different types of presentation spaces.

**Interface**

The interface is made up of the playing environment, the two craft-tech dice, and the twelve tagged PLA geometric forms. André thought the dice would be the principle design challenge, and suggested we leverage the combined skills of both groups to develop a solution. We discussed the requirements and materials with the groups, and agreed they would each design a maquette. They drew up cube nets for the core structure on paper to explore folding, tabs, and an opening and
closing mechanism, and iterated the results until they were happy with the outcome. The groups observed each other’s work and shared insights, but pursued their own ideas when they thought they were superior. When they were confident they had a good result, they implemented it in recycled cardboard and covered the faces with sponge for shock absorption (figures 31). Afterwards, they marked up the faces with the numbering and ran a series of playful tests with both dice. While playing the tests, they discussed the merits of the designs. They observed that both dice were opening frequently during rolls. João, the self-appointed leader of the Funda Glória group, proposed they use Velcro to secure the lids. Youth liked his idea, and agreed that the Funda Glória solution was the better. Members of the group agreed to assist the A Batalha Ecológica group to implement it. João and Alex led the design of the main structures; Superman the internal divider to which they secured the readers; João the recycled envelope ‘pockets’ which held the readers; and Tomé the electronics (figure 42). Justin assisted Alex and João, and Bernardo and Tiago assisted Tomé. João, Alex and Tomé showed their peers how to use tools, provided them with simple low-risk tasks (sometimes performed together to scaffold participation), reviewed their work, and offered feedback. Tomé had difficulty adapting his normal photoresistor soldering technique for the dice, and required my support. João and Tomé, who were brothers, re-emigrated shortly after the group had embedded the sensor cables in the main structures. Superman and Alex led work from then on. Each assumed responsibility for a dice, and Tiago and Bernardo assisted them. After using the dice with the software they were developing for them, the group decided that it would be more exciting to have no numbering on the faces, and have the host reveal the result as a surprise. They developed a solution for it, in which they marked the dice with colours to indicate their user group, and placed icons on faces one and six to show users where to cover the faces to request a roll event (figures 30, 35). They also built a debugging tool, which enabled them to check that photoresistor cables were plugged into the correct sensor ports on readers (figures 12, 33). They played with the dice throughout the design process to test their work, make decisions, and have fun.
After an unsuccessful attempt to prototype an FSR module for the playing environment, youth asked me to design a low-res prototype as a starting point. The design of the prototype helped me to grasp the scale of the task youth had set for themselves. I encouraged the groups to join forces and design a flexible solution that worked for both interactives. My prototype integrated elements of both groups' designs, and addressed issues surfaced through the first round of tests. The group worked with Paula, the new staff member running the digital inclusion programme. They developed the prototype ideas further to meet the various project requirements. After defining tasks and their order of implementation, they established teams and allocated tasks. Afonso, Alex and Superman were responsible for measuring and cutting the cardboard layers; Lara, Paula and Luciana, for marking up and cutting out the reader recesses and wiring channels; and Tomé and Tiago, for assembling and soldering the sensor cables. I took over Tomé's role after he re-emigrated, and drew Justin and Bernardo into the electronics team. After completing the first set of tasks, youth self-organised into flexible teams for the remaining tasks. They took temporary ownership of parts of the interface to implement tasks on them, and came together regularly to solve problems, check progress and plan next steps. They built on each other's ideas, explained things to each other, observed each other, corrected each other's errors, and shared insights in an ongoing cooperative manner (figures 36, 37). Co-construction affordances in the FSR modules, portability of the individual parts and devices, and repetition of tasks, created multiple opportunities to share and develop skills through objects, and progressively increase participation.

Lara and Luciana wired up the first assembled module for a test and detected issues with the resistance levels immediately. Alex and Superman showed them the mistake they had made with the wiring, and Alex worked with them to fix it. Each youth assumed responsibility for a conductive surface. The two girls observed Alex to learn from him, and Alex observed their work to ensure that they were implementing the changes correctly (figure 36). The combined group
retested the module with light, average and heavy users, observing data output in the terminal and providing interaction instructions to the tester, and confirmed they had a working solution. They used the module as model for the rest of the playing environment. While they were working on the remaining fifteen sensors, Paula proposed a solution for the graphic layer. She suggested a fixed frame on the top of the sensor, with a loose layer that fitted inside it. We worked together to develop her idea into a solution which enabled the groups to quickly reconfigure the sensors for their respective projects – one side of the loose layer was used for the *Batalha Ecológica* and the other for the *Funda Glória*. Lara assisted the *Batalha Ecológica* group with their graphics, and Alex helped the *Funda Glória* group to balance and space the different game challenges along their player path (figure 32). During the last set of tasks for the playing environment, youth identified peers with desired skills and worked with them until they were able to perform the task alone, observed peers with desired skills until they felt confident enough to take on the task themselves, adopted asymmetrical roles and implemented tasks together, and picked up tasks where others left off and completed them (without instructions). They read the work-in-progress object and communicated with each other throughout the process to maintain shared understanding of what they were trying to achieve together.

The twelve tagged recyclable objects were originally envisaged as recognisable recyclable objects which would be made by hand. I saw the objects as an opportunity to explore digital fabrication, and suggested youth draw them in Tinkercad [Tinkercad] and print them on a 3D printer. The group responded positively to the idea. They eventually decided to temporarily map recyclable objects to more general forms, so they could increase the number of recyclable objects included in the interactive, and alter the object collection from one game to the next. They chose to work with geometric forms because none of them could be misconstrued as recyclable objects. They also saw
it as a novel way to teach younger peers about the forms, which were part of the school curriculum.

The group took it in turns to draw up the forms on a computer in the CID. While one youth drew, the others observed and offered support. They adapted those geometric forms that were available in the Tinkercad object library, and drew up the remainder. For the new drawings, they consulted traditional geometry tutorials. One youth sat at the neighbouring PC and controlled the tutorial – rewinding and pausing the video when told to do so – while the other drew in Tinkercad. The pair discussed how to implement the steps with the new tools, and coordinated their actions carefully to produce the desired result. The models were too large to print on the low-cost open-source printer I assembled for the study [RepRap], and online printing services cost much more than the centre would have been able to afford, so I printed them at the University of Bremen fab lab.

Content

The content included the colour codes, the recyclable objects and associated geometric forms, and the multiple-choice trick questions. The group used numbers to represent the colours in the codes.
They planned each code together, and Bernardo wrote up the lists of numbers on a sheet of newsprint. They later consulted the newsprint sheet to incorporate the codes into the programme. The group held a brainstorming session for the recyclable objects and associated geometric forms, and Alex wrote down their decisions on a sheet of paper. They decided to print each geometric form in a different colour, and announce the form's name and colour in the mapping output to help younger users learn the names of the forms. For example, the lead-in segment for the pyramid is: 'The green pyramid is the …' (own translation). They divided up the narration task, and took turns to do the recording. Superman, whose mother tongue was Cape Verdean Creole, had difficulty pronouncing the names of some of his geometric forms. He asked Alex to narrate them for him. Alex refused, and instead encouraged him to persevere. Superman succeeded after a few takes.

For the multiple-choice trick questions, which were based on a Portuguese language riddle form known as *adivinhas*, the group conducted research on the internet. They consulted dedicated *adivinha* sites, discussed their contents, and wrote down the ones they wanted to use. Afterwards they discussed a distractor to accompany the *adivinha* key, and wrote it alongside the key. Narrating and recording roles were rotated as normal. Tiago, who was classified as a special needs learner at school, rarely spoke in the centre. I asked him if he wanted to do some of the narrating. He indicated that he did. We went over the recording process together, and I asked Alex to work with him. Tiago indicated that he also wanted to control the software. His first efforts were difficult to understand. He also transposed words and repeated sections unintentionally. We listened to the results. Sometimes Tiago picked up the errors himself, sometimes Alex pointed them out to him. Alex talked him through each question and answer pair, first reading it to him from the script, then coaching him off-mic, and finally allowing him to record the take himself. While Tiago narrated, Alex ran a pen underneath the words on the script to help him keep track of his position. Alex insisted that the result had to be fully usable, and only moved on to the following question.
when he felt they had achieved this. Afterwards Alex took over the narrating and shared the recording role with Tiago. Youth tested all their audio files before integrating them into the programme. A homework group working on the other side of the main space that morning, stopped what they were doing when they heard Tiago's voice being played back through the computer. Ana, who was running the homework session, came over to our side of the space and asked if it was really Tiago narrating.

*Programming*

The interactive contains four distinct game challenges, each with its own set of rules and use of the playing environment. The ordering of challenges follows no predictable pattern – they are chosen by users during the run of play – and at different points in a game the same user interaction can serve as different input to the system. For example, an FSR event, generated by a user presence on one of the sensors, can be produced by a user making their next move, answering a question, or making a colour choice while pacing out a secret colour code. The 'meaning' of the event is derived from the game circumstances in which it is produced. I designed a challenge management framework to enable us to respond appropriately to FSR events, and worked with youth to implement it. We then worked together to implement the four challenges, using the conversational approach we had developed over the course of the study (pg. 91-92). The group consulted large flow diagrams they had drawn up for the programme, established tasks, discussed the tasks (through the maquette if they were related to the playing environment), built consensus, consulted the maquette and wiring plans for relevant data, implemented decisions, tested their work by acting out interaction sequences in the live playing environment or rolling the live dice, and iterated.

Superman and Alex led the group's efforts. Bernardo followed their discussions closely, made occasional contributions – which Alex praised immediately – and routinely participated in the
implementation. The implementation was performed collaboratively, with one youth holding an idea in the maquette, while another did the programming, and a third observed to catch errors. Bernardo took on a leadership role when Superman or Alex were unable to make a session, and worked with the youth who was present to drive the *shared thinking* [Rogoff, 1990, 1998] and implementation processes (figure 33). At these points, he revealed a growing understanding of the concepts, technical decisions, and processes the group were using. He also took on the role of group scribe. When he perceived that the group would need to record something, he picked up the felt pens and moved toward a blank newsprint sheet. He listened to discussions and wrote up decisions. Superman and Alex kept an eye on what he was writing, and corrected the occasional mistake. His participation increased progressively through the phase, and they acknowledged this in the later stages by sharing the scribe role. In the final iteration of the flow diagram, Superman, Alex and Bernardo each adopted a recycling bin (yellow, green and blue), and detailed the steps for when a user moved to their sensor type. They worked side by side on a single sheet of newsprint, independently writing down steps for their recycling bin (figure 33). The diagram was the most accurate and succinct representation of the programme.

Tiago followed interactions between the three youth from a peripheral position in silence. The other boys tried to involve him in the implementation process by asking him to programme repetitive bits of code which required minor changes from one construct to the next. Tiago was able to realise most of these tasks successfully, but required close supervision. It became harder to do this later, when the environment became sluggish because of the size of the programme. The setting up and breaking down of the host for sessions was his task, and he always performed it. He also worked with the others to build up and break down the playing environment; a process which took up to twenty minutes. He participated actively in the testing, interacting in the environment in ways that revealed understanding of what his peers were trying to achieve in the programming.
He left the group midway through the second year because of a clash in timetables and other peer-related issues, and later joined a beginner group launched by Paula.

Superman and Alex's knowledge of Scratch developed differently over the three years they worked together (phases two and three). Alex often found it easier to grasp and apply concepts, whereas Superman often displayed a better overall understanding of the Scratch language, the programme, and the various processes involved in it. These divisions were not hard and fast, and the boys regularly stepped in to correct or extend each other's ideas. Their combined understanding and experience, as well as a friendly rivalry that permeated almost everything they did together, made them a formidable 'problem-solving system' [Wertsch et al., 1980]. They pushed and pulled each other, coordinated efforts carefully, and filled in for each other in moments of uncertainty. They always programmed with the maquette at hand, and referred to it repeatedly to illustrate points, align perspectives, and plan next steps (figure 30). Roles were fluid and complementary. Repetitive constructs were generally built together, with one youth assuming responsibility for the drag-and-drop programming with the mouse, while the other entered numeric and string inserts in block arguments through the keyboard (figure 30).

The group implemented the challenges one by one, and integrated them into the management framework. After integrating the last of the challenges, they found that the programme became sluggish. Members expressed deep disillusionment and nobody showed up for the following session. In the session thereafter, Alex proposed they break the programme in two, and run it on two computers. We eventually adopted his idea, running the dice software on one of the computers and the game system on the other. The winners of a dice roll entered the result into the game system by standing on the first three sensors on their side of the playing environment (figure 36). Alex's idea solved the problem.
Figure 33: Bernardo’s Participation – the ‘A Batalha Ecológica’
(left) Bernardo and Alex coordinating interactions to check connections in the dice. (right) Superman, Bernardo and Alex authoring the last iteration of their flow diagram. Each youth has assumed responsibility for a recycling container type (yellow, green and blue), and is detailing steps for when a user moves to one of their sensors.

Testing and Debugging

Each challenge was a game in its own right, and they were played as such during the tests. While playing, the group identified software bugs and additional output they wanted to include. They worked their way systematically through the code to find and fix the bugs, and to integrate the new output. They also discovered hardware bugs. For example, while playing the recycling challenge for the first time, the group discovered that the conductive layers in the FSRs impeded the RFID signal. For the hardware bugs, the group came together to analyse the problem and devise a solution, and then split up to implement their solution on the various parts (figure 30).

The group also improvised playful variations during the tests. An example occurred during the testing of the secret colour combination. Alex played the challenge with Raquel on a day when the others were unable to make the session. The two youth turned the test into a little game to test each other’s recall abilities. They used the level variables – there are three levels of difficulty – to configure the challenge to each of their capabilities (which were not the same), and then played
against each other. One sat at the host, while the other paced out their answer in the playing environment. The youth at the host was able to observe their peer's progress in real-time in the Scratch GUI, by comparing the contents of the 'answer' and 'secret combination' lists. They offered misleading feedback on progress, like 'Ah, you got that one wrong, now you are going to lose', to unnerve and distract one another. Alex sometimes offered Raquel encouragement, saying things like 'OK, if you get this one right, I'll call my mom and ask if you can have lunch at my place'. When one of them answered incorrectly, they joined the other at the host, and compared the two list monitors to see where they went wrong. They swapped roles after each combination, and played the game for over an hour. Both were fully engaged, displaying signs of happiness, nervousness, pride and disappointment. Debugging was smoothly integrated into their little game.

The group invited members of the Funda Glória group to test the completed interactive with them (figure 34). The Funda Glória group had made a similar request earlier in their design process, to

Figure 34: Inter-Group Testing – the 'A Batalha Ecológica' and 'Funda Glória'
(left) Members of the Batalha Ecológica group playing an improvised version of the Funda Glória with its authors to test the ideas. Youth are using the empty sensors with the Batalha Ecológica dice maquettes. (right) Members of the Funda Gloria group playing the Batalha Ecológica with its authors to test the completed interactive.
test their ideas and get feedback about their design (figure 34). The Batalha Ecológica group had made constructive contributions, which were incorporated into their design. After the two groups had played the Batalha Ecológica together, the members of the Funda Glória group offered them feedback about the use experience. They observed that it was hard to remember the many detailed rules for the different challenges, which were played back at the start of the game in the introduction, and suggested the group discuss the rules with new users prior to the start of a game. The Batalha Ecológica group adopted this approach for the centre presentation.

Use
The interactive was presented to peers on a Saturday afternoon (figure 35). Members of the Funda Glória group offered to help the Batalha Ecológica group build up the interactive. They positioned the playing environment near the entrance to the main area, placed plastic chairs around the environment for observers, and set a small work table alongside the environment for the tagged geometric forms and dice.

Alex began by talking the community through the game. He opened up one of the dice to show everyone the readers and sensor connections inside, and passed around some of the tagged geometric forms to allow peers to inspect the prints and concealed tags. When he felt they had grasped the basics, he picked out three girls and three boys for the two teams, and instructed members to stand on the four corner FSRs to start the game. After they had listened to the introduction, Alex asked if they understood everything. Some of the older youth sitting around the environment shouted that they didn't. A few of the users also admitted that they hadn't fully understood everything. Alex told them not to worry, and assured them that he would provide support when it was needed.
The boy group chose to collaborate at a game level, each assuming responsibility for a part of the interface. One acted as the group's playing piece, moving from FSR to FSR in the playing environment, another rolled the group's dice, and the third recycled their tagged geometric forms in the environment. They later swapped tasks. The girls collaborated in a more fluid manner around each of the challenges. Alex supported both groups as they advanced through the game. Peers huddled around the environment, observing, discussing decisions, and offering assistance. A group of older girls, which included members of the Os Seis Amigos and Funda Glória groups, sat at the table with the tagged objects and dice. When a group opted to complete a recycling challenge, they provided support, reminding youth which recyclable objects were mapped to which geometric forms, and helping them group the forms into recyclable material categories (yellow, green and blue). Groups quickly picked up how the grouping strategy could help them with their answers, and also began remembering the material categories for the various objects included in the game. Once they reached this stage, they indicated that they no longer required support. The older girls remained at the table to observe decision-making and steer their younger peers away from bad decisions.

Most users had difficulty hearing the multiple-choice trick questions over the low-level din in the space, and there was no way for them to repeat questions. Some of the older youth tried to help by shouting out what they heard, or what they thought they had heard. Their advice often differed, which only confused the younger users further. Superman tried to solve the problem by fetching the group's script from the activity cupboard, and reading the questions to users when they failed to hear them. The older youth who had been offering support for the questions, switched to offering support for the answers. Alex later took over Superman's support role. This rich social use of the interactive continued for close to forty five minutes. The boy group eventually won the game. Everyone appeared to have enjoyed the event.
Figure 35: Using the ‘A Batalha Ecológica’ (Ecological Battle) Interactive
(left to right and top to bottom) The two user groups listening to the introduction; a user reflecting on a task while a peer offers support; Alex showing users how to cover faces one and six of the dice to request a roll event; rolling the dice; sorting tagged geometric forms into recyclable material categories; recycling objects in the playing environment.
5.4.3 Study Questions

i. Did the design activity promote diverse participation?

Observations

There was commonality and difference in the A Batalha Ecológica group. All five boys enjoyed constructing things with craft materials and playing games. During the twelve months that it took to prototype and build the playing environment and craft-tech dice, members participated actively in the process (Tomé’s participation was negatively influenced in the later stages by his family’s decision to re-emigrate). Setbacks temporarily dampened spirits, but youth bounced back. Their interest in games was evident throughout the two-year period. They played out their ideas as a group and with the other group during the concept development stage, and displayed interest in test and game results. They crammed as many game ideas as they could into the interactive, even when warned not to do so. And they spontaneously improvised little games within the bigger game to test elements of the work-in-progress object and have fun. All five boys also enjoyed playing internet-based games, console games, board games, card games and outdoor games like football. They were also keen users of the inclusive interactives designed in the activity.

Differences were also apparent. Tomé continued to express a strong interest in electronics during the phase, always setting up the tools, leading on tasks, and tidying away afterwards. He was deeply disappointed when his parents, who had been out of the country looking for work, were too late to secure him a place on the electrician course at trade school. Tiago was classified as a special needs learner at school. He rarely spoke in the centre, and when he did, it was invariably in response to a question put to him, and limited to a single word. These difficulties hindered contributions to group discussions and ongoing interactions around the emerging design object, but did not impede him from making a major contribution to the group's content. He also struggled
to perform tasks involving fine motor skills, requiring close supervision and support from a
colleague – the two boys normally worked as a dyad to facilitate this. His favourite task was setting
up and breaking down the host for sessions, and he always did this on his own. He also enjoyed
working with the other members to test the work-in-progress interactive. Alex, Bernardo and
Superman were happy to work on any task, and each made significant contributions to the
construction, writing, narration and programming. Their knowledge of programming developed
differently over the course of the study, enabling them to step in regularly and help each other in
moments of uncertainty, offer alternative explanations, and continually raise the bar of participation
for each other. When choosing an area of specialisation at school, Alex and Bernardo opted to
pursue the science and technology route, and Superman the economics route. They were the first
youth in the centre to pursue these options. Alex said that he planned to study computer science
after school, and had already identified the university with the best reputation for this course (and
toughest entry requirements).

Conclusion

The design of playful craft-tech interactives promoted diverse participation. The activity drew in
youth with overlapping and different skills and interests. Areas of overlap included constructing
things and playing various sorts of games. Areas of difference were expressed through the
decisions youth were making about their futures at school. One youth wanted to study to become
an electrician at trade school, another chose the economics path in his last three years, and two other
boys chose the science and technology path for their last three years. One of these two boys had
already decided that he wanted to study computer science at a tertiary level. The fifth boy was
classified as a special needs learner at school, and had not yet reached the grade where he had to
make such decisions. The combination of crafts, computers and games appears to be a way to
promote diverse participation in design activities.
ii. Did the kit and environment support interpersonal connections?

Observations

The kit and environment played important roles in interpersonal connections from design through to use, but there were also points where interpersonal connections were strained. Previous participation in the activity helped to build shared understanding about the kit and the kinds of things that could be designed with it. This was the common ground that enabled engagements around the shared design problem. A phase two exercise, in which youth built their own force-sensitive resistors (FSRs), and used them in a running-on-the-spot competition, was particularly important in this regard. The group built out from this common understanding, working with their shared repertoire of games and athletic activities.

The interactive gained composite form around the multiple devices in the kit, and the external development process facilitated the 'mutual bridging of meanings' and 'mutual structuring of participation' [Rogoff, 2003]. The group discussed ideas for a playing environment which sensed user positions, as well as 'wireless' dice that would be rolled alongside the environment, and tagged recyclable objects that would be swiped over designated playing positions in the environment. Members sketched up rough representations of their ideas to communicate them to each other. After establishing the main ideas, they built a maquette. Youth and staff probed game ideas by playing them out in the maquette. Physical contact with the different colour-coded positions helped to make ideas concrete and public, which facilitated the stretching of common understanding to fit with new perspectives in the shared endeavour [Rogoff, 1998]. The group wrote up their final decisions in a project plan. The maquette and project plan captured the shared understanding of what the group planned to create together.
Multiple craft-tech parts provided the group with multiple points for engagement in the shared implementation process up to a point. Groups co-constructed maquettes for the dice, and rolled their designs against each other to identify the best approach. Members then assumed responsibility for individual tasks and proceeded to implement the final design together. Tomé developed his own technique for soldering the photoresistors to the cables. It involved twisting the stripped wire ends around the sensor legs. I feared the long legs would stand proud of the insides of the enclosures and be susceptible to damage. To limit the chances of this happening, I proposed we cut them to less than half their length. Tomé found it hard to use his technique on the shorter legs, and struggled with other approaches. He expressed frustration, and opted to work on the FSRs instead. I soldered most of the remaining cables with the support of some of the other youth who were less experienced in soldering. Members working on the FSRs spent three months designing and iterating the first module. An initial round of tests produced inconsistent results. The group expressed despondency, and requested that I design a low-res prototype as a starting point for them. I designed the prototype in a way that secured ongoing access to the design object, and proposed that groups work together to design a flexible solution that worked for both interactives. Members of both groups worked together to plan; took temporary ownership of discrete parts to implement decisions; and came back together to solve problems, check progress and plan next steps. They explained things to one another through parts, observed each other, supported each other, and shared insights in an ongoing way. The twelve tagged geometric forms were researched and drawn collaboratively. A combination of model size, print job size, and the cost of local printing services, forced us to print them at the DIMEB research group's fab lab in Germany, and youth were not involved in the process.

Co-construction of the concept and interface scaffolded three members' software co-constructions. A fourth member endeavoured to participate, but found it hard to engage. Members wrote up and
drew up their decisions as we progressed through the project. These included flow diagrams, the game rules, and wiring plans. The materials were taped to the walls of the design space. We connected through them and the playing environment maquette to build components in the programme. We consulted the flow diagrams to establish tasks, and then discussed how to implement them. Discussions were grounded in the game rules, and youth referred repeatedly to the hardware they had co-constructed while developing their points. Ideas related to the playing environment were played out in the maquette to facilitate shared thinking [Rogoff, 1998]. After making a decision, the group shifted between their wiring plans and the maquette (for components related to the playing environment) to identify and extract relevant data, and implemented their idea together. They played their tests with the different hardware parts, and iterated the component until they were happy with the results. Understanding of Scratch developed differently amongst the three members driving the process. This enabled the boys to step in regularly and help each other out. These interventions required intersubjectivity and helped stretch understanding [Rogoff, 1995]. Tiago, who had participated meaningfully in the design of the hardware and content, found it hard to engage in the programming discussions. The other members drew him in by providing him with simple repetitive tasks with minor changes from one construct to the next. He was generally able to complete these tasks, but required close supervision. It became harder to involve him as the programme grew in size, and system responses to mouse events suffered minor delays. Tiago often disconnected sections of code unintentionally, and then reconnected the stack in the wrong place. Checking and repairing the damaged code was a time-consuming process. There were also less and less simple 'low-risk' tasks [Lave & Wenger, 1991] for him to perform. The size of the programme became an issue for the other members after they integrated the four game challenges and ran them together, with data received from the ten-node project PAN. They expressed frustration with the sluggish processing, but eventually devised a solution which we planned and implemented together.
Members took responsibility for discrete parts in the tests (an FSR in the playing environment, a
dice, a collection of tagged geometric forms, the Scratch editor on the host) and connected through
the interactive. They communicated to coordinate efforts, and analysed output together. When they
identified a bug or a missing piece of content, which required common understanding of what was
supposed to have happened or what users needed to know in order to make informed decisions, they
worked together to fix the bug or co-construct and integrate the outstanding content, and then
repeated the test together. This ongoing cycle of coordinated interaction, collaborative analysis, and
co-construction, helped to further interlock participant cognitions [Miller, 1987]. Most tests were
played as a game, and youth generally displayed equal interest in the results of the test and the
results of the game. This playful form of analysis appeared to resonate with local culture deeply.

Users connected through the completed interactive in various ways. Older youth offered younger
youth a range of support from their 'passive' positions; team members collaborated and studied
opponent moves; and other youth observed and listened with interest. Ongoing engagements
around the object helped constitute a rich and extended social event which cut across age and
gender. Young users did, however, find it hard to follow the multiple sets of rules devised by the
group. This frustrated collaborative efforts within groups at times. There was no external
presentation of the interactive despite repeated attempts to organise such an initiative with staff.
Figure 36: Multiple Points for Engagement in the Shared Design Process – the 'A Batalha Ecológica'
(left to right and top to bottom) Discussing the separation buffers on the FSRs; altering contacts to conductive layers during a test; completing wiring work started by others; removing hardware from FSRs after a test; entering a dice result into the game system during a test; Superman on the verge of winning the first test of the completed interactive.
Figure 37: Multiple Points for Engagement in the Shared Design Process – the ‘A Batalha Ecológica’
(left) Members of both groups gluing graphic layer frames to the top of the assembled FSRs. (right) Group members working together to solve a problem related to one of the frames. Luciana is sharing information with the others.

Conclusion

Previous participation in the activity helped build the common ground that enabled engagements around the shared design problem. The group negotiated and consolidated their developing shared mental model of the design project at each stage of the design process through their developing shared external model. There were three developments in the external model in this example which were important for interpersonal connections. Firstly, I continued to encourage youth to ‘off-load’ [Pea, 1993] decisions into the environment. Different uses of these materials revealed their different affordances and complementary roles in co-construction. The large flow diagrams were used to establish tasks and situate them within the broader shared endeavour; the playing environment maquette was used to act out ideas and ‘hold’ them for implementation in the programme; and the wiring plans were consulted for data required for the implementation. Youth built out their idea together from one support to the next. Secondly, the low-res prototype I designed for the playing environment helped guide group thinking away from single unitary forms. I designed it as a discrete part of a loosely-coupled composite, and youth developed it into the full
interactive surface by discussing problems, making decisions, implementing decisions concurrently on like parts, and coming back together to review work and plan next steps. Low-res prototypes therefore appear to be an effective way to introduce ideas into group discussions, and loosely-coupled composites a way to safeguard access to certain types of unitary forms to stimulate conversations with and through objects. Thirdly, encouraging the two groups to design the playing environment as a flexible solution that worked for both interactives, helped boost interpersonal connections between groups. Both groups were able to use their shared surface as a foundation for their own distinct projects.

There were also moments when interpersonal connections were strained. Tiago's limited participation in the group's programming revealed how members' zones of proximal development [Vygotsky, 1978] may vary widely in certain areas. When they do, it can be challenging to secure and maintain meaningful engagement in the shared endeavour. Tomé's decision to opt out of the photoresistor soldering task when he was unable to perform it in an independent manner, and other youths' willingness to work with me to complete the soldering, showed how individual dispositions and histories play an important role in interpersonal connections. Youths' lack of involvement in the printing of the tagged geometric forms suggests that for the moment, while the costs of 3D printing are still high, it may be more appropriate to explore low-tech sustainable options.

iii. Did interpersonal connections help advance the centre's transformative agenda?

Observations

Interpersonal connections promoted individual development within the group. Youth had to co-construct and maintain a shared mental model (e.g. [Mohammed & Dumville, 2001][Van den Bossche et al., 2011]) of their design problem to proceed with the shared endeavour, and involve
participant-leaders in an ongoing way in the process. The model was built between individuals, and could not be attributed to any one of them alone. It involved communication and coordination, and involvement in each other's thinking processes – what Rogoff calls shared thinking [Rogoff, 1998].

The majority of members were continually in the process of stretching their common understanding to fit with new perspectives in their shared endeavour, and using this understanding in context. Peers served as resources and challenges for each other. There were two instances where interpersonal connections were interrupted. These interruptions limited opportunities to learn.

The stretching of common understanding was an ongoing process. For example, youth learnt about force-sensitive resistors (FSRs) in a phase two exercise. They designed their own thumbnail size versions, used them in a running-on-the-spot competition, and analysed the competition code afterwards to understand why the winner's interaction style had been so successful. They knew from the exercise that FSRs could sense user presence, and designed their playing environment around the idea. The environment was a three-by-six grid of foot-sized FSRs with built-in RFID capabilities. Members discussed game challenges, the allocation of challenges to the sensors, the layout of challenges in the environment, and user movements through the environment. They designed a maquette to represent the core ideas, and played them out in it to think them through. André probed their ideas through the maquette to encourage them to reflect further. Final decisions were written up in a project plan. Members coordinated their contributions carefully throughout, so that the 'structural whole' (the shared mental model) could result [Miller, 1987]. The outcomes of their engagements were evident in the first flow diagram. It was a simple, high-level representation, showing how the four challenges were integrated in the game. I sketched up a rough idea for a challenge management framework from the diagram and worked with youth to implement it in the programme. Youth led the implementation of the individual challenges. At one point it became evident that the group had not thought about a way to start the game. They considered adding
a start button, but there were no free sensor ports on the ten readers, and no more readers to add to the project PAN. They also observed that they couldn't ask users to stand on a particular sensor, because, as they put it, 'the system was already expecting this' (own translation). They eventually opted for four users standing on the four corner FSRs in the playing environment, and I worked with them to implement their idea in the programme. After testing their solution they realised that users might not want to listen to the full set of rules every game. They rerecorded the introduction in two distinct parts, and reworked the code. Their solution provided users with a choice: after outputting the first part, they instructed two users to move to the first middle FSRs on either side of the environment if they wanted to hear the full introduction. Later, after integrating the four game challenges, they found that processing became sluggish. They proposed to break the system in two, and run it on two computers to solve the problem. I developed a rough plan for running the dice on one computer and the playing environment on another, and explained to youth that we would need to think of a way to input dice results into the 'main' playing environment system. They reflected for a while, and told me that we could instruct the winners of a roll to stand on the first three sensors on their side of the playing environment. They implemented their idea without support. As Rogoff has observed, the ongoing stretching of common understanding to accomplish something together is development, and later involvement in similar events reflect these changes [Rogoff, 1998].

Alex's changes were evident throughout the two-year design process. He was a newcomer in the previous phase. In the new phase he co-led the group with the old-timer Superman, and regularly drove programming discussions. He supported and encouraged Bernardo in the programming, and did the same for Tiago in the content narration and recording. He was the member who proposed we split the system in two after the group identified the sluggish processing problems. In phase two, he told us that he planned to study law. He changed his mind to computer science in phase
three. He chose to follow the science and technology track in grade ten, and to repeat grade eleven to increase his chances of getting into a highly regarded computer science programme. He was the first youth in the centre to follow the science and technology track.

Superman's changes were evident in an ongoing way in the programming. He participated in phases one, two and three. In each he showed peers how they could combine new concepts with syntax and constructs used previously. He appeared to enjoy using his new knowledge to design increasingly challenging games for himself and peers. These interests became apparent in the final session, when Alex scolded him in a friendly way for coming up with so many ideas during the concept development process. His participation in the narration of the content (authored in his second language), grew from discreet avoidance in phase one to equal participation in phase three. He also persevered with challenging words like *paralelepípedo* – with some encouragement from Alex. He chose to follow the economics track in grade ten. He was the first youth in the centre to pursue this option.

Tiago’s changes were apparent at various points. He was an active user at the phase one presentations, and participated in the phase two group led by João. He assisted João with hardware tasks, and followed peer discussions around content and programming. In the new phase he assumed a greater role in the hardware development. He normally worked with a peer on tasks, which included checking photoresistor cables, cutting materials, gluing FSRs, and applying vinyl to the FSR surfaces. He also made significant contributions to the content narration and recording; a new area of participation. He persevered through multiple takes of each of his segments, and shared the recording and editing role with Alex. He sat behind his peers for the programming, and listened to their discussions. They asked him to implement simple repetitive bits of code that required minor changes from one construct to the next. He was generally able to perform these tasks, but
required close supervision. It became progressively harder for the others to involve him in this manner as they advanced with the programme. He always set up the host for sessions, and participated actively in the tests. He regularly revealed understanding of what his peers were trying to achieve in the tests by acting in advance of instructions.

Bernardo also participated in phase two, where he played a role in the co-construction of his group's hardware and content. In the new phase he continued to participate in these areas, and engaged with Alex and Superman in the programming. He listened closely to his two more experienced peers' discussions, made occasional contributions, and participated actively in the implementation. His changes were apparent when Superman or Alex were unable to make a session. He discussed problems with the partner who was present, and revealed growing understanding of the concepts, technical decisions and processes they were using in the programme. Superman and Alex acknowledged his gains in the later stages of the programming, by working with him to author the final version of the flow diagram. Each boy assumed responsibility for one of the colour-coded challenges, and detailed steps for when a user moved to one of their sensors. The diagram was the most accurate and succinct representation of the programme. He also chose to pursue the science and technology track when he reached grade ten.

Tomé's changes were visible during the first eight months of the hardware design. He worked with his peers to generalise the plug-and-play model to other types of interfaces, and mentored Tiago by providing him with simple 'low-risk' tasks. His participation in the activity became increasingly intermittent after he learnt that his parents planned to re-emigrate, and friends shared that he rarely left home. Prior to his departure, he had expressed a strong interest in taking an electrician course at trade school.
Interpersonal connections also enabled the centre to effectively aggregate youth skills and interests in a small design team in which the whole was more than the sum of its parts, which enabled youth to design an engaging new interactive resource for the institution. The community, including staff, gathered around the environment, and played along with the members of the two teams by offering various forms of support and commenting actively on proceedings. A group of older girls, which included members of the Os Seis Amigos and Funda Glória groups, reminded the young users which recyclable materials were mapped to which tagged geometric forms, and helped them to group the forms into the different recyclable material categories in preparation for the task. The strategy was effective, and helped the kids learn about the recycling of materials found in their community. Previous efforts by staff to raise awareness around recycling had not found the same level of traction in the community.

The interactive was carefully designed for presentation in the broader community, but no presentations were realised. The failure to achieve this step revealed the importance of the synergistic relationship that existed between the craft-tech activity and the centre's outreach programme in the first three years of the study. During this period, staff followed what we were doing in the activity and kept a finger on the pulse of the broader community. They identified ways in which our work could be used to advance the programme, discussed ideas with us, and liaised with external partners to set up the presentations. Presentations in the broader community quickly became an integral part of what we did in the craft-tech activity as well as the outreach programme. A more than one hundred percent turnover of staff during the four-year study period appeared to have shifted the focus of the programme, and broken the link with the activity.
Conclusion

Interpersonal connections helped to advance the centre's transformative agenda at an individual and institutional level, but not at a community level. On an individual level, there was evidence of transformation of participation [Rogoff, 1998, 2003] through mutual involvement [Rogoff, 1995] in co-construction activities. All five youth had designed and used interactives previously. They chose to raise the bar significantly in the new phase by designing a multi-challenge game that took two years to complete. One youth who had entered the activity in the previous phase assumed a leadership role. He supported peers in the planning, narration, and programming, and chose the science and technology track when he reached grade ten. He opted to repeat grade eleven to raise his chances of entry into a coveted computer science programme. Another youth who had participated in both earlier phases regularly showed peers how they could solve problems by combining new concepts with constructs and syntax used previously. He also increased his participation in the content narration, an area he had avoided because of linguistic insecurity. He chose the economics track when he reached grade ten. A boy who was classified as a special needs learner, and rarely spoke in the centre, narrated and recorded a significant portion of the group's content. He also participated actively in the hardware design, and performed simple 'low-risk' programming tasks with support from other members. A fourth boy increased his participation in the programming by working closely with two more experienced peers. His changes were apparent when one of the boys couldn't make a session. He discussed problems with the partner who was present, and revealed growing understanding of the concepts, technical decisions and processes they were using. He also chose to follow the science and technology path in grade ten. Finally, the youth who made important contributions to the development of the plug-and-play interface model in the previous phase, showed how it could be generalized to other types of interfaces through his contributions to the various hardware components. He expressed a strong interest in doing an
electrician course at trade school. Members' various career ambitions and decisions, suggest that their involvement in the activity could be read in part as preparation for what they expected later on the basis of prior participation in related activities. How people prepare now for what they expect later on the basis of their prior participation, is one of the central questions raised by the transformation-of-participation view [Rogoff, 1998: 690].

At an institutional level, interpersonal connections enabled the centre to aggregate and leverage youth interests and skills for the design of a new learning resource. The interactive supported playful learning through mutual involvement in shared activities, and social interaction as an 'integrated multiparty group' [Rogoff, 2003: 144]. It demonstrated clearly how youth could design engaging new solutions to their community's problems, and how peers welcome these contributions. It also showed how youth could successfully shape technology for mixed age social activities, which were popular in the centre but not supported by available technologies. The group succeeded in stimulating discussion, sharing and reflection around the recycling topic. These engagements cut across different age-groups and gender. Young users revealed greater understanding of recycling by completing the challenge independently towards the end of the game. This was an important gain for the centre, because recycling was not viewed as an exciting topic.

There were was no engagement with the broader community because staff were unable to arrange a public presentation. Failure in this area appeared to be related to the high turnover in staff during the study period. Resignations erased institutional memory - in our case about youth's achievements in the community, and new staff brought in their own priorities and approaches. This led to changes in the outreach programme. Failure in this area highlights the importance of a synergistic relationship between the craft-tech activity and centre's outreach programme.
5.5 Patterns in Interpersonal Engagements and Arrangements that Established Opportunities to Learn

I now describe patterns in interpersonal engagements and arrangements across the four interactive design and use processes that established opportunities to learn. The patterns are offered as insights with import for the design of transformative technology-based activities in after-school centres – what Dourish calls 'models for thinking' [Dourish, 2006].

5.5.1 A Shared Interest in Acting Together

Youths' interest in co-construction was evident throughout the study. They always waited for at least one other member of their group to arrive before starting to work on their interactives, and stated that they were doing so because there was no fun in designing on one's own. They also called on each other when one overslept or forgot about a session. They demonstrated their interest in co-construction in the activity, by actively building on each other's contributions, making concerted efforts to bring each other into the design process, collaborating with tools that were not originally designed to support collaboration, and valuing design decisions which promoted cooperation over those that didn't. All but one of the participants interviewed after designing an interactive stated that they preferred working in groups, and the one person that didn't said she participated in the activity because she valued the opportunity to share with and learn from others. She used the term *solidariedade* (solidarity) to describe her form of socially-engaged participation.

This shared interest in acting together, what Markus and Kitayama call *conjoint agency* [Markus and Kitayama, 2003], was not limited to the research activity. I rarely saw youth do anything other
Figure 38: Playing as an Integrated Multiparty Group
(left) Youth engaged in a rule discussion during a game of UNO in the centre. Passive users are seated between active users to observe play and participate in discussions. (right) Youth engaged in a game of urim – a game for two users – during a visit to a museum. The group have opted to apply their winner-stays-on-the-table rule rather than play multiple exhibits separately. Passive users are following active user moves while they wait for their turn.

than using computers and completing their homework on their own, and even then they worked hard to find ways to do it together. Physical play resources designed for dyads were almost always adapted to support larger group use, usually through the addition of a simple winner-stays-on-the-table type rule. These adaptations were driven by collective interest rather than necessity, because there were always other resources at hand which passive users could have opted to play with. The same practices were also observed during activity group outings to museums, where youth regularly chose to interact as a group with a single exhibit, alternating between active and passive user roles, rather than interact separately with multiple exhibits.

Markus and Kitayama have shown how motivational dynamics vary across sociocultural contexts, and how agency isn't separate from these contexts, but rather patterned on the ideas and practices of these contexts. For their conjoint model of agency, good actions are defined as relationship-focused, and arise in interaction with and response to others. Agentic feelings may include
relatedness, connectedness, solidarity and sympathy. Actions are responsive to obligations and the expectations of others, and preferences, goals and intentions are 'interpersonally anchored' (emphasis added) [idem]. Conjoint models of agency are closely associated with socialisation to interdependence, which involves 'orienting to the group' [Rogoff, 2003] (e.g. [Rogoff, 1990] [Markus & Kitayama, 1991, 2010]). Interdependence is prevalent in the Global South.

This pattern, which was observed in all groups, and more broadly in the day-to-day activities of the centre, has relevance for transformative initiatives in after-school centres in the Global South, as well as those situated in the Global North which cater to communities with cultural roots in the Global South (e.g. [Greenfield, 1994]) – as was the case with Centre D. Motivation patterns – a shared interest in acting together rather than as separate individuals – set up opportunities to learn from more skilled peers and adults in a zone of proximal development [Vygotsky, 1978]. These opportunities can be harnessed through tools and environments which engage these patterns.

5.5.2 Common Ground and Play

Playing interactives together helped establish the common ground which enabled engagements around the shared design problem. Play events included the use of interactives designed by others, the use of interactives designed by peers, and group use of own exercise projects. The common thread running through them was the ongoing development and maintenance of a common ground of understanding, through playful engagement with the shared interactive object and each other. Understanding built through these engagements served as a platform for subsequent joint action. Common ground was built in many different of ways, and often involved one or more youth leading in a particular area, and then sharing with the others.
For example, in phase one, youth used an example interactive comprising an interactive mat and a reader. They gathered around the mat, and passed the reader to each other to facilitate read interactions, and to bring everyone into the game. Excitement on and around the mat periodically led to tags being moved out of alignment with the craft objects they represented. This rendered craft objects 'unreadable'. The more curious members of the group figured out the problem and how to fix it, and explained their solution to the others so that they could participate in ongoing repair work too. This unplanned hardware bug, as well as other ongoing interactions and observations around the mat, helped youth learn about the connections we were establishing between digital and craft objects, the hardware involved, the way in which one interacted with it, and the passage of the RF signal through certain materials.

In another group in phase two, youth designed their own thumbnail size FSRs, and used them in a running-on-the-spot competition. The system was a low-tech pedometer which counted participant steps. One participant grasped how the system counted steps, and developed a unique running style exploiting this understanding. His style gave him a distinct advantage over youth who simply ran as fast as they could. Participants observed each other and the resulting scores. Afterwards we analysed the code to work out why the winner's style had been so effective. Peers were very keen to understand his strategy. Discussions helped build understanding about how the sensor detected user presence and how we worked with data from it.

Groups tapped into their shared repertoire of play to design their own interactives. The group which used and repaired the interactive mat, saw it as a form of treasure hunt. This inspired them to design their own. They worked with their common understanding of treasure hunts – everyone was very familiar with the rules – to develop a version that was firmly grounded in their lifeworlds
(O Quarto da Paula). Youth who participated in the running-on-the-spot competition and analysed the winner's strategy afterwards, followed a similar path. They understood that the sensor could detect user presence, and that it was the kind of thing which could be useful in board games. They worked with their common understanding of board games – snakes and ladders, chess, drafts, monopoly, etc. – to design a life-size board game which recorded, checked and responded to user movement (A Batalha Ecológica).

5.5.3 Device Collections and Composite Objects

Multiple craft parts associated with multiple devices in the kit provided groups with multiple points for engagement in their shared endeavour. Members worked together to plan; took temporary ownership of discrete parts to implement decisions; and came back together to solve problems, check progress, and plan next steps. They explained things to one another through parts, observed each other, supported each other, worked together on challenging tasks, and shared insights in an ongoing way. Communication and coordination to achieve a collectively-valid result involved adjustments between participants, to stretch common understanding to fit with new perspectives in the shared endeavour [Rogoff, 1995]. Some modifications in the perspectives of each participant were necessary to understand the other person's perspective, and as Rogoff has shown, these modifications can be seen as the basis for development [Rogoff, 1998].

I found that constraining access to the object under construction, by limiting the number of devices included in the kit, constrained interpersonal connections; whereas promoting access to the object under construction, by increasing the number of devices included in the kit, promoted interpersonal connections. For example, in an exercise in phase two, groups shared access to a single reader to design a hand-held light meter. One youth assumed responsibility for the electronics work, and two
youth programmed the device together afterwards. Members then took it in turns to use the device, and there was little sharing or comparison of data. Co-construction in this case, was primarily external. In another exercise in phase three, group members each adopted the identity of an animal in the Scratch sounds library, and worked together to create a project which enabled them to greet each other with appropriate calls. Youth took temporary ownership of a reader and a tag, and designed a mobile project identity around them. They invested personally in their objects, shared insights, learnt from each other's mistakes, and supported one another. Object relationships and collaboration patterns established through hardware were carried over into software. Each youth created their own virtual tag object in the funda project to represent their physical tagged object, and authored the scripts that handled tag events transmitted from their reader in the Scratch programme. While one youth programmed, the other members observed to learn from them, catch errors, and provide support. They interacted playfully and thoughtfully through the finished interactive to explore the exercise concepts together. Co-construction in this case occurred

Figure 39: Device Access in the Exercises
(left) Building the hardware for the hand-held light meter exercise. The use of a single device constrained access to the design object, and interpersonal connections. (right) Group members with the hardware they built for the animal identity exercise. The use of multiple devices promoted access to the design object, and interpersonal connections.
externally in the composite exercise object, and internally in the form of the group's shared mental model of the exercise problem.

The use of a device collection can promote interpersonal connections, but it doesn't guarantee them. This was evident in phase two, when a group of three youth worked with a three-node configuration of the kit and twelve tags to design a multi-lingual language game (A Casa das Palavras). Members took temporary ownership of individual devices and associated craft parts, and coordinated efforts toward a collectively-valid result. The completion of the mobile devices and embedding of readers in a single interface form, erased earlier co-construction affordances, and youth acknowledged this by assigning two members to new tasks while the third continued to work on the hardware alone. In this case, the theme constrained access to the design object, and this had a knock-on effect on interpersonal connections. The experience highlighted the importance of structuring the design process for co-construction through themes which safeguard access to the physical object, and timely interventions which guide group thinking away from unitary forms that constrain access.

The use of a device collection theme in phase three (Os Seis Amigos), promoted similar access to the shared external model throughout the design process, and enabled youth to implement group decisions concurrently on like parts. It also allowed them to take temporary ownership of like parts to test the object together. Similarities in access and task, as well as proximity to each other while working on a task, enabled youth to hold parallel conversations with the object [Ackermann, 2004], in which issues surfaced were likely to be familiar to the others, and to converse with the others about these issues through their parts of the object. In another interactive designed in the same phase (A Batalha Ecológica), I designed a low-res prototype to guide youth thinking away from
single unitary forms. I designed it as a discrete part of a loosely-coupled composite, and youth developed it into the full interactive object by discussing problems, making decisions, implementing decisions concurrently on like parts, and coming back together to review work and plan next steps. Low-res prototypes therefore appear to be an effective way to introduce ideas into group discussions, and loosely-coupled composites a way to safeguard access to certain types of unitary forms to stimulate conversations with and through objects.

5.5.4 Scaffolding Software Co-Constructions

Constrained access on the host worked as a co-construction affordance. It focused member attention on individual shared problems, and enabled them to leverage their combined understanding to solve them. Youth demonstrated their interest in programming together by listening carefully to each other, and actively building on each other's contributions in an ongoing and fluid way. In a number of instances they also appeared to enjoy the social act of thinking through problems together; where peers served as resources and challenges for each other. This was especially true for the older participants (14-16 years). Members devised their own workarounds for the physical access problem, often sharing access to the input devices and coordinating efforts in the user interface to implement ideas together (e.g. figure 30). Working in a projected image of the user interface provided youth with a number of distinct roles, which were always rotated. Three sets of cognitive resources helped scaffold collaborative efforts.

The first was the interactive's rules. These were always developed early in the design process. They provided the group with a common set of references and boundaries [Nicolopoulou, 1993], which helped structure shared thinking around the individual problems [Rogoff, 1998]. Members owned and understood their rules deeply, and were quick to point out when a peer 'broke' one with a
particular contribution. We began work on a problem by articulating a rule or rule element, then expressed it in pseudocode (natural language emphasising Scratch syntax and logic), and finally worked together to reformulate it in Scratch with the blocks. The focus was always the same: how to build the rule or rule element with Scratch. We worked systematically through the game, from beginning to end.

The second was the interactive's hardware. Groups generally built the hardware after they had worked up the rules, and before starting work on the programming. Building the hardware together helped firmly establish the shared external model in the world and ground the shared mental model. Both models were important for collaborative efforts in the programming. The shared external model provided the group with additional shared references and a physical context in which to locate their discussions. For example, when members spoke about the temperature-related feedback for the *O Quarto da Paula*; how they would know when users had built a new word in the *A Casa das Palavras*; how to eliminate a user for an incorrect guess in the *Os Seis Amigos*; or how to record a secret colour code answer in *A Batalha Ecológica*; they were talking to and thinking with something they had built together in the world. Their discussion was situated in a collectively-owned object, and this made it easier for others to follow and build on their ideas. Two old-timers (Alex and Superman) said that it was better to build the hardware first, because the physical co-construction process helped introduce ideas used in the programming. The convergence of individual mental models through exchange in communication – towards the shared mental model – increased the group's ability to share, process and utilise information.

The third set of resources comprised the various planning materials groups developed over the course of the design process. In phases one and two we worked on A4 sheets of paper. In phase
three, I taped up large sheets of newsprint on the walls, and provided groups with felt-tipped pens to draw up and write up their ideas. I also encouraged them to 'off-load' [Pea, 1993] technical decisions into the environment, and build simple maquettes. Materials included large flow diagrams, lists of rules, wiring plans with associated project information, schematic diagrams, and drawings of hypothetical lists using the Scratch representational model. The newsprint sheets were kept taped to the walls for the duration of the design process. In phases one and two, groups worked with these resources at their desks, using them to plan constructs in the programme. In phase three, the more public nature of the materials made it easier for members to consult, refer to,

*Figure 40: Technical Lists for the 'A Batalha Ecológica'*

(left) The wiring plan for the playing environment, showing reader numbers, module numbers and colours, sensor ports, and sensor numbers. (right) The wiring plan for the dice, showing dice numbers and colours, reader numbers, sensor port numbers, and face numbers associated with their corresponding roll result.
and connect elements of the external model in the course of discussions. The different uses of these materials revealed their different affordances and complementary roles in co-construction. The large flow diagrams were used to establish tasks and situate them within the larger shared endeavour; the maquettes were used to act out ideas and to 'hold' them for implementation; and the wiring plans were consulted for information required for the implementation. Youth built out their idea together from one support to the next, using them to bridge different perspectives.

5.5.5 Connecting through Use

Craft-tech interactives comprising multiple devices, supported *multidirectional shared engagements* in a group [Rogoff, 2003]. Active users took possession of individual devices and collaborated with others to advance through the game. Passive users stood and sat around them or between them. Active users exchanged ideas and information related to the interactive to support each other and draw each other into the game. They also observed each other, coordinated interactions, and became involved in each other's thinking processes. Passive users followed proceedings to learn how to play the game, develop playing strategies, and offer assistance to active users. These playful *ensembles* [idem][Mejía-Arauz et al., 2007] reconfigured after each game, with passive users moving into active roles, and active users regularly reverting to passive positions. Social affordances in the interfaces shaped engagements differently.

A supportive form of use was observed in a treasure hunt game made up of a static table-top interface and two mobile devices (*O Quarto da Paula*). Two youth paired up with two elderly folk to play the game. The youth first played against each other to show the older users how to play, and then played with them to assist them with interactions they wanted to make. A youth and elderly person shared access to a single device. A staff member joined the group to provide additional
assistance. She observed proceedings and explained things to the older users. The five users sat around the interface facing inward towards each other and the unfolding interaction event. Members of this intergenerational ensemble communicated fluidly across the interface and coordinated interactions in it.

A cumulative form of use was observed in a multi-lingual game, made up of a static interface and twelve mobile tagged objects (A Casa das Palavras). Users took temporary ownership of individual tagged objects to co-construct words in the interface to advance through the game. One or two users began using the interactive, and were gradually joined by others through the course of the game. Active users encouraged passive users to move into active roles to increase their chances of passing game levels. Passive users often did this in a staged manner, first offering words which active users built in the interface, and then, after gaining confidence, working with them to build additional words. New users were both known and unknown to the original users. Members of these impromptu ensembles coordinated interactions verbally by suggesting new words out loud and offering feedback about these suggestions. They also observed each other's moves with cards, prepared new words outside the interface, built and removed words together, and manipulated the tagged objects in the interface to facilitate their reading.

A scaffolded form of use was observed in a general knowledge game about six animals for six users, comprising six wearable tagged objects and six mobile devices (Os Seis Amigos). Two teenagers played the game with younger children to teach them about the animals. The group stood in a circle facing inward towards each other and the current user, who stood in the centre of the circle. The teenagers offered hints and asked questions to guide the younger users towards the correct answers. When they observed that a child was about to answer incorrectly, they posed
additional questions to encourage them to reflect further. Passive users sat around the active user circle, observing, listening, and providing further support. Members of the active user group interacted physically with one another to answer questions, observed each other, and listened to contributions from others. Members of these multi-age ensembles celebrated a draw as a collective achievement.

A guided form of team use was observed in a game about recycling, comprising an interactive surface, two 'rollable' devices, and twelve mobile tagged objects (A Batalha Ecológica). Two teams of three children played against each other. Members of one of the teams assumed responsibility for specific tasks, and rotated responsibilities through the game. The other team collaborated in a fluid manner around each of the tasks. Passive users sat around the interactive surface observing the unfolding event and each other. Older youth in the passive user group guided active user participation in the game. They reminded users which recyclable objects were mapped to which tagged objects, and taught them grouping strategies that helped simplify the recycling task. Members of this multi-age ensemble listened to each other, exchanged ideas, observed each other and coordinated interactions in and around the interface to advance through the game.

5.5.6 Shared Activity Repertoire

We developed and maintained a shared repertoire [Wenger, 1999] of co-construction resources over the four-year study period. The repertoire included procedures for simplifying processes, strategies for supporting shared thinking, techniques for organising group ideas, ways of addressing recurring problems, and methods for advancing sustainability. Examples included the breaking up of extended narratives into collections of smaller segments, and the simulation of a single take with the programming; the acting out of interaction scenarios in sketches and maquettes to make ideas
Figure 41: Shared Repertoire Resource – the Procedure for Extended Narratives

(left) The Start-Restart script for the O Quarto da Paula. The introductory narrative has been broken up into four segments – selected in the first four toque o som () e espere blocks – and a single take is simulated with the programming. Audio files are named with the first few words of the segment to facilitate identification. (right) The Start-Restart script for the A Casa das Palavras. The introductory narrative has been broken up into three segments – selected in the first three play sound () until done blocks – and a single take is simulated with the programming. Audio files are named with the first few words of the segment to facilitate identification.

public and concrete; the collaborative drawing of large flow diagrams on sheets of newsprint taped to the walls; and the plug-and-play interface model. The resources were developed through the combined efforts of various members of the activity community in the activity. Some resources, like the procedure for recording and outputting extended narratives, were developed independently by groups after the idea had been introduced into the activity, because members could see how it helped solve an immediate problem. Other resources, like the plug-and-play interface model (section 3.3.3), which were designed to address broader issues like sustainability, required active encouragement and support from participant leaders. Once a resource found traction in the community, it was reused and refined in an ongoing way by participants and participant leaders.
Resources were also generalised to other related tasks and problems. The ongoing accumulation, refinement and generalisation of the different resources strengthened our ability to co-construct interactive objects (externally and internally), and share them with the immediate and surrounding community.
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