The Potentiality of Play

The shifting design language of play-based learning

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Abstract

This thesis, underpinned by cross-cultural design ethnography (DE) and research through design (RtD), re-reads play-based learning constructs as design practice. In doing so, it charts the shifting relationship between design and theories of play-based learning. The work frames the design of play-based learning processes, from their emergence in historical learning environments such as the Montessori method to current pedagogies of STEAM learning. This evolutionary focus will be of interest to a wide range of stakeholders such as pedagogues, designers, and policy makers, each of whom contribute to where, what and how children are taught.

This thesis presents the following arguments: Firstly, it frames and re-reads key historical play pedagogues as designers and design thinkers, whose work has shaped and influenced the evolution of play-based learning through the inception of play artefacts, spaces, and structures. This thesis further elucidates that design-thinking has been at the heart of play-based learning, demonstrated through the design of modular and standardised pedagogic objects and spaces of historic learning environments. The design evolution within this framework helps to enlighten the development of tinkering and iterative prototyping as twenty-first century affordances of learning through play. Secondly, this thesis uses observation-based design ethnography of the Montessori method, to argue that Montessori's restrictive pedagogy can be counterproductive to learning through intuitive processes of exploration and iteration. Thirdly, by adapting the practice-based research method of research through design (RtD), the thesis demonstrates and proposes that twenty-first century design affordances of tinkering and iteration can be suitably integrated to enrich historic play-based learning environments such as the Montessori method. In each of these arguments, the ways in which pedagogic theories of play are interwoven with the language of design thinking are revealed.

By bringing into focus the triad of play, pedagogy, and design, an additional educational landscape of twenty-first century cultural learning environments is explored. Cultural learning environments (CLEs) such as museums and public galleries extend the scope of play-based learning beyond formalised spaces of schools and bring into relief, the predominance of design while incepting platforms, ateliers, and activities to initiate learning through play.

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ACM	Association of Children's Museums
AMI	Association Montessori Internationale
AMS	American Montessori Society
BRAC	Bangladesh Rural Advancement Committee
BRIO	Brothers Ivarsson of Osby
CfE	Curriculum for Excellence
CLE	Cultural Learning Environment
CM (cm)	Centimetres
DE	Design Ethnography
DEEWR	Department of Education, Employment and Workplace Relations
ECD	Early Childhood Development
ECE	Early Childhood Education
ECCE	Early Childhood Care and Education
EiE	Engineering is Elementary
GERM	Global Educational Reform Movement
IPA	International Play Association
IMF	Indian Montessori Foundation
LCD	Liquid crystal display
LEGO	Leg Godt (a contraction of the two Danish words. It means: Play well)
MDF	Medium density fibreboard
MDT model	Multimethod Design Thinking model
MKO	More Knowledgeable Others
M.S.1.0	Montessori School 1.0 – located in Scotland
M.S.2.0	Montessori School 2.0 – located in Bangalore, India
M.S.3.0	Montessori School 3.0 – located in Pune, India
MSTEM	Middle School Science, Technology, Engineering, and Mathematics
NUEPA	National University of Educational Planning and Administration
NCERT	National Council for Education, Training and Research - (India)
PEDAL	Play in Education, Development and Learning
PE	Physical Education
POP	Potentiality of Play
PVG	Protecting Vulnerable Groups
RtD	Research through Design
STEM	Science, Technology, Engineering and Mathematics
STEAM	Science, Technology, Engineering, Arts and Mathematics
TED	Technology, Entertainment, Design
UK	United Kingdom

UN	United Nations
UNCRC	United Nations Convention on Rights of the Child
UNESCO	United Nations Educational, Scientific and Cultural Organization
US/USA	United States of America
ZPD	Zone of Proximal Development

Prelude

My fascination with play-based learning stems from my personal experience of growing up in India where I was subjected to rote-based and didactic learning environments. That along with my parent's educational background (my father is an engineer and product designer, and my mother is a psychologist and has worked as an additional-needs educator) led to me develop a keen interest in design and play-based learning.

While pursuing my under-graduate degree in graphic design in India in 2011, I developed a play-based learning project that conceptualised alternative modes of study for young Indian children, especially those experiencing dyslexia and dysgraphia. Here, I designed a bilingual play-based learning system to help young Indian students learn simple English words using phonetic cues from Hindi (one of India's official languages).

As part of this play-based learning system, I incorporated the design aesthetic of roulette wheels and dice to introduce playfulness and gamification; by engaging in playful interactions with various multi-sensorial components, children could be incentivised to learn simple spellings. Due to restrictions of time and travel, the project was limited to basic user-centric research, it therefore lacked in-depth empirical research and extensive onsite data at the time.

My interest in theories of play continued into my post-graduate studies in Interaction Design in Scotland (2013-2014). My fascination with play and design led to the formulation and creation of *VIBE* – a sound-based installation designed by me, which focused on play and design as siblings of collaboration, materiality and participation. During this time, I developed another project called - *The Tweeting Pillows*, which won the Curator's Choice award at the NOISE Festival in London, in 2014. This project was designed to incorporate and visualise play, playfulness, feedback, and interaction. The main focus of the project was to gather data by giving people an inanimate object (here - a pillow) and completely altering the object's physical persona and characteristics.

With the help of Makey-Makey kits embedded inside, the pillows were coded to responded to tactile touch and physical contact. The pillows were coded and given twitter profiles, where, the moment a person would hug a pillow, it would immediately tweet its disapproval online. This back and forth between an inanimate object and humans on a digital platform such as Twitter, led to this entire interaction becoming highly playful and engaging.

When the opportunity arose to pursue research into play-based learning and design through the means of this Ph.D., it presented possibilities to extensively study play-based learning environments through the lenses of design. The Ph.D. also presented a valuable opportunity to respond to a query that I had ruminated over since childhood "would I have taken a more vested interest in technical and scientific subjects as a child, had I experienced and learned about them in a more play-based, creative and explorative manner."

Introduction

Today, the prevailing context of play-based learning across the globe is increasingly designed into a wide range of everyday spaces. Whether it is seen in the design of urban parks and adventure playgrounds, maker spaces focusing on STEM and STEAM comprehension, tinkering studios, designed ateliers of the Reggio Emilia programmes, or dedicated play-based learning venues such as the LEGO House[1] in Billund, play has become pervasive and intertwined with design, by increasingly offering an experimental and interdisciplinary interaction with the world.

While the benefits of play for children have been widely promoted, less attention has been given to how pedagogies of play implicate design in the interactive learning experience. A well-established body of research into play reflects a proclivity to view play through the lens of psychology and pedagogy (Bennett et al., 1997). The predominance of this approach eclipses the role of design thinking and design in the form and experience of play. Play implicates design as an instrument and an environment for children to demonstrate their learning and development (Broadhead and Cuckle, 2002; Broadhead, 2006; Samuelsson and Johansson, 2006; Wood, 2007). Although design is often implicit in the infrastructure, environment, and theoretical models of play, its significance is overlooked.

This omission overlooks a historic relation between play, design, and pedagogy. From the earliest forms of block play in the fourth century to the digital gamification of geography and science in Minecraft, the design of play artefacts has been underwritten with the pedagogic intent of enhancing cognition (Gura, 1992; Cuffaro, 1995; Franklin, 1973) and language (Isbell and Raines, 1991), and developing socialisation. In this way, design has always been implicated in theories of play (Samuelsson and Carlsson 2008). This thesis aims to redress the gap in research and to view design as inseparable from play-based pedagogic epistemologies.

As a designer and outsider to the pedagogic theories this thesis describes, it was my intention to more fully understand the way in which design supports and actualises certain play-based learning experiences. Throughout the thesis, design thinking and design are

1 The LEGO House was opened for schools and the public in Billund on 28th September 2017.

identified as common elements in the historic development of play (both in academic research and school practice). Moreover, the thesis argues that approaching play-based learning environments through the lenses of design thinking and design can help develop an understanding of play that is sensitive to the role of materiality and interaction in education.

The research presented in this thesis is of interest to designers who are currently working or hope to work within formal and informal educational settings. This thesis aims to present guidelines and valuable design mindsets to help designers examine the cause-effect relationship of design and play. Through its contributions to knowledge, this thesis aims to guide designers to consider play-based learning approaches and interventions through the lenses of design thinking and design, to help them design for future educational landscapes. Along with designers, this thesis also hopes to present valuable insights to current pedagogues, educationists and policy makers, each of whom contribute to where, what and how children are taught.

I.1 The entanglement of design and play: Identification of research gaps

According to Hatch (2010), the ways in which children access content through play-based learning can be understood as a research process of discovery that privileges the relationship between children and teachers as foundational to learning. This approach begins to grasp the significance of design thinking in formalised and institutional pedagogical play. Here, I refer to Tim Brown from IDEO[2] and his book *Change by Design*, where he defines design thinking as "A human-centred approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success." (Brown and Kātz, 2009).

I.2 Research aims and questions

This thesis explores play-based learning through the study of play artefacts, learning structures, and learning environments, which have been designed to enhance the

2 IDEO is a global design and innovation firm founded in 1991. Tim Brown is the executive chair at IDEO.

experience and learning outcomes of formal[3] and informal[4] educational organisations. Through research undertaken at distinct learning environments of Scotland and India, this thesis aims to critically review and identify ways in which design thinking and design have contributed to play-based learning environments and frameworks of educational play.

This thesis answers the following research questions:

1. What are the contributions of design thinking and design to play-based learning environments?

2. In what ways has the design language of play evolved, from its emergence in historical learning environments to the current landscape of twenty-first century education?

3. How can design thinking and design support play-based learning's migration beyond the scope of formal classroom environments, in the twenty-first century?

I.3 Thesis structure

The thesis is organised into four parts to progressively study the contributions of design thinking and design in play-based learning environments. Part One consists of Chapter One and Chapter Two, each of which present distinct current and historical contexts of play and play-based learning environments through a review of relevant literature. Chapter One introduces a way of understanding play-based learning environments by revealing the pervasiveness of design within both formal and informal learning spaces. Chapter Two provides a historical background to the thesis by exploring the trajectory of play-based learning through the works of key pedagogues like Vygotsky, Montessori, Dewey, and Fröbel. These theorists are re-read as design thinkers whose works have influenced how design has implicitly and explicitly contributed to play and education. Part One aims to break down the research questions outlined in the Introduction in order to reveal the connections between, and historic foundations of, play and design.

3 Formal educational organisations refer to schools.
4 Informal educational organisations refer to CLEs (Cultural Learning Environments) such as museums, science centres and art centres/galleries.

Parts Two and Three highlight methodological discourses. Part Two consists of Chapters Three, Four, and Five, which examine the research method of design ethnography (DE). Chapter Three begins by introducing the research method of DE, in relation to the wider scope of ethnographic research. This chapter argues for the relevance of DE to this thesis and to design research. DE supports the empirical exploration of applied play-based learning theories introduced during the literature review.

In this thesis, DE was undertaken in a cross-cultural capacity, to allow for immersive observations of site-specific knowledge acquisition and relational insights gained from the dynamics of distinct learning environments. Formal school environments in Scotland and India were selected as DE research sites. My familiarity with the local and internationalised curricula and practices of the Indian education system as well as my exposure to the graduate education system in Scotland made access to formal play sites in Scotland and India more feasible and workable, given the limited time and resources available during this thesis. Chapter Four presents DE fieldwork undertaken across three research sites in Scotland and India. It discusses the global and local adaptations of formal play environments, by presenting sections of empirical data as discursive notes and vignettes. This chapter further analyses the researcher's fluid positionality during cross-cultural DE. Chapter Five assimilates findings and empirical data from the DE fieldwork and draws out key design themes and characteristics of play-based learning environments, to address the first research question of this thesis. By highlighting design gaps for intervention, this chapter subsequently leads to the identification of design opportunities to engage in RtD as a practice-based research method.

Part Three consists of Chapters Six, Seven, and Eight, which examine the participatory research method of research through design (RtD). Chapter Six introduces RtD as a practice-based research method and its significance in conducting improvisational, and participative research in this thesis. RtD was adopted in this thesis, to respond to design opportunities in play-based learning environments as identified during DE. Chapter Six introduces play workshops, which were designed to undertake RtD by prototyping and testing play-based learning materials[5] in-situ. This chapter discusses the relevance of cultural learning environments (CLEs) such as museums and public galleries, which were

5 Materials in the context of this thesis, is a term deployed to describe pedagogic objects, play tools, toys, and artefacts. This term is specifically used as 'sensorial materials', while referring to Montessori's designed pedagogic tools.

chosen to conduct the RtD play workshops (in Scotland). This chapter also focuses on the evolving positionality of the researcher, from being an observer during DE to essaying the role of a designer, researcher, and active workshop facilitator during RtD. Chapter Seven presents observations and inferences from the thirteen RtD play workshops, through diary narratives supported by sketches and images. It discusses the format, feedback, and findings from facilitating thirteen play workshops. Chapter Eight presents an analysis of the RtD play workshops. It segregates the empirical data from these workshops into several design categories and reads them along with the literature discussed in Part One of this thesis. This is done to address the first and third research questions, which focus on design thinking and design's contributions to play-based learning and its migration beyond formal classroom environments.

Part Four, which consists of Chapters Nine and Ten, presents research consolidated from the first three parts of the thesis. Chapter Nine summarises the contributions of design and design thinking in play-based learning environments. It brings the interconnectedness of design, design thinking, and play-based learning at the forefront of this thesis, based on the research conducted through the literature review as well as the research methods of DE and RtD. Chapter Ten is the conclusion chapter. It responds to the research questions introduced at the beginning of this thesis and presents an overview of the thesis's contributions to knowledge. It relates back to the historical and prevailing contexts of play-based learning environments as presented in the earlier parts of this thesis. This chapter also reflects on the benefits and limitations of the research methods of DE and RtD. Finally, it concludes the thesis by presenting suggestions and recommendations to further develop an understanding of play-based learning and its relation to design thinking and design.

I.3.1 Methodological choices

To undertake a comprehensive study of design thinking and design's contributions to play-based learning, a multimethod research approach (Morse, 2003) was adopted in this thesis. Multimethod research, as defined by Morse (2003), usually combines both qualitative and/or quantitative methods. The main principle of a multimethod research approach is to identify the theoretical drive of the research methods, which could be inductive (for discovery) or deductive (for testing) (ibid).

At the outset, it was my aim to adopt a beginner's mindset during design research, which as Brown and Kātz (2009) explain, allows one to keep an open mind, comprehend ambiguity as an opportunity, and remain curious. Within this thesis, embracing a beginner's mindset during the primary research helped to decipher the contextual meaning and behaviour patterns observed at play environments on-site.

In this thesis, design ethnography (DE) and research through design (RtD) were selected as the two methods within a multimethod research approach (Morse, 2003). Prior to commencing with fieldwork for both DE and RtD, a decision to engage in pilot studies and identify potential problems was made. Within research paradigms, a pilot study can consist of pretesting a particular research method or a trial run for a major study topic. Pilot studies are crucial to research projects as they help uncover potential problems before the main study and help undertake corrective measures beforehand (Salkind, 2010). Pilot studies help prepare for logistical problems and other possible design deficiencies which a real study might face; this helps make adjustments and corrections to the main study before executing it (Salkind, 2010).

I.2.1.a Pilot study: Design ethnography (DE)

Figure 1: Inch Plus toy library

To familiarise myself with the format and limitations of conducting observation-based DE research in an environment with young children, I initially conducted a pilot study in Edinburgh for six weeks in 2016. During the pilot study, I volunteered at a local toy library in Edinburgh called Play Plus[6], which is run on a non-profit basis with the help of staff and volunteers from the Smart Play Network[7].

This pilot study helped me gain access to local play networks, organisations, unfamiliar play spaces, and environments. Through this pilot study, I was able to observe how children communicate and interact with each other and with play resources in their play environments. This pilot study presented me with opportunities to attempt various methods of documenting design ethnographic data and select the most appropriate methods which would be useful to the eventual DE study.

While planning for future DE research at play-sites in Scotland and India, it was crucial to factor in unforeseen problems which could occur during the research phase. This pilot study also helped factor in contingency and address limitations of documenting DE research. For example, I was allowed to observe children and take notes at the toy library but was not allowed to take any photographs or videos. I was also aware of the possibility of having access to limited visual documentation later during DE, since only a few schools allow researchers to take photographs and videos in schools. Consequently, I began to document my observations and findings through everyday private blogs[8] and vignettes, which were supported by sketches and diagrams. I also developed a method to address the lack of visual documentation of the play sessions, by taking before and after photographs of the play spaces (before children interacted with a play environment, and after they had interacted with and exited the play environment). Some of these documentation techniques were eventually adopted during DE.

6 This library was located in the Inch Park/ Cameron Toll area of Edinburgh in 2016. For a membership fee of four pounds sterling a year, parents could come to the toy library with their children and borrow a few toys every month. The toy library was a mobile space and was organised in a room at the Inch Park Community Center every Tuesday from 9.30 am to 1 pm. The library was arranged as a playroom with dedicated zones of play. Play objects were arranged across the room on cloth and foam mats along with child-sized furniture (benches, stools, beanbags) in each play area.

7 The Smart Play Network is an organisation in Scotland aimed at bringing families with young children (ages zero to five years) together to engage in dedicated playtime.

8 The blogs were created on a secure private platform which was accessible only by me and my thesis supervisors, in compliance with Edinburgh Napier's research framework and ethics guidelines. Links and passwords to the research blogs were only given to my supervisory team. All information in the blogs was anonymised, in compliance with Edinburgh Napier University's data protection policies

I.2.1.b Pilot study: Research through design (RtD)

As a RtD pilot study, I organised a participative play workshop at a play conference called CounterPlay[9] in Aarhus. Through this workshop, I designed and facilitated a thematic play session to instigate co-creation, exploration, and collaborative play between the conference delegates. This play workshop helped me factor in the advantages and limitations of conducting a participative research study and eventually helped with the development of research workshops, for the subsequent RtD fieldwork.

Figure 2: Counterplay: Workshop participants at *I am a toy!*

Table 1: Excerpts from the RtD pilot study titled *I am a toy!*

Title of the RtD pilot study	This workshop was called *I am a toy!* and was categorised under the theme *Reconfiguring the Playful Maker*, as a part of the Counterplay conference in Aarhus.
Workshop premise	Workshop participants assumed the role of a toy ('toy' with reference to this workshop, is an agent or initiator of play). Through collaboration with other 'toys' (other participants), participants engaged in a playful activity to achieve a common goal. By introducing a scenario where toys (in this case participants) compete with other toys (other participants) to achieve a common goal, this workshop allowed the construction of an imaginative space in which strangers could team-up to share a common inter-present experience of playful collaboration.
Design of the workshop activity (rig)	For this pilot study, Makey-Makey kits were incorporated as play materials to design scenarios of playful collaboration. Makey-Makey kits are electronic prototyping kits that mimic some functions of a keyboard and mouse. These kits are safe and easy to use and can be connected to conductive objects (fruits, water, conductive tape, human skin, amongst others) using alligator clips, to control any computer program. For this workshop, I designed a play

9 ~~The~~ Counterplay conference was organised in Aarhus, Denmark, between the 14th and 16th of April in 2016.

	environment using Makey-Makey kits, conductive tape, sheets of paper, alligator clips, and a laptop connected to a large LCD screen. These materials were arranged to form a play *rig*. By engaging with this rig, participants could engage in collaborative play.
Play activity for the pilot study	The game of Pac-Man was chosen as a play activity, for the participants to engage in, during this workshop. This workshop had ten participants in total. Two teams of five participants were formed (which consisted of both adults and children). In each team - Four of the participants had to essay the role of a game *switch* (four participants became the four arrows of a computer keyboard) and one participant became the key player. These five participants were connected (as *switches* ~~of a~~ in the game) to the rig, using one Makey-Makey kit. Each participant had conductive sticky tape fastened to the palm of their hand, to which an alligator clip from the Makey-Makey kit was attached. Four participants collectively essayed the role of a gaming console. The fifth participant essayed the role of the main player and interacted with these *switches* (other participants) through physical touch (by giving each other a high five or by holding hands), to play Pac-Man.
During the workshop	During this workshop, two groups of five participants each played Pac-Man against each other. The game of Pac-Man was projected on a large LCD (liquid crystal display) colour screen. The teams focused on the Pac-Man game displayed on the screen, as they competed against each other ~~in a race~~ to finish the game.

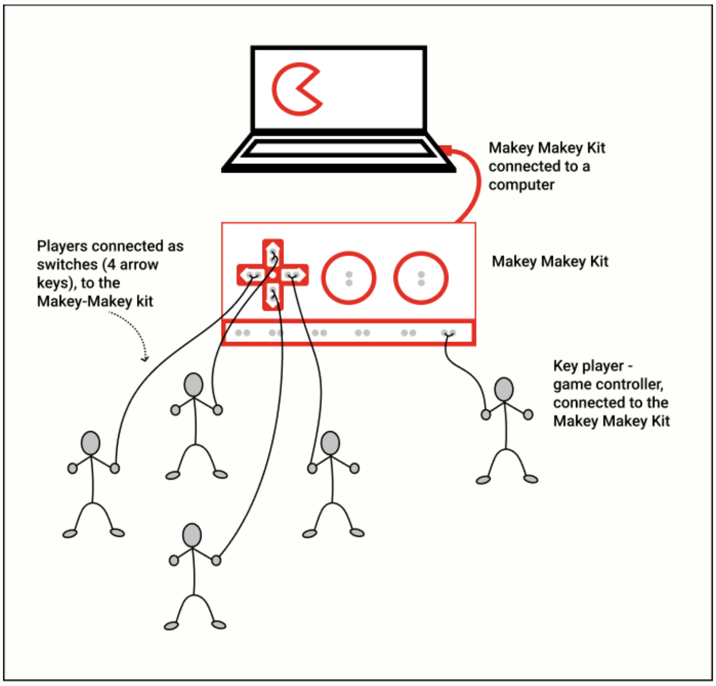

Figure 3: Design of the RtD workshop rig using Makey-Makey kits

This pilot study had a low-risk premise since it was an informal play session at a play conference. This pilot study was designed as a play experiment using various play materials (refer to Table 1) to help initiate collaborative play. It allowed me to tailor my facilitation technique to suit the play environment and participants; herein I designed an approachable and improvisational style of workshop facilitation which helped in the RtD workshops subsequently.

I.4 Play Policies and concerns

The geographic scope of play is significant to this thesis since it has become a global commodity and is informed by increasingly globalised professional networks. Article 31 in the UN Declaration on the Rights of the Child, frames play as essential to the well-being of a child. Article 31 promotes and protects the development of creativity, imagination, physical, social, and cognitive skills in children; all of which contribute to learning. Article 31 is now embodied in the United Nations Convention on the Rights of the Child (UNCRC) and is read in conjugation with the International Play Association's[10] (IPA) Declaration on the Child's Right to Play.

In Scotland, the right to play is part of governmental decree and protected by law. The Scottish Government has advocated for children's play as being crucial to Scotland's social, economic, and environmental well-being. The government identifies play as the universal language of childhood, where all children and young people should have the opportunity to play. This has led to the creation of the National Play Strategy in Scotland (gov.scot, 2020). Scotland has recognised the importance of playtime and incorporated it within its national curriculum. Additionally, frameworks such as the Curriculum for Excellence through Outdoor Learning[11] have been drafted, to design the outdoors as a creative space to help children and young people develop twenty-first century skills (gov.scot, 2020).

10 IPA: International Play Association; founded in 1961. This is an international non-governmental organization, with members across 50 countries. It focuses on protecting,, promoting, and preserving the child's right to play as a fundamental human right.
11 More information about the Curriculum for Excellence through Outdoor Learning can be accessed at https://education.gov.scot/Documents/cfe-through-outdoor-learning.pdf

In India, the design of Early Childhood Development (ECD) programmes for children between the age range of prenatal to six years, as investigated by Kaul and Sankar[12] (2009), is based on inculcating lifelong skills, personal behaviours, and values. In historical India, social values and skills were passed on within the family structure through stories, lullabies, traditional infant games, and grandmother's tales. The authors (ibid) argue that this family-oriented legacy of education slowly disappeared due to the modernisation of India and the transition from joint to nuclear families. Education and childcare responsibilities in India have now shifted from reliance on a joint family structure to immediate parents and nuclear families.

Kaul and Sankar (2009) list the following reasons which have led to the deterioration in the quality of early years education in India:

- The absence of an accreditation and regulation system in India.
- Private unrecognised institutions adopting academically rigid and regimented curricula.
- The absence of resources and trained ECCE facilitators.
- Adaptation of rote and memory learning as pedagogic practices.

To cope with this changing social context while ensuring quality early childhood care and educational practices in India, the Early Childhood Care and Education (ECCE) framework was drafted. ECCE in India, at the moment, urgently calls for a play-based and child-centred methodology which demands specialised skills, access to affordable and accessible play-materials, and knowledgeable educators who are equipped to address the contextual needs of children (Kaul and Sankar, 2009). Despite India's endorsement of the United Nations Convention on the Rights of the Child (UNCRC), insufficient measures have been taken by the state to safeguard this fundamental right of its children due to different social, economic, and cultural beliefs and gaps.

12 Venita Kaul is a Senior Education specialist from World Bank, who has written extensively on Early childhood and primary education in India. Deepa Sankar is an Education Economist with the South Asian Human Development Department at the World Bank. Excerpts from their report, as cited in this thesis, have been published by the National University of Educational Planning and Administration (NUEPA); however, the views addressed in that report and as cited in this thesis, belong to Kaul and Sankar.

I.5 Geographic scope of this thesis

According to Whitebread (2018), a renewed focus on play has emerged due to a matrix of interwoven forces, namely, a reaction to urbanization and national education policies[13], heavily scheduled and supervised home lives, high stakes testing, and strict accountability regimes, which have led to more instructional and less playful learning approaches. Sahlberg[14] (2012) coined the acronym GERM (Global Educational Reform Movement), while referring to international groups that contribute to the research landscape of play-based learning. Some organisations such as Play Scotland, Unilever's Outdoor Classroom Day project, Toys Industries for Europe, BRAC[15], Reggio Emilia in Italy, Association Montessori Internationale (AMI), Sesame Street preschools in India, the International School of Billund in Denmark, and Inspiring Scotland share a commitment to extending playful learning across curriculum. Together these organisations form a global network that privileges a way of understanding play as inseparable from design.

The following pages begin with Part One, which explores the evolution of design thinking and design in the conceptualisation of historical and current play-based learning within both formal and informal learning spaces.

13 According to Whitebread (2018), 50% of children in the global population, reside in urban instead of rural contexts, which severely curtails outdoor and natural play.
14 Pasi Sahlberg has worked as an educator and school teacher, and analysed education policies in Finland.
15 BRAC is an acronym for Bangladesh Rural Advancement Committee. BRAC has designed play interventions which focus on achieving large-scale, positive changes through economic and social programs. Further information about this organisation can be accessed on https://www.bracusa.org/who-we-are/.

Part One

Part One (Chapters One and Two) explores the evolution of design thinking and design in the conceptualisation of historical and current play-based learning environments.

Chapter One aims to trace the development of design in play-based learning environments and reveal its prevalence within both formal and informal learning spaces. This chapter maps the ways in which play has been structured within formalised spaces such as schools, institutions, and twenty-first century cultural learning environments (CLEs) such as museums, STEM and STEAM maker spaces, public galleries, and so on. By analysing play-based learning environments through the design of artefacts, materials, structures, and spaces, this chapter begins to place design as a central feature of play-based learning.

Chapter Two aims to develop a wider context by tracing the historical trajectories of play-based learning. This chapter re-reads key pedagogues such as Fröbel, Dewey, Montessori, and Vygotsky as design thinkers. Re-reading these key pedagogues as design thinkers illustrates that design thinking's prevailing emphasis on current play-based education structures (as elaborated upon to Chapter One) has in fact, a far longer history of underpinning play-based learning environments since before the twentieth century.

Chapter One:
Play-based learning environments

Children don't see play as utilitarian; on the contrary, play allows children to test bodies, ideas, and materials in exploratory, creative, random, and potentially irrational combinations, while suspending limitations of reality. Nevertheless, play is increasingly put to serviceable ends in schools and other learning environments. Chapter One aims to trace the pervasiveness of design thinking and design in play-based learning environments. This chapter focuses on the relationship between play personnel (teachers, children), play materials (play objects, tools, spaces), and play structures (activities, tasks, themes) to addresses the significance of design and design thinking in examining pedagogical play. This chapter then discusses how play-based learning in the twenty-first century has escaped the constructs of formal learning environments such as schools and been assimilated in informal and active learning spaces or CLEs such as museums, maker spaces, and tinkering studios.

1.1 Play

The comprehension of play across pedagogic institutions today has been influenced by key thinkers such as Piaget (1936, 1952, 1962, 1963, 1965, 1976, 1983), Bruner (1972, 1983) and Vygotsky (1933/1969, 1962, 1967, 1978, 1997). Each of these pedagogues have contributed to the vocabulary of play and implicated design in varying degrees. Bruner (1972), a key figure and psychologist of the *cognitive revolution*, defines play as an opportunity for children to take risks without the fear of failure.

> *"Play appears to serve several centrally important functions. First, it is a means of minimising the consequences of one's actions and learning, therefore (it is) ...a less risky situation. Second, play provides an excellent opportunity to try combinations of behaviour that would, under functional pressure, never be tried" (Bruner 1972, p. 693).*

Piaget's and Vygotsky's contributions to play focus on invoking design through interaction with objects and reciprocal behaviour. Piaget (1952) argues that play helps construct knowledge in the individual child through interaction with play materials (toy, objects, artefacts). While Vygotsky (1978) endorses play as social interaction and collaboration, Levin (1996) identifies play as that which provides opportunities for children to exercise self-control and interact with objects in a way that is meaningful to them. In each of these invocations of play, the theorists see play as productive since children acquire knowledge when they play (Dau and Jones, 1999).

Twenty-first century psychologists Smith[16] and Pellegrini[17] (2008) view play as a flexible activity undertaken for its own sake. Moreover, the authors (ibid) recognise the *process* of playing as more important than the outcome. Based on this point of view, play is seen as having a positive effect on the person engaging in it, often characterised by laughter, joy, and excitement. The authors (ibid) argue that these characteristics set play apart from *exploration* (examining a new toy or environment while playing/which might lead to play), *work* (goal-defined activity), and *games* (rule-led and organised activities with an end goal in sight).

In their insistence that children do not differentiate between playing and learning as they occur simultaneously through the creative exploration of ideas, Smith and Pellegrini (2008) develop the work of both Levin (1996) and Dau and Jones (1999). Similarly, Samuelsson and Carlsson (2008) also see play and learning as natural components of children's daily lives. The authors (ibid) argue that play is a practice initiated by children and learning is the result of a practice or activity initiated by adults. Within the framework of early childhood education, distinguishing between play and learning is still a prevalent praxis. Winsler and Carlton (2003) discuss that disputes with play have become highly debated as researchers emphasise on the need for adult interaction during children's play to support learning.

These authors outlined above imagine an interactive relationship between play and learning, one that begins to bring design into view through an active and exploratory engagement with materials.

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1.2 Design thinking and designerly thinking as perspectives

Razzouk and Shute (2012) argue that design thinking is an analytical and creative process that offers people opportunities to experiment, build, prototype, gather feedback, and redesign. The authors (ibid) conceptualise design thinking as beyond the conventional disciplinary boundaries[18] of design (such as visual design, product design, interaction design, service design, user experience design, user research, and digital design). Similarly, Li et al. (2019) argue that design thinking transcends all professional frameworks, where it is observed and carried out as both formal and informal activities in our daily lives; from decorating baked foods to designing furniture, and so on. Much like Dalsgaard (2014) in line with Buchanan (1992) and Cross (2011), Li et al. (2019) view design as a problem-solving approach and a way of framing approaches as "challenges that characterize design" (p. 144).

Somewhat differently, Johansson-Sköldberg et al. (2013) refer to a designer's professional practice as "designerly thinking" (p. 124). Li et al. (2019)~~)~~ conceptualise design and designerly thinking as five activities: (1) constructing artefacts, (2) a reflexive practice, (3) a problem-solving activity, (4) a way of making sense of things, and (5) the creation of meaning. The authors (ibid) use the term design thinking while referring to design competencies and practices which are used beyond professional design contexts (such as art and architecture). The authors (ibid) also use the term design thinking while referring to individuals *without* an academic background in design, to illustrate skill and applied knowledge.

Li et al. (2019) view design thinking as a model that grants diverse opportunities to help facilitate learning. However, in relation to play and its pedagogical value, Li et al. (~~2019~~ ibid) also acknowledge that the obscure nature of design thinking leads to difficulty in terms of the practical application of design concepts in curricula. Here, the authors (ibid) refer to approaches such as (1) modelling of design processes (Simon 1973; Schön, 1983) and (2) identification of specific design thinking strategies, tactics, and skills (Lawson 2006; Wendell et al., 2017).

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18 Design specialties such as visual design, product design, interaction design, service design, user experience design, user research, and digital design focus on specialised skills and training, while also comprehending and practicing design thinking.

Subsequently, Li et al. (ibid) argue that in the current educational landscape, design thinking is essential to the development of creativity and innovation. Design thinking and design action inspire multiple approaches and perspectives to view and solve problems. The current landscape of educational play needs to focus on children's ideas and intuition, to help foster a mindset that supports design thinking and creativity. This can be done by integrating design within its content and curriculum.

1.2.1 Play-based learning environments: Play-tutoring

Play-based learning environments are viewed by Vickerius and Sandberg (2006) as designed physical environments which accommodate children's interests and needs (how they feel, act, and behave) and influence how children learn through play. Observing play-based learning environments through the lens of design thinking can evidence how design is framed, approached, and addressed to overcome pedagogical challenges though play (Dalsgaard, 2014).

Children's play environments and play resources are usually designed and curated by parents and educators intending to enrich children's learning experiences. This instrumental view of play starts early in the child's life; from the creation of play artefacts (Johansson-Sköldberg et al., 2013) such as building blocks to designing problem-solving activities. This coexistence of play artefacts supported by categories of play (refer to Table 2) to further cognitive development is referred to as *play-tutoring* (Tan, 1993; Smith and Pellegrini, 2008; Christie, 1983; Smith and Syddall, 1978). Play-tutoring aids the development of skills such as language, cognition, and creativity by designing learning environments that embed categories of play and stimulate their learning experience (Yawkey and Pellegrini, 1984; Sylva, 1990).

Table 2: Categories of play - as defined by Smith and Pellegrini (2008)

Locomotor play	This play category embodies large body movements through physical exercises such as running, climbing, jumping, and so on. It supports muscle training, strength, endurance, and aids development of physical coordination and growth in children (Smith and Pellegrini, 2008).
Social play and parallel play	This play category refers to playful interactions between parents or caregivers and children (up to 2 years old). Smith and Pellegrini (2008) argue that these playful interactions become a common occurrence amongst children as they grow older, between the ages of 2 to 6 years. A subset of social play is parallel play, during which children play near each other without much interaction.
Rough and tumble play	Smith and Pellegrini (2008) argue that rough and tumble play mimics real-life fights and chases. These are typically enjoyed by children, where they laugh, have fun, and pretend to hit each other, without causing actual physical harm (ibid).
Object play	Object play is characterised by playful interactions with play objects such as building blocks, puzzles, toys, and so on (Smith and Pellegrini, 2008).
Language play and solitary play	Smith and Pellegrini (2008) argue that language play begins at the age of two for children; here, they learn to make sounds and start talking to themselves, often playfully and repetitively, which is typically followed by laughter. According to the authors (ibid), development of language skills such as semantics (vocabulary and meaning), phonology (speech sounds), grammar (syntax), and pragmatics (use of language within social situations) occurs in children during preschool years. Development of phonological skills also occurs during solitary play, when children talk or *babble* to themselves (ibid). A subset of social play is solitary play, where children play individually (Smith and Pellegrini, 2008).
Pretend play	Pretend play involves the idea of pretence, where an object or an action can be represented as something else than it is.
Sociodramatic play	Sociodramatic play is where language skills benefit extensively (Smith and Pellegrini, 2008). It is often observed in children during object play. For example, when children engage in simple activities and actions with objects such as pretending to put a doll to sleep or pretending to be a doctor with a doctor's kit. These sequences evolve into stories and longer narratives (Smith and Pellegrini, 2008).

Play is understood as a complex concept in relation to learning infrastructures and outcomes (Brooker et al., 2014). Chaiklin (2003), Lillard (2013), and Wood (2013) examine the kind of interactions characterised by play-based learning environments that are optimal for children and reflect different kinds of structures. These interactions range from one end with *free play* where children develop their own experiences individually or with their peers, to the other end of adult-led *didactic learning* and teaching environments, which are designed for knowledge acquisition through academically structured schedules and curricula (Hedges and Cooper, 2018). It could then be inferred that play-based learning environments can be seen as mediational spaces on this spectrum between free play and didactic learning, in which play can be drawn in through various measures through play-tutoring formats designed to stimulate a child's learning experience and aid knowledge acquisition.

1.3 Design of flexible and creative learning environments

The theory of *loose parts* (Nicholson 1972/2009) is an interesting historical marker of design's influence in encouraging an adaptive and experimental relationship to learning environments.

> *"In any environment, both the degree of inventiveness and creativity and the possibility of discovery, are directly proportional to the number and kind of variables in it." (Nicholson, 1972/2009, p. 6.)*

Nicholson (1972/2009) argues that children relish participating in the design process. This can consist of (1) familiarising themselves with the nature of a problem, (2) reflecting on needs, (3) planning for contingencies and alternatives, (4) engaging in model-making through the construction of prototypes, and (5) engaging in experiments, modifications, and at times, even destruction; all of which necessitate the design of learning environments that are flexible and adaptable. Nicholson (ibid) further argues that some learning environments are unsuccessful (not engaging or able to encourage human interaction), because they are unable to accommodate loose parts or variables. When learning environments such as schools, playgrounds, galleries, and museums are designed to be absolute, structured, and static, they are not flexible or adaptable to the needs of the learners (ibid).

Building on Nicholson's (1972/2009) theory of flexible learning environments, Cochrane and Antonczak (2015) argue that designing creative learning environments involves facilitating creativity as well as modelling creative pedagogical practice. Furthermore, Cochrane and Antonczak (2015) argue that creative learning environments must be designed to be supportive, dynamic, and receptive to children's new ideas. According to the authors (ibid), a creative learning environment should support interaction and collaboration between learners, which in turn allows them to develop ideas and constructs at their own pace. Here, design processes such as critical thinking, exploration, risk-taking, and productive failure are accepted as positive outcomes of a learning process (ibid). In a creative learning environment, the teacher becomes a designer, who designs and initiates events to facilitate interaction between students and teachers. The authors (ibid) argue that this collaboration helps determine the direction of learning communities. This, in turn, leads to the formulation of a creative pedagogical design experience for the teacher, and a creative learning experience for children (ibid). Hence, a learning environment must encourage collaboration, rather than a solo pursuit undertaken by lone educators (Laurillard, 2012; Cochrane and Antonczak, 2015).

According to De Valk et al. (2015), designing interactive play environments presents challenges when conceptualising novel play opportunities. Here, the authors (ibid) insist that flexibility must be designed within the play environment since interactions between objects and spaces will evolve over time. With this in mind, the authors (ibid), while endorsing Nicholson's theory of loose parts, recommend the design of flexible play environments, where rules and goals are not pre-set by the designer but can instead be interpreted by the player. The authors (ibid) argue in support of the design of play materials and activities that encourage open-ended play, where players can use their imagination in multiple ways.

To illustrate this argument, De Valk et al. (2015) refer to Fröbel[19], who incorporated open-ended play as a play-tutoring format in the design of his pedagogical tools, which provided children with multiple possibilities (Zuckermann, 2010). Similarly, De Valk et al. (2015) also refer to open-ended play as a design approach incorporated within Reggio Emilia learning environments, where materials are designed to support creativity and imagination and children are considered as active co-participants who are given the freedom to conceptualise their learning activities.

19 Fröbel's designed toys for open-ended play and his design philosophies have been further examined in Chapter Two.

1.4 Design thinking in STEM environments

While recognising the importance of design thinking in formal play-based learning environments, Li et al. (2019) argue that design is being increasingly recognised not only through pedagogic objects but also through the design of integrated learning school frameworks in STEM disciplines (Honey et al., 2014, Kelley and Knowles 2016; English 2016). STEM is an acronym for Science, Technology, Engineering, and Mathematics; it is typically used in reference to commonly known science disciplines (English, 2016). Perspectives on how these disciplines can be integrated range from core concepts and skills taught individually in each discipline while placed under a common topic, to adopting a transdisciplinary approach to engage in real-world problem-solving using multiple skills from each discipline (English, 2016).

Design thinking is viewed by Li et al. (2019) as a continuous cognitive process, involving creation, experimentation, feedback, and iteration, which are competencies transferable across various fields. To illustrate, Li et al. (2019) refer to programmes such as Engineering is Elementary (EiE) (2011) at the Boston Museum, which study how engineering design can help engage children and facilitate the learning of STEM themes. Li et al. (ibid) refer to Kelly and Cunningham's (2017) analysis of design in STEM disciplines, which has identified novel ways of supporting design thinking skills. Kelly and Cunningham (2017) identify physical, symbolic and discursive artefacts of design thinking such as (1) construction of models and prototypes, (2) cooperation between criteria and constraints for design challenges, and (3) communication through written, symbolic and verbal discussions; all of which help foster creation, allocation, and assessment of knowledge. These epistemic artefacts help identify key areas to engage in further examination and comparison of pedagogic practices related to various STEM disciplines, which can be integrated to facilitate learning through design thinking.

1.5 Affordances of play-based learning environments

The theory of *affordances* as introduced by Gibson (1979), proposes the potential of an action on an object or environment. Norman (2013) defines an affordance as the relationship between the properties of an object and the capabilities of an agent to help determine how that object can be interacted with; for example, buttons designed to be pushed, knobs designed to be turned and rotated, and handles designed to be pulled. Flint

(2016) describes affordances as the experiential properties of objects, where affordances are specifically concerned with action on, and with the objects. Flint (ibid) further argues that affordances exist as opportunities for an animal while referring to their bodily relationship with the world; here, it is through this interaction with the world that affordances reveal themselves. Flint (ibid) applies the same metaphor to human-object interactions while focusing on the use of tools, where the perception of grouping together or bundling of affordances (for example, using an automatic drill to fasten wooden structures instead of a hammer and nails), can, in turn, afford a more stable construction and less use of time.

Norman (2013) uses the example of a chair which affords support and, in turn, affords sitting. Most chairs also propose lifting as an affordance; a single person is often able to carry a single chair (if it affords the ability to be lifted). However, some chairs can only be lifted by a team of people. If someone relatively young or weak cannot lift that chair, then for that person, the affordance of lifting the chair does not exist.

How, then, might we understand play-based learning in relation to affordances? Cantada (2010) suggests that if affordances are properties of an environment, which are relative to an agent or an animal, then it could be argued that affordances can be designed into pedagogic objects as properties which are relative to the learner. The author (ibid) further explains that one might also be able to enhance and develop specific abilities to exploit the features in pedagogic objects that afford learning.

Kennedy and Barblett (2010) are pedagogical researchers who have developed a structure to comprehend the early years learning framework in Australia. Their framework helps educators share methods and adapt play-based learning modules and teachings in their pedagogical practices. Concerning design, the authors (ibid) consider the influence of both tangible or physical and social aspects (affordances), while envisioning play-based learning environments.

The concept of affordances is particularly useful for thinking about play with reference to design because it integrates action and interaction with the human/animal environment. By observing and analysing the affordances of objects, structures, and spaces, we can identify design opportunities to enhance the capacity of play-based learning. In the following chapters, the concept of affordances becomes increasingly useful in understanding the components and behaviours of play-based learning. The following sections explore different aspects of the concept of affordances.

1.5.1 Affordances and value of play artefacts (or how about *Value as an affordance of play objects*)

Sutton-Smith[20] (1997) in his book *The Ambiguity of Play*, draws parallels between evolution as a model of human development and play-based learning. One of Sutton-Smith's (1986) most significant contributions to the study of play stems from his interdisciplinary approach. Based on collaborations with a diverse range of scholars from subjects such as history, psychology, sociology, and folklore, Sutton-Smith (ibid) argues that play's potential extends beyond disciplinary boundaries of psychology. He proposes that play is "either a form of progress, an exercise in power, a reliance on fate, a claim for identity, a form of frivolity, an issue of the imagination, or a manifestation of personal experience" (Sutton-Smith, as cited by Brown and Patte, 2013, p. 14).

Based on Sutton-Smith's (1986) accounts in *Toys as Culture,* Goldstein (1994) discusses how until the seventeenth century, toys were identified as commodities of minimum value, which reflected the mind-set of the society regarding toys at that time. Borrowing from Gump (1989), Goldstein (1994) contends that toys can function as a part of a larger, coercive environment to elicit specific behaviour. According to Pellegrini and Jones (1994), this unidirectional view of toys is rooted in ecological psychology, which tends to minimise the role of individuals in specific environments.

Hinde (1976) argues that children's interaction with toys cannot be easily categorised because the forms of play children exhibit varies based on the type of play materials, play partners, and social settings afforded by the play environment. However, he suggests that children exhibit more intricate forms of play when they interact with toys that they value, and when they engage with familiar adults and children. Hinde's (1976) argument is echoed by Pellegrini and Perlmutter (1988, 1989) and Pellegrini and Jones (1994), where these authors maintain that children exhibit high levels of competence, complex play, and language use while interacting with valued toys and with familiar adults or friends because they are motivated to participate.

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20 Brian Sutton-Smith is a play theorist, whose book The Ambiguity of Play is regarded as a pillar of play theory. Sutton-Smith was awarded for his work and research on material learning and language of toys from LEGO and BRIO in Denmark and Sweden respectively.

Sutton-Smith (1986) argues that there is a lack of a rudimentary theoretical database on toy technology. While studying how toys are used by researchers, he (ibid) realised that toys were rarely studied as a specific subject. Instead, they were used as rewards to motivate children's participation in experiments within the scientific paradigm[21] of educational psychology (ibid). Here, it can be argued that interactions with play artefacts such as toys afford distinct degrees of value and competence.

According to Sutton-Smith (1986), viewing toys as part of the culture (the environment) is extremely general and viewing toys as the expression of some underlying physical dimension (colour, shape) is quite abstract. This may be true; however, Sutton-Smith's comments about the dearth of research are applied to the 1980s and research within the field of play-based learning has developed since then, with studies on playful curricula such as Reggio Emilia (Kinney and Wharton, 2008) and constructionism (Ackermann, 2001). These more recent studies discern the use of specific toys to uncover how children think, explore, and interact with play materials (objects, toys, tools, spaces, and systems) and resources.

1.5.2 Affordances of safe risks

Kennedy and Barblett (2010) argue in favour of providing safe physical, emotional, and social environments that incentivise children to take appropriate risks while learning. In this specific context, the authors (ibid) use the example of educators and facilitators who provide challenging activities or *designed risks* (for example, climbing experiences, hurdle races, and so on) within learning environments, to help children extend their physical skills while simultaneously staying close by to monitor them and offer support. The authors (ibid) argue that the design of play environments that afford physical proximity can, in turn, encourage children to take *safe risks*. Here, the authors (ibid) point to the affordances of toys and play environments to sustain ambiguity and risk. According to the authors (ibid), play environments designed to be *risky,* yet secure, safe, and challenging, can aid the development of cognitive skills such as imagination and dialogic interactions. This risk-taking is particularly interesting to pedagogues because it is seen

21 For example, the study of objects which had one colour as compared to a study of objects with two or more colours, or a comparative study of objects of different shapes.

to be intrinsic to acquiring new experiences[22]. Risky play affords co-creation of vivid, challenging, and playful experiences (Lester et al., 2014) while also contributing to refining adaptive systems commonly associated with resilience and well-being (Lester and Russell, 2008).

1.5.3 Affordances of spatial arrangement

The design, spatial layout, and segregation of the physical play environment affords certain kinds of engagements and interactions. Catron and Allen (2007) argue that the design and layout of the physical play environment must focus on the cognitive, social, physical, and emotional development of children. According to the authors (ibid), while being suitably organised for comfort, the physical play environment must offer opportunities for exploration, and a wide range of play materials which afford manipulation and iteration (also known as *manipulatives)*.

Although learning takes place every day and everywhere, Biddle et al. (2014) argue that for the purpose of examining formal learning environments of classrooms, learning centres refer specifically to designed physical spaces within specific locations or *zones*, where instructional materials and play objects are placed and organised. These would commonly be categorised on the basis of themes such as art, block play, dramatic play, science activities and experiments, reading and writing corners, games, manipulative materials, and so on. These zones are often designed and changed on the basis of the age group, interests, and abilities of children who use them.

As argued by Biddle et al. (2014), the layout and segregation of a formal learning environment (for example a classroom) into specific zones is consciously influenced by the teacher's vision and organised to aid management of the classroom and implementation of the curriculum. Biddle et al. (ibid) further argue that spatial arrangement for play activities in classrooms or play zones is crucial to fostering a child's social and language development, where crudely designed classrooms can be counter-productive and cause disruptions in learning. To illustrate, the authors (ibid) refer to learning environments where conflicting spaces for music and writing are next to each

22 This concept of designing a safe physical and social environment to foster appropriate risk-taking and challenge oneself with the help of facilitators is what Vygotsky also refers to, while defining the Zone of Proximal Development. This has been further expanded upon in Chapter Two.

other; here, engaging with one activity hinders or disrupts the other. Their claim supports Clayton and Forton's (2001) argument that a disorganised and ill-arranged environment can lead to frustration in children.

Kennedy and Barblett (2010) argue that resources in a play-based learning environment's physical setting should support and not hinder play. The authors (ibid) identify how spaces can be designed to employ resources (media, technology, objects, and activities) as *provocateurs* to afford specific interactions. Here, the authors (ibid) use the example of a *provocative* bookshelf which is designed to pique a child's interest in reading. The design of bookshelves that are low in height helps young children access toys and activities independently, and thereby supports their capacity of making choices, which is agency in action.

The authors (ibid) also argue that play environments should provide equipment and artefacts that afford multiple kinds of interactions in order to promote exploration and creativity. Here, they suggest block play as an example, since blocks are designed to afford numerous interactions and structures, promote creative exploration, both indoors and outdoors, as well as by children across a wide range of age groups.

1.5.4 Affordances of sociality, facilitation, and communication

Broström (2017) sees play as being intrinsically motivated, creative, and imaginative. He emphasises the importance of interactions and conversations that support play, where play becomes more relevant and effective in a learning environment when it is well-communicated, and when the learning outcomes are comprehended and embraced in a more active manner. Furthermore, Broström (ibid) argues that we need a more nuanced and dynamic way of viewing play, learning, and teaching, in order to avoid overly simplistic ways of connecting play and academic outcomes. This is further supported by Grossman et al. (2009, as cited by Hedges and Cooper 2018), who propose that a theoretical blend of play, learning, and facilitation should be integrated into the core of early childhood pedagogy.

Samuelsson and Carlsson (2008) argue that a teacher's role is crucial to the success of play-based learning environments since it directly influences the way children make sense of objects and object-relations. Similarly, Hedges and Cooper (2018) argue that teachers should transition from being non-active observers of play or didactic instructors in playless sessions, to engaging as knowledgeable co-participants in play activities with children. The relationship between children and adults is seen by Kennedy and Barblett (2010) as central to teaching through play, where a dialogic exchange of ideas between children and adults influences their continued motivation and interest in knowledge acquisition.

In *the Death of the Preschool,* Tullis (2011) examined children's behaviour in two scenarios; firstly, where direct instructions were provided by teachers while introducing a new toy in class and, secondly, where children were allowed to explore the same toy without specific instructions. His observations revealed that the group of children who could explore the toy in an open-ended manner demonstrated more patterns of design thinking through creative problem-solving in comparison to the group of children who were directly instructed. According to Tullis (2011), direct instruction or didactic learning hinders natural curiosity in children as well as their ability to learn, which, in turn, inhibits their inquisitiveness in investigating their worlds. Tullis (2011) echoes Mangione's findings by arguing that activities that afford narratives, story-telling, comedy, and play help build extensive vocabularies, unlike direct instruction.

Snow (2011) argues that in order to create a balanced relationship between play and direct instructional learning, both these activities need to be viewed as complementary in classroom spaces. While summing up this dichotomy between play and direct instructions in learning environments, Snow (ibid) believes that although research between balancing play and instructional learning is still in its infancy, it is imperative that instead of viewing play and instructional learning from an either/or perspective, we need a approach them as reciprocal methods.

1.6 Migration of play-based learning to CLEs

While the literature so far has focused on comprehending formal play-based learning environments of schools, it is important to acknowledge that play-based learning has escaped educational school structures and permeated into cultural learning environments (CLEs) such as children's museums, public galleries, tinkering studios, and so on. These alternative CLEs, as documented in the later chapters, open up new relationships between design, play, and learning beyond the confines of schools. The following section of this chapter begins by introducing the design and structure of CLEs. It then identifies the conceptual framework of tinkering, which is intrinsic to the kinds of experimental spaces and experiences associated with CLEs rather than formal play-based learning environments.

1.6.1 STEM and maker spaces

Irie et al. (2019) describe maker spaces as learning environments designed to house DIY tools and materials that afford participative activities. Roslund and Rodgers recognise maker spaces as "places where people get together to make things while focusing on skills such as electronics, robotics, woodworking, laser cutting, computer programming, or so on" (2014, p. 9). Irie et al. (2019) argue that the maker movement ideology is a set of values affirming making, sharing, learning, and playing. Irie et al. (ibid) further argue that, as a global phenomenon, maker spaces have expanded from formal school learning environments to CLEs such as libraries, community centres, and so on.

Bevan et al. (2014) maintain that the maker movement is of interest to pedagogues due to its potential to engage young learners in exploratory investigations of the material and social world. Litts (2015) argues that the maker movement is fundamentally altering the way educators and educational researchers are envisioning teaching and learning. Design thinking as a model (Cochrane and Antonczak, 2015) is embodied within the maker movement since it supports active construction, design, iteration, and engagement with tools and materials to develop artefacts (Litts, 2015). Hence, the movement is being recognised as a network of tinkerers, hackers, designers, and inventors who share a responsive and experimental approach to design. Ryoo and Barton (2018) argue that maker spaces offer innovative opportunities to engage in inquiry-based, play-based, and learner-driven knowledge comprehension by affording the use of both traditional tools and new technology. The LEGO Foundation proposes that inquiry-based learning affords the questioning of relevant, authentic, and open-ended queries, which is an incentive to develop mathematical and scientific skills, along with a strong motivation to learn by engaging in active and hands-on investigations.

Herold (2016) argues that despite the variety of activities and tools employed within maker spaces, maker movement as an ideology is uniform. Based on the wide range of activities that maker spaces espouse, children and youth engaging in investigations and critique may not undergo typical school lab experiences (Sanders 2006; Ryoo and Barton 2018; Petrich et al., 2013; Bevan et al., 2014). However, Herold (2016) further clarifies that as the maker movement is now entering K-12 (from kindergarten to grade 12) education systems, educators have begun to negotiate with design conflicts between schools and maker spaces, such as the physical and spatial form adopted by maker spaces within schools, as well as balancing the curriculum with self-directed learning.

1.7 Tinkering

The term *tinkering*, as discussed by Koupf (2017), historically carried a negative overtone, where tinkering typically described the work of a tinsmith, who roughly repaired broken metal utensils. However, Koupf (ibid) elaborates that, in recent times, the term tinkering has developed a positive meaning, where it refers to modification and refurbishment of materials, both for creative and functional results. Koupf (ibid) identifies tinkering as a method that affords non-predictable and non-prescriptive exploration, which is undertaken either to create options for a specific concept, or to go back and repair a previous version of the same concept.

With its emphasis on improvisation, iterative processes, and problem-solving, tinkering can be conceptualised as an open-ended design process that employs both specialised and basic low-tech tools (from microprocessors to pipe cleaners and cardboard) (Bevan et al., 2014). Activities designed *for* tinkering, allow the learner to switch between materials, experiment with different techniques, and engage in open-ended exploration. Tinkering as an affordance *of* design thinking in play-based learning environments encourages learners to recognise limitations, allowances, and learn to compromise or redesign based on the identified constraints.

Within the current play-based learning landscape, tinkering is perceived as a design thinking-based generative process that affords (1) incepting a new concept, (2) engaging in trial and error as one tries to physically realise that concept, (3) persistently iterating, and (4) eventually experiencing improvements as the concept develops and comes to life (Petrich et al., 2013; Vossoughi et al., 2013, Bevan et al., 2014).

Bevan et al. (2014) argue that tinkering supports play-based learning within educational platforms like STEAM[23] (Science, Technology, Engineering, Arts and Mathematics). The integrative nature of tinkering provides a relational and experimental tool for STEAM learning agendas by encouraging investigation, critique, and open-ended exploration of real-world and interdisciplinary concepts. The following section examines STEAM as a twenty-first century play-based learning environment that afford tinkering and iteration as approaches to engage in design inquiries.

1.7.1 Integrating arts within STEM: STEAM

Yakman (2008) describes STEAM learning as a developing educational model that focuses on restructuring the conventional academic subjects of STEM (Science, Technology, Education and Mathematics) into an integrated curriculum (see Figure 4). Yakman (2008) has paraphrased this relational definition from the following quote on STEM education: "The study of Technology and Engineering is not possible without the study of the natural sciences. This in turn cannot be understood in depth without a fundamental understanding of Mathematics" (Dugger, 1993). STEAM is a relatively recent concept, where teaching and learning practices of STEM silos are purposefully combined with arts (Sanders, 2006; as cited by Yakman, 2008).

While historicising STEM epistemologies, Yakman (2008) argues that the first major epistemologist to make significant contributions to the STEM movement was Descartes (1596-1650) who saw all educational subjects as interrelated. Descartes (1947) insisted that the *process* of discovery was more important than merely accepting silos of disciplinary logic and methods.

Educational reformer Dewey (1974) can also be viewed as an antecedent to STEAM education, supporting an inter-disciplinary system of teaching. According to Yakman (2008), Dewey (1974) as a progressive educator discouraged separating content and context in learning. Instead, he (ibid) called for a progressive understanding of the complete (holistic) fact. Yakman (2008) maintains that Dewey's (1974) work aligns itself to the primary principle of constructionism (Papert, 1980; Ackermann, 2001) wherein, a complete understanding of content comes through integrated learning in specific contexts.

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23 Also read as ST∑@M (Yakman, 2008)

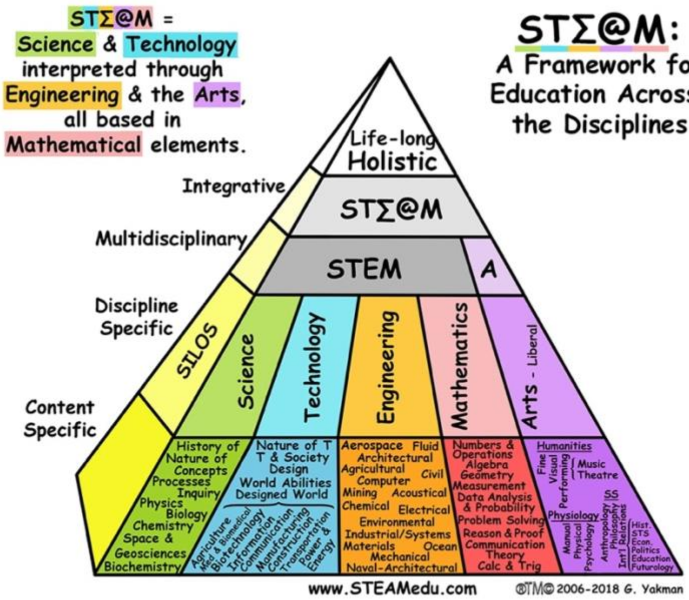

Figure 4: STEAM Pyramid (Yakman, 2018). Used with permission (https://steamedu.com/pyramidhistory/)

Similarly, tinkering and making as educational practices echo several historical pedagogues. We could trace tinkering through the learner-driven inquiries of Dewey (1987, 1929, 2007), Fröbel (1887/1902) and Papert (1980), as well as through the support-learning theories of Vygotsky (1967, 1978) and Lave and Wenger (1991).

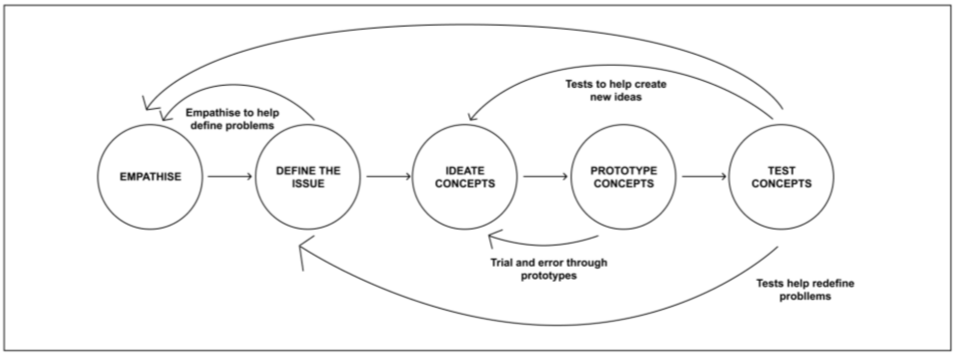

Figure 5: Illustrating the design thinking process model (INTERACTION-DESIGN.ORG)

Through the maker movement approach, children are encouraged to tinker with designed materials and activities in a play-based capacity. In this approach, problems and issues are not predefined but emerge while exploring materials and ideas (De Valk et al., 2015). Bevan et al. (2014) and De Valk et al. (2015) argue that activities designed for tinkering in STEAM environments also encourage employing scientific and technical tools and processes to test various core-building STEM concepts such as balance, light, force and motion, magnetism, resonance and so on. These concepts are experienced through core-skills of design thinking such as exploration, inquiry, testing, iteration, and problem-solving (see Figure 5).

1.8 Museums as twenty-first century CLEs

Andre et al. (2017) define museums as informal learning spaces that are visited by the general public. The authors (ibid) argue that museums are designed with rich artefacts and materials that afford exploration and discovery through visitor interactions. The authors (ibid) further argue that museums as designed environments are segregated into zones based on subjects such as science, history, archaeology, and the arts, which involve various live or simulated objects and programmes. These cultural spaces afford informal learning and are qualitatively different from schools. Interestingly, Mayfield (2005) identifies a pattern between the growth of children's museums during the 1920s and the prevailing influence of educational reformers Dewey and Montessori on learning through lived experience.

1.8.1 Children's museums as CLEs

Andre et al. (2017) argue that children's museums (as defined by the Association of Children's Museums (ACM, 2008)) are spaces where children (typically ages 10 years and younger) learn through play by exploring environments designed for them. The authors (ibid), referring to studies conducted on preschool children, argue that learning in informal spaces like children's museums exceeds factual acquisition of knowledge and alternatively navigates towards developmental areas like cause/effect learning. Farné (2005) describes children's museums as places where play is the raw material of knowledge, often pre-arranged based on thematic environments such as communication, water, electricity, mechanics, and so on, to offer children spaces to stimulate, build, and interact with the exhibits. Lester et al. (2014) argue that children's museums can be understood as spaces that afford play-based learning actualised through designed environments that provide spaces dedicated to structured play activities.

Mayfield (2005) argues that play-based learning in children's museum environments is implicated in various capacities. Examples of play programmes for children which are a part of a museum's larger mandate include the Natural History Museum in London, with its Explorer Backpacks activities (where children interact with pens, paper, activities, and a map arranged in the museum's galleries) (ibid). Other formats include interactive play exhibits designed as a part of regular museum displays (e.g. the National Museum of Scotland in Edinburgh), children's galleries, and interactive rooms within a traditional museum, which are designed to allow children to touch, play, examine, and interact with objects related to the museum's overarching theme (e.g. the Discovery Room at the Smithsonian Institution) (ibid). Apart from these examples, CLEs are also increasingly designed as self-contained play labs and maker spaces, which are a part of larger museums, such as the Tinkering Studio which is a part of the Exploratorium in San Francisco.

According to Wöhrer and Harrasser (2011), learning practices in children's museums encompass physical, emotional, and intellectual experiences. The authors (ibid) endorse play-based interactions with objects in diverse settings to help understand play practices within children's museums; here, children's knowledge acquisition is seen as being embedded in their handling of objects and involvement in tasks. Mayfield (2005) insists that children's museums should be designed as exploratory, non-threatening, and sensorial environments, which afford hands-on learning, interaction with real materials, and integrated participation.

Lester et al. (2014) argue that children visiting museums typically experience the space through accompanied guided visits with adults (family, acquaintances, teachers and so on). The authors (ibid) explain that museum visits are perceived as a broadly educational experience by adults, where the museum houses educationally inclined activities. Jordanova (2006) argues that children visit museums with a range of desires, experiences, and expectations that may not align to adult intentions and idealised images of children as eager and passive discoverers of fascinating objects.

Lester et al. (2014) suggest that designing encounters and interactions between objects, spaces, and people is intrinsic to designing CLEs such as museums, where children need to be perceived as more than passive observers and learners. Andre et al. (2017) argue that despite significant studies and advances which have taken place during the last few years of museum research, a few learning gaps have also been identified, such as the relevance of a visitor's motivation, experience, and social interaction within the context of the museum, which influences museum learning and meaning making.

1.8.2 Play-based learning in children's museums

Based on Sutton-Smith's (1997) research that connects learning to play while discussing the nature and value of play in children's museums, Lester et al. (2014) explain that the idiom of play in educational forms can be observed in museums, which have dedicated spaces designed to promote *play through discovery* (Mayfield, 2005). Lester and Russell (2008) argue that a limiting perspective of play and learning can lead to a lack of defining characteristics of play such as spontaneity, tenor of pleasure, unpredictability, and excitement. Lester et al. (2014) argue that the challenge lies in perceiving and valuing play and learning as mutually influential as well as distinctive processes.

Falk and Dierking (2000) argue that play-based learning activities organised by museums are fundamental to imagining spaces for motivation and inquiry-based learning in STEM and STEAM platforms. However, such playful museum spaces face specific challenges such as the lack of teachers, facilitators, and supporting frameworks to develop children's understanding of concepts.

Scaffolding[24], as defined by Vygotsky (1978), is the guidance provided by adults and peers while assisting children at tasks in learning spaces, to help them complete the task at hand. While designing play-based learning activities at CLEs such as museums, Andre et al. (2017) argue that scaffolding (Vygotsky, 1978) plays a critical role for amplifying children's learning during school or family visits to museums. Andre et al. (2017) argue that active and involved scaffolding by adults has positive effects on children's learning experiences in museum spaces. Andre et al. (ibid) argue that guided (either by parents or museum professionals) play activities are an effective method to help facilitate learning through scaffolding in children's museums, where these activities represent interaction between children, the environment, and adults/peers.

This focus on the critical role of adults as members of the learning environment had initially been overlooked by museum professionals (Andre et al., 2017). However, eventually the integration of adults in the learning process was identified as a catalyst to extend learning. This can be evidenced by the focus shifting from child-centred to family-centred experiences in museum learning. Jahreie et al. (2011) argue that it is critical to

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24 This has been further discussed in Chapter Two

examining the extent and degree of this guidance or scaffolding provided by an adult to aid knowledge comprehension in a child.

1.8.2.a Tinkering at CLEs

As a means of accessing information through inquiry-based learning, Tenenbaum et al. (2004) emphasise on the importance of hands-on interaction with media such as booklets, props, and materials in exhibits, as this can enrich their conversation and increase engagement with the exhibits. Melber (2003) endorses integrated hands-on learning and inquiry-based activities as being conducive to channelling attitudes, motivation, and comprehension of knowledge, as well as critically viewing and discussing the object's characteristics with peers, adults, and/or curators at the museum.

The Tinkering Studio at the Exploratorium (San Francisco) is one such play-based learning environment that has successfully designed activities that afford tinkering and iterative prototyping, to foster inquiry, design thinking, and inspire STEAM education in children. It is an immersive and creative space within the Exploratorium, where museum visitors, museum staff, visiting artists, and educators can conduct design experiments, engage in iterative prototyping, and tinker with materials designed for STEAM comprehension. Here, learning takes place in an open-ended and exploratory manner.

The design of the physical space and aesthetics of the Tinkering Studio is inspired from kindergarten classrooms, garages, repair shops, artist ateliers, and design studios. The studio has been furnished with various manipulatives, tools, and technology to support iterative prototyping. The Tinkering Studio regularly engages with young children and learners from across the country and organises STEAM play sessions to aid exploring concepts in art, science, and technology, while emphasising the documentation and propagation of design thinking and knowledge acquisition.

Tinkering activities at the studio have been designed by educators, designers, artists, and school teachers, where all of them collectively essay the role of *tinkerers* and facilitate play sessions, workshops, and installations in the studio space as well at the Exploratorium museum. The Tinkering Studio in collaboration with the LEGO Foundation is currently developing exploratory and iterative STEAM tinker toys by combining the design language of the classic LEGO brick with STEM concepts such as linkages, circuits, motion, balance, light, force, and motion to promote the premise of iterative and creative play-based learning.

Figure 6: The Tinkering Studio at the Exploratorium (Florin, 2016)

1.9 Chapter summary

This chapter introduced the relationality of play (children and adults as actors with a desire to play) and the performative nature of play (objects, toys, materials, and systems) within learning environments. This chapter has traced the development of play-based learning in both formal and informal educational learning environments. It has revealed various categories of play which embody designed materials and interactions when employed within play-learning environments, to support cognitive development, language skills, knowledge acquisition, and literacy in children. It has introduced affordances of play-based learning environments such as flexibility, safe risks, segregation into zones, and facilitation frameworks as drivers that can embody design thinking perspectives and creative pedagogical practices.

This chapter has outlined design thinking perspectives such as (1) construction of artefacts, (2) reflexive practices, (3) problem-solving activities, (4) a way of making sense of things, and (5) the creation of meaning (Johansson-Sköldberg et al., 2013) to help examine play-based learning environments. This chapter has also introduced how play-based learning has embodied design-thinking in twenty-first century STEM and STEAM disciplines at CLEs through tangible and intangible design affordances such as (1) tinkering, (2) constructing models and prototypes, (3) communicating through verbal, written, and symbolic discourses, and (4) conceptualising interactive environments that support creativity, flexibility, and open-ended play (Bevan et al., 2014; De Valk et al., 2015; Kelly and Cunningham, 2017; Andre et al. 2017).

The next chapter looks at the historical contributions of key pedagogues and re-reads them as key design thinkers, whose conceptualised objects, systems, and spaces have influenced, enriched, and developed prevalent practices of play-based learning.

Chapter Two:
Re-reading key pedagogues as design thinkers

Chapter Two aims to address ways in which design thinking and design have historically been central to both play and learning environments. This historical dimension is key to the thesis in two ways. Firstly, a historical tracing brings to light the development of play-based learning practices through time and the socio-economic framework within which play-based methods have emerged. Secondly, the tracing of design's influence in historical play-based learning theories allows for a diachronic view of design's centrality to the evolution of play-based pedagogy.

The separation of childhood from adulthood was introduced by pedagogues such as Fröbel (1887/1902, 1900; Fröbel et al., 1889; Fröbel and Heinemann, 1893), Dewey (1897, 1929, 1938, 1974, 2007; Dewey and Dewey, 2008), Montessori (1912/1964, 1914/1965, 1946/1963, 1967; Montessori and Claremont, 1969), and Vygotsky (1933/1969, 1962, 1967, 1978, 1997), who advocated for a form of play that supported children's learning and development (Platz and Arellano, 2011; Cutter-Mackenzie et al., 2014). This chapter re-reads Fröbel, Montessori, Vygotsky, and Dewey as design thinkers since these theorists in particular, have established a view on materiality, interaction, pragmatism, social play, and creativity that lends itself to the design of play-based learning environments.

Learning by doing as a crucial ingredient of play theories conceptualised by Fröbel, Dewey, Montessori, and Vygotsky, is perhaps the most critical attribute of play-based learning which is inseparable from design thinking and design practice. It is central to design thinking since it encompasses active interaction with artefacts, environments, and events in their tangible form to experience reality.

2.1 Design of Fröbel's kindergarten

Friedrich Fröbel (1782-1852) was an educator and pedagogue from Germany who designed the *kindergarten*[25], a play-based learning environment of early childhood education. The kindergarten embodies games, free play, songs, and activities to inspire

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25 The first kindergarten was opened in Blankenburg, 1837, in Germany.

imagination in children while simultaneously help develop their physical and motor skills and encouraging active interactions with nature. Fröbel also designed *Spielgaben*, which are known as being among the first tools designed for educational development in children (discussed in more detail later). Provenzo Jr. (2009) discusses that, as a pioneer of play-based learning, Fröbel believed that children expressed their innermost thoughts, needs, and desires through playful experiences. Fröbel established the kindergarten or the *garden of children* as a design model to facilitate play-based learning, creative exploration, and *self-activity* (original emphasis), an approach which encouraged children to be led by their interests (Brosterman, 1997).

Fröbel had undergone formal design education when he briefly studied architecture in Frankfurt in 1805. He developed his knowledge of nature while working at the Royal Museum of Berlin as a Mineralogist (Brosterman, 1997). Fröbel was also an avid crystallographer, having handled crystals while working as an assistant to Christian Samuel Weiss (1780-1856), a famous mineralogist, who created paradigms of modern crystallography and was responsible for designing it as a mathematical science (Brosterman, 1997). Fröbel's training as an architect, mineralogist, and crystallographer gave him a working knowledge of artistic perspective, symmetry, and materials, and influenced the design of his play objects. Fröbel introduced children to the principles of point and translational symmetry by designing lattice building devices in his pedagogic material menu, through which he hoped to instil an appreciation of *natural or organic harmonies* (Kahr, 2004). Fröbel's architectural and design background provided him with a distinct approach that sought to incept playful and iterative learning environments with the help of an abstract and creative material menu.

In addition to his knowledge on architecture and minerals, Fröbel was influenced by the work of Pestalozzi (1892, 1947, 1977). Pestalozzi's view on children as *active learners* appealed to Fröbel's aims to encourage curiosity and experimentation. Both Fröbel and Pestalozzi advocated for a socially inclusive approach to play theory, which advanced the benefits of play to those from oppressed and poor backgrounds by inviting them to come and study in their schools.

2.1.1 Affordances of Fröbel's *Spielgaben* (Gifts and Occupations)

Fröbel designed a series of twenty play artefacts and materials called *Spielgaben* to encourage inventive play in children through hands-on object interactions, introduction to physical and abstract patterns, and helping children unravel connections found in nature (Fröbel, 1887/1902; Provenzo Jr., 2009).

Fröbel's *Spielgaben* consist of *Gifts* and *Occupations*. Gifts are primarily designed to encourage children to construct abstract forms and engage in symbolic and open-ended play, to help them transition from the material to the abstract (Provenzo Jr., 2009). According to Fröbel, Gifts help children discover perceptive properties of objects such as number, shape, size, weight, and composition. Gifts are a part of Fröbel's wider language of play, which is further supported by songs, moving games, gardening, and art activities called Occupations (Fröbel, 1887/1902; Provenzo Jr., 2009).

Occupations are designed as complementary art activities with manipulatives such as clay, sand, beads, rope, thread, and wax pellets. These materials afford creative remodelling, manipulation, and are meant to motivate children to invent by giving them agency in the act of making. Fröbel argues that his design work supports a child's need to play, which, according to him, is also nature's way of supporting both brain development and social awareness (Fröbel, 1887/ 1902; Provenzo Jr., 2009).

Dougherty (2012) argues that Fröbel's Gifts are essentially what current designers would now categorise as one of the earliest examples of framing design through the maker movement. Here, Fröbel conceptualised design solutions after identifying problem areas through observations and investigations with materials and forms through trial and error, construction of hand-made prototypes, and testing these prototypes in-situ by letting children interact and engage with them.

2.1.1.a Gifts

The first six of Fröbel's Gifts focus on three-dimensional objects, and are designed to help children interact with three-dimensional solids and complete forms of the physical world. The First Gift (Fröbel, 1887/1902; Provenzo Jr., 2009) visualises Fröbel's interest in both materials and playful movement. It is designed as a set of six soft woollen balls with strings attached to each ball (see Figure 7). The first three balls are made using wool dyed in primary colours, whilst the second three balls are made from wool dyed in secondary colours. Provenzo Jr. (2009) argues that Fröbel employed the sphere (ball) as an idealised geometric form (since it is equally proportioned on all sides with a continuous and unending surface). Fröbel further explains that the First Gift is designed to afford tactile and visually dynamic play where it allows a player to grasp, swing, roll, drop, and hide the balls, thereby introducing a child to concepts such as size, weight, texture, directions, and object permanence[26].

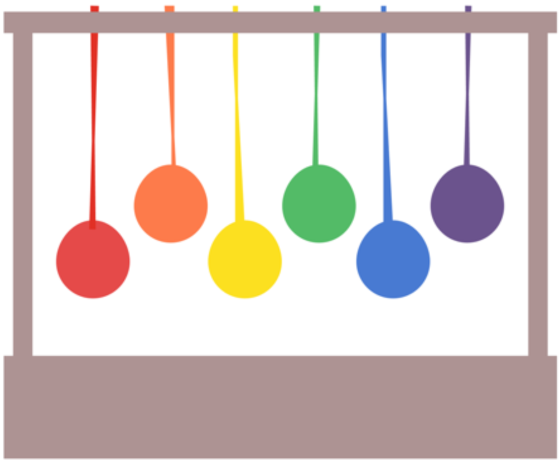

Figure 7: Illustration representing Fröbel's First Gift

The Second Gift (Fröbel, 1887/1902; Provenzo Jr., 2009) is an abstract contraption that consists of three wooden components; a sphere (approximately three inches in diameter), a cylinder, and a cube. According to Provenzo Jr. (2009), the Second Gift exhibits the principle that synthesis is an outcome of thesis and antithesis[27]. This argumentative principle has been explored by the German Romantic-era philosopher Hegel, according to whom seemingly paradoxical and opposed things can be synthesised through a rational approach to creating a new unified concept.

26 Here, Provenzo Jr. (2009) recommends accessing more information on object permanence by referring to Ann E. Boehm's theories in The Boehm Test of Basic Concepts (Manual - 1969, p.12).

27 Provenzo Jr. (2009) argues that when Fröbel was questioned whether his system was based on Hegel's dialectical theory, Fröbel responded that he had not investigated Hegel's work and clarified that the complete meaning of his created system rested upon this law alone. Provenzo Jr. (2009) argues that it might be reasonable to think that Fröbel was influenced by Hegel's theories, which were popular in German universities during Fröbel's era, without his realising its actual source.

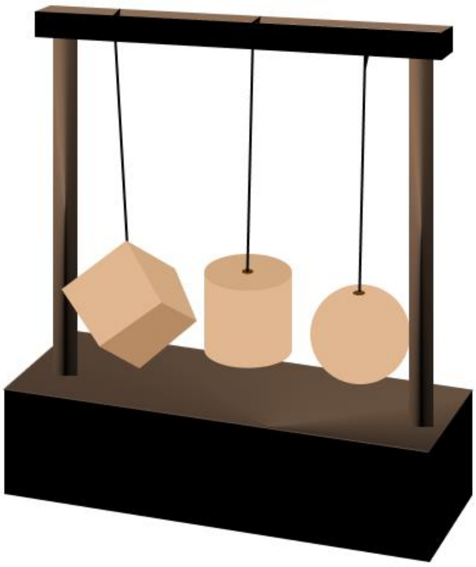

Figure 8: Illustration representing Fröbel's Second Gift

By combining two seemingly visually contradictory objects such as the sphere (with all round sides) and cube (with all rectilinear or square sides) in the Second Gift, the visual form of a cylinder appears, which comprises both flat and rounded sides (Provenzo Jr., 2009). This contraption went on to inspire the design of Bauhaus toys and construction blocks, which were assembled using a combination of different shapes and sizes to help children comprehend abstraction, and positive and negative space (ibid).

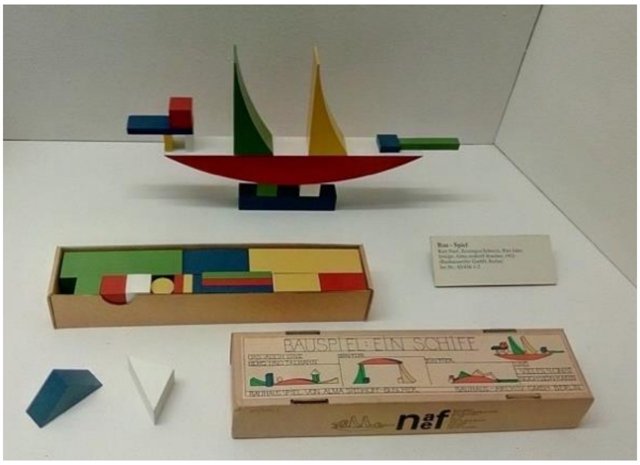

Figure 9: Bauhaus Toys at the Munich Technical Museum, 2016

The Third Gift is a two-inch cube, that can be deconstructed into eight smaller and equally sized cubes (ibid). The Fourth Gift is a deconstructed cube as well, which can be assembled from oblong blocks; here the oblong blocks are twice as long in comparison to their breadth, and twice as broad in comparison to their height. The Fifth and Sixth Gifts are designed as extensions to the Third and Fourth Gifts (ibid).

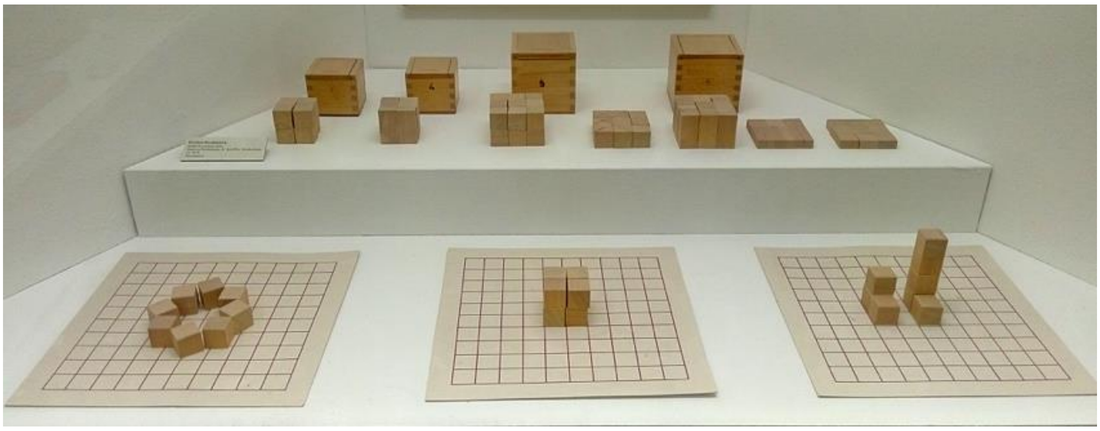

Figure 10: Fröbel’s Third and Fourth Gifts at the Munich Technical Museum, 2016

Figure 11: Diagrams of Fröbel’s Gifts at the Munich Technical Museum, 2016

Fröbel has designed his Fifth and Sixth Gifts as modular and exploratory construction blocks that afford the building and assembly of new structures (Fröbel, 1887/1902; Provenzo Jr., 2009). By manipulating these blocks, which are often placed on gridded tables (a feature typically observed in nineteenth-century kindergarten classrooms; see Figure 10), children can construct modular furniture pieces, complex patterns, or architectural models. With Gifts numbered Seven to Nine, children interact with two-dimensional shapes and symmetry of form (ibid). The Seventh Gift is designed to help children transition towards abstraction; it is based on the concept of parquetry[28]. It consists of brightly coloured wooden or cardboard pieces (such as squares, semi-circles, and triangles). Each piece is based on a one-inch module of the block system and the gridded table surface (ibid).

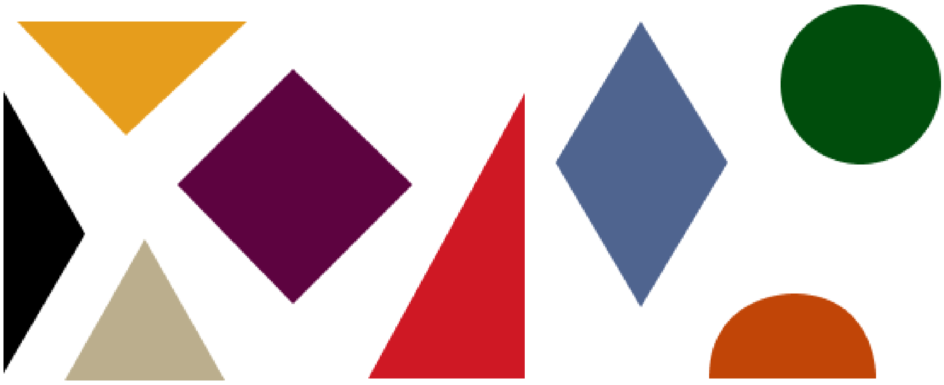

Figure 12: Illustration representing the shapes in Fröbel's Seventh Gift

The Eighth Gift consists of sticks which can be arranged to design patterns on a flat surface. The Ninth Gift encourages pattern making with circular pieces. The Tenth Gift is represented by three-dimensional objects made from solids and lines. The Eleventh Gift is designed to afford sketching on printed grids and the Twelfth Gift is designed to allow children to sew images of objects onto cards using gridded patterns. Provenzo Jr. (ibid) argues that these Gifts are designed to afford abstraction and help children perceive geometrical building blocks of the world, especially at an age when they are unable to understand these concepts intellectually.

A crucial Gift from Fröbel's material menu as identified by Provenzo Jr. (2009), is *Peas Work* (Nineteenth Gift), which is conceptualised as a tinker-toy made of peas or cork balls, and small wooden sticks. Peas Work is an interesting manipulative since it introduces children to basic engineering principles by taking visual elements of points (peas or cork balls) and lines (small wooden sticks) and extending them into volumetric forms (see Figure 13).

28 A geometric mosaic formed by pieces (often wooden) which can be arranged to design abstract patterns.

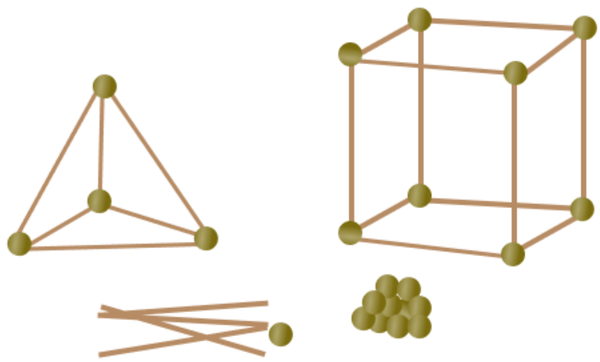

Figure 13: Illustration representing Fröbel’s Peas Work

In his emphasis on play as an expressive and iterative interaction with form, Fröbel has also designed three *Principles of Play*: *Forms of Life, Forms of Knowledge,* and *Forms of Beauty* (Fröbel, 1887/1902). As supervisors of these playful principles, adults are supposed to guide children’s interaction with each of the forms, by allowing them to explore the mathematical and scientific properties of the Gifts. These guided interactions could range from counting each side of a cube to discussing the visual properties of a specific kind of triangle. By designing his Gifts with a specific objective of aiding these interactions, Fröbel maintains that children build a foundation of symbolic learning through object play (Fröbel, 1887/1902; Provenzo Jr., 2009).

Fröbel’s Twentieth Gift is designed to afford experimental modelling with the help of clay or beeswax, which allows children to work with flexible materials and construct any shape from them. Though he never used the terms himself, the affordance of manipulating and tinkering with responsive forms is intrinsic to the philosophical framework that Fröbel developed and is both intuitive and aesthetic since it produces distinct playful interactions with space and objects.

Although Fröbel’s work has influenced both education and play theory, his contribution to both these areas has not been grasped in terms of the design principles of his pedagogic objects. Re-reading Fröbel as a design thinker allows us to see the implicit role of design in advocating modular form, aesthetics, materiality, block play, and sequential learning towards what is now the dominant structure of preschool education. Moreover, re-reading Fröbel as a design thinker allows us to grasp the ways in which play-based learning has developed through experiential design and design for empathy. Fröbel, the theorist of play, is well-documented (Brosterman and Togashi, 1997), but Fröbel, the designer of preschool education, is an unexplored history, and one that draws us more to the production of play spaces and objects. Fröbel's work was conceptually advanced for his time, where he engaged in extensive design thinking (Rowe, 1987) and research through design (Frayling, 1993; Godin and Zahedi, 2014) methods. Fröbel's work is useful to both educators and designers who have an interest in playful learning environments, as it demonstrates how one can take a model of education, and translate its abstract concepts into tangible, manipulatable, and engaging play materials and activities for children that afford acquisition of spatial knowledge.

In addition to the theoretical framework of Gifts and Occupations, Fröbel's work provides a historical way of understanding children's participation in practice-based design projects. We can reflect upon Fröbel's design work in multiple ways. He engaged in practice-based research methods by designing and employing specific tools (Gifts and Occupations) at play sites in order to gather data and observe how children interact with them. Analysing these observations helped him further develop his play theories and materials. These readings of his work relate to the research interests outlined in this thesis, where he primarily designed agents (materials, tools, systems) of play-based learning by adopting observation and practice-based design research methods.

2.1.2 Form and symbolism of modular toys, inspired by Fröbel

According to Turner (2011), Plato once advised future architects to play with construction kits like children, as it would help them learn about physics, engineering, and control. Turner (2011) suggests that in this way, construction sets are philosophical toys that play a crucial representative and experimental role in shaping the world.

In the book *Inventing Kindergarten*, Brosterman and Togashi (1997) discuss the pedagogical grounds for geometric abstraction through art and architecture. Brosterman and Togashi (1997) argue that Fröbel's twenty Gifts, which are designed to teach children an appreciation of abstract patterns, can also be considered as the building blocks of Modernism.

Provenzo Jr. (2009) reveals how Fröbel's Gifts influenced the work of Frank Lloyd Wright and Buckminster Fuller, two prominent American designers and architects. Buckminster Fuller argues that that he discovered the triangle (the fundamental unit of the geodesic-dome[29] system) as a structural and architectural concept by working with Fröbel's Nineteenth Gift (see Figure 13) in his kindergarten in Milton. Turner (2011) argues that in the early twentieth century, many avant-garde architects such as Josef Hoffmann, Bruno Taut, and Hermann Finsterli designed modular toys that narrate the history of modern architecture in miniature form. Turner (2011) further argues that the simple and modular forms of Fröbel's *Gifts* afforded the inception of a relationship between architecture and play.

2.2 The Montessori method

Dr. Maria Montessori (1870-1952), an educator and physician, designed the Montessori method (1912/1964), which is a play-based learning environment guided by the design of play artefacts and a framework of interactions to support learning. The Montessori method is based on the foundation that children learn most effectively when their environment aids their natural desire to acquire knowledge and skills.

Montessori determined, that in order to be comfortable and independent in their learning environment, children need furnishings and objects proportionate to their physical stature. Mooney (2013) argues that due to the lack of availability of such furnishings at that time, Montessori designed her own objects and furniture. Her work also focused on designing play environments that are both orderly and sensorial. The physical learning space is called the *prepared environment* (Mooney, 2013), and is designed to aid independent learning and interaction.

Montessori's background in medicine and engineering, which, as Lillard (2005) notes, were both rare studies for a young Italian woman during the nineteenth century, provided a unique vantage point from which to view the issues surrounding children with learning disabilities.

During this time, Lillard (2005) describes how children with physical and learning disabilities were poorly treated, often institutionalised, and left in empty rooms where their food was thrown at them. While working with these children, Montessori studied

29 Further information about the geodesic dome can be found at https://www.britannica.com/technology/geodesic-dome

how they snatched at food for sensorial stimulation rather than simply as a result of starvation (ibid). Consequently, Montessori designed a sensorial pedagogy that would benefit them.

She studied and adapted the methods of Jean-Marc Itard and his student Edward Seguin, who were exploring ways to provide sensorial stimulation to children with learning disabilities (Marshall, 2017). Based on their work, she designed what in the Montessori method are now known as *sensorial materials*. Marshall (2017) argues that when her designed sensorial materials helped students with learning disabilities fare well in state educational tests designed for *normal/typically developing* children, Montessori was able to demonstrate how the current education system was failing both disabled and non-disabled children in Italy. Egan's (2002) accounts of Montessori's time reveal that young people were more capable than the traditional curriculum deemed them to be, putting Montessori at loggerheads with the educational trends of her time, which sought to simplify the curriculum for young children. Systematic prototyping and redevelopment of her sensorial materials by trial and error eventually led to Montessori adapting her curriculum for non-disabled children by 1907.

2.2.1 Design thinking in Montessori's work

Montessori followed an in-depth, longitudinal ethnographic process of observing children in their specialised surroundings and documenting their detailed interactions with objects and spaces. This first-hand experience of interacting with children with learning disabilities led her to continually redesign and improve her sensorial materials.

Although the term research through design (RtD) is not more than thirty years old (Frayling, 1993), I argue that Montessori employed a similar approach in the 1900s. The argument that Montessori might be best described as an antecedent to the design thinking process (Brown and Kātz, 2009) is supported by historical evidence of her documented work. Montessori designed sensorial materials through extensive experimentation, alteration, and observation of her objects (Marshall, 2017), which led her to develop a system of education that relied on an iterative design process tailored to the needs and pedagogic requirements of young children. Her observations captured the interactive relationship between children, her designed materials, and learning environments. According to Lillard (2005, 2008), she frequently tested her sensorial materials across ages in-situ and observed that some sensorial materials appealed to children younger than those for whom they were designed.

Within the current practice of facilitating and guiding children in Montessori learning spaces, trained Montessorians are supposed to observe and document how each child works within a specific peer group. Montessori learning spaces are typically segregated based on ages one to three-year olds, three to six-year olds, six to nine-year olds, and so on, where every child's work and interests in specific subjects or skill sets is documented by the facilitators.

Lillard (2008) reflects on Montessori's global legacy, which in its field-tested curricula (mathematics, music, art, grammar, science, and history) for children between the ages of three and twelve, migrated to places like Spain, Rome, India, the Netherlands, and the United States. Montessori's theories went on to influence early childhood programmes globally and her work set new foundations, which later influenced pedagogues like Jean Piaget and Lev Vygotsky.

2.2.2 Design language of the Montessori method

The Montessori method focuses on multi-sensorial learning through the design of child-appropriate spaces, which provide a rich repository of objects and activities designed for sensorial stimulation. Montessori's sensorial materials, in turn, are meant to guide children to organise their intelligence and learn to adapt to their surrounding environment. The visual form, measurements, and materials used in the design of these sensorial artefacts are meticulously selected to make the intended *sense* or *affordance* explicit. Montessori's attention to design and the proportionality of her objects is allied to a teaching approach that foregrounds respect for children and their abilities to refine their competence in tailor-made spaces.

Montessori's views on beauty, order, and aesthetics inform the design of her classrooms by focusing on multi-sensorial factors (smell of a classroom, colour schemes, documentation of children's artworks, brighter and more cheerful lighting). Montessori maintains that children must internalise care and responsibility for themselves and their surrounding environments, which informs her methods of learning through repetition, and constant cautious interaction with her designed sensorial materials and activities.

2.2.3 Colour, form, and material selection

Most Montessorian sensorial materials are modular in form and designed using bright and solid colours as well as texturally pleasant natural materials such as wood, wool, and yarn to add to their appeal and playfulness. This was a conscious design decision taken by Montessori since she observed that bright colours and light, yellow-tinted wood attracted children and made the play space seem brighter and cheerful. The visual aesthetics of these sensorial materials communicate the object's affordance (Gibson, 1977), without irrelevant adornment to distract the child (Zuckerman, 2010). Lillard (2005) argues that each sensorial material is designed to fulfil a primary purpose as detailed within the curriculum and there are prescriptive ways of using the materials, which children are introduced to during the lessons (known as presentation time in the curriculum).

For example, the Montessori material menu consists of four sets of a sensorial material called the Wooden Knobbed Cylinders. The first set is designed with the cylinders varying in width while their height is consistent. The second set is designed with cylinders varying only in height, the third set with cylinders varying in both height and width, and the fourth set with cylinders that decrease in width and progressively increase in height. Montessori designed specific activities to interact with these Wooden Knobbed Cylinders to train children in skills of observation, comparison, reasoning, and decision-making.

Activities for the Wooden Knobbed Cylinders are designed to assign each cylinder to its *intended* set. Interaction with these Wooden Knobbed Cylinders focuses on measurement and spatial comprehension and is supposed to prepare children for mathematics while strengthening their observation and concentration skills. *Knobs*[30] as a tactile feature on the surface of the cylinders have been designed to help children strengthen the muscles of their index finger and thumb by employing a *pincer grip* (Lillard, 2005). A pincer grip refers to the thumb and index finger coming together to form a grip, typically required to hold a pencil. Interaction with the wooden knobs helps children develop hand coordination and gestures that are essential to holding a pencil correctly. Most of Montessori's sensorial materials incorporate knobs within their physical form to help develop the pincer grip.

30 Resemble a circular (usually spherical or oval in form) wooden doorknob.

Figure 14: Wooden Knobbed Cylinders and Insets at the Montessori Congress in Berlin, 2016.

2.2.4 Ateliers and Montessori's design of space

The term *atelier* is defined as an artist's or designer's studio or workroom in the dictionary (Miriam-Webster, n.d.). The idea of the atelier was incepted by Loris Malaguzzi, who founded the Reggio Emilia approach to revolutionise teaching and learning for children in early childhood programmes (Gandini et al., 2005). The atelier eventually became central to Malaguzzi's (1994, 1998) preschool curriculum. The atelier was established in 1963 as a complex space designed for interaction between the hands and the mind, to develop an eye for refinement through visual arts (Gandini et al., 2005).

> *"We would have gone further still by creating a school made entirely of laboratories similar to the atelier. We would have constructed a new type of school made of spaces where the hands of children could be active for messing about. With no possibility of boredom, hands and minds would engage each other with great liberating merriment in a way ordained by biology and evolution" (Malaguzzi, 1998, p. 73-74).*

Ateliers are designed as exploratory workshop spaces to allow interaction with materials in an informal setting (Wendell, 2014). The Reggio Emilia approach emphasises the importance of exploration through art in a social setting. By socially exploring art materials, children gain fluency in expressing their thoughts and ideas by producing artistic works (Wendell, 2014). The atelier therefore affords the development of a non-verbal language using multiple forms of media along with music and performing arts (ibid).

Wendell (2014) defines an *atelierista* as a designer, organiser, interpreter, facilitator, and collaborator, often with a formal art background, who facilitates interaction between children, teachers, parents, and the community. An atelierista provides materials and guidance to children to produce artistic works or expressions, which help familiarise teachers with their interests, motivations, values, and their understanding of the world (Wendell, 2014). Similar to ateliers in Reggio Emilia classrooms, which are essentially workspaces arranged to allow independent interaction with materials, the learning spaces and prepared environments in Montessori schools are designed to instigate certain behaviours in children. Unlike Reggio ateliers where children are encouraged to interact with materials socially and produce artistic expressions and works, in Montessori schools, workspaces or ateliers are designed to instil independent movement, material selection, and interaction.

Figure 15: Low-lying Montessori shelves at the Montessori Congress in Berlin, 2016

The Montessori learning space is segregated into areas divided by low-lying shelves to store sensorial materials, where the space is designed to afford freedom and convenience for the children accessing them (Montessori, 1912/1964). Play artefacts on low-lying shelves are placed in specific zones to pique children's interest and to teach concepts via repeated use. Montessori also observed that children had an elemental sense of order and they tend to return an object to where it belongs. The Montessori method has embodied this observation as it encourages children to arrange materials on open shelves instead of locked cupboards. Low-lying and open shelves promote freedom of choice for the child; here, they can choose and easily access materials they wish to interact with.

2.2.5 Design for language acquisition in the Montessori method

Lillard (2005) argues that in the Montessori method, children are introduced to a language through a defined progression of lessons, which start with the spoken language. Children are usually somewhat familiar with a spoken language, as they are introduced to it at home or based on their cultural background. Based on this assumption, the Montessori environment is designed to further their understanding by introducing children to phonemics, which consists of learning sounds within words and relating them to alphabetical symbols in that language (Montessori, 1912/1964). Children are taught to put their recently acquired knowledge of alphabets and phonemics to use by being introduced to writing skills. This step then progresses to the next level when children are introduced to reading, where they learn to decode those written sounds to decipher words.

As argued by Gibson and Ingold (1993), language development can be observed by training vocal, written, and gestural domains. Montessori's language materials are designed to afford this process by helping children develop their communication skills and broaden their thought process in a guided play-tutoring format. Considerable accountability of directing a child's language development in a Montessori environment also rests with the facilitators, as they are meant to support children by building their self-confidence and providing them with meaningful activities to aid their language development.

The following visualisation (see Figure 16) illustrates this step-by-step process of language acquisition as prescribed by the Montessori method along with the designed sensorial materials and activities that support the process.

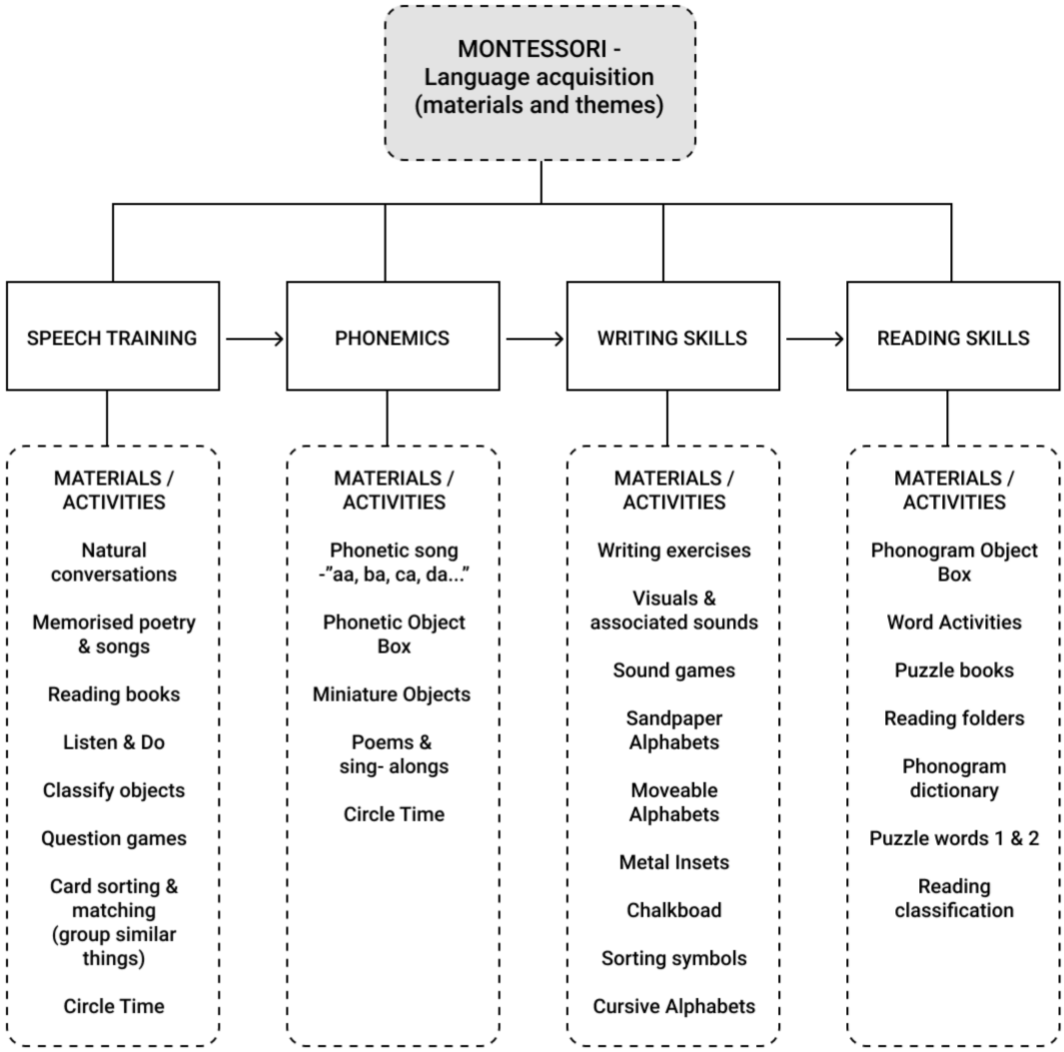

Figure 16: Language acquisition in the Montessori method

2.2.6 Design of the geometry material menu

Sensorial materials for geometry in the Montessori curriculum are designed to train a child's visual sense. These are introduced to children initially between the ages of three and six years. Sensorial materials such as the Geometric Cabinet, Geometric Solids, and Constructive Triangles are a part of Montessori's geometry material menu. The geometry material menu is designed to afford exploration of shapes and their relationships to each other, as well as geometrical concepts of point, lines, planes, and solids. Children are also introduced to concepts such as angles, relationships between angles, intersections, plane figures, construction of shapes, and so on.

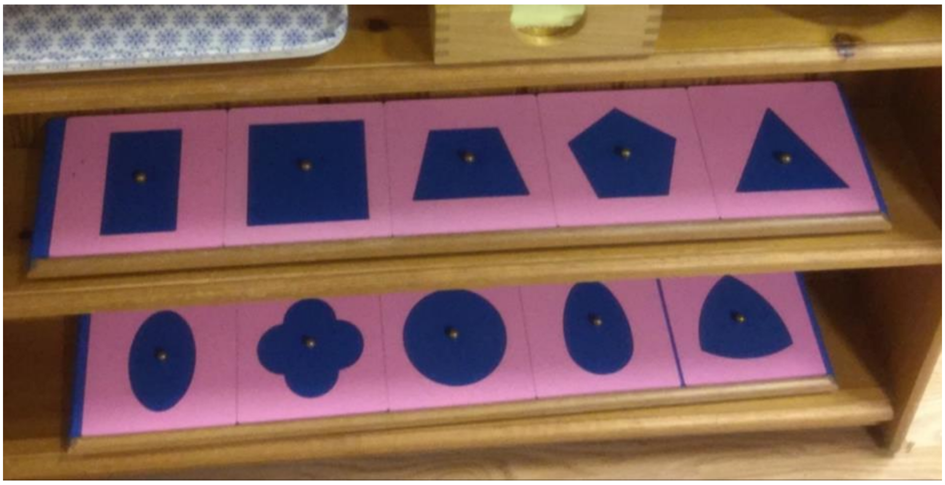

Figure 17: Geometric Cabinet Insets.

The Geometric Cabinet is a wooden cabinet which consists of six drawers, each of which house two-dimensional geometrical shapes. Each drawer in the Geometric Cabinet accommodates Geometric Metal Shape Insets such as circles, squares, and triangles. Montessori preferred to maintain consistency with the colour allotment for all her designed materials. In the Geometric Cabinet, the shape insets as well as the bottom section of the drawers are painted in the same shade of blue. These shapes are systematically arranged in each drawer (usually made of wooden frames) to show the sequential metamorphosis from one geometric form to another (for example, from a square to a circle). The design and arrangement of these shape insets in the drawers affords visual progression of form, as their measurements and angles change systematically to show the evolution of their contours and transformation of the geometrical shape. The Geometric Cabinet is designed to aid discrimination of geometric form and orient children to the world of shapes, along with preparing for future writing skills. These insets afford easy tactile interaction due to the presence of a knob on every inset's surface to help develop a child's pincer grip, eventually supporting the development of hand muscles to aid writing.

Table 3: Montessori's Geometric Cabinet – design blueprint

First drawer	This drawer consists of six circles, increasing in ascending order of diameter (5 cm to 10 cm).
Second drawer	This drawer consists of one square and five rectangles. The bases of these quadrangles transition from 10 cm to 5 cm, while the height remains the same.

Third drawer	This drawer consists of six triangles: equilateral, acute-angled isosceles, right-angled isosceles, obtuse-angled isosceles, right-angled scalene, and obtuse-angled scalene.
Fourth drawer	This drawer consists of six regular polygons that are in the sequence of ascending numbers of sides: a pentagon, a hexagon, a heptagon, an octagon, a nonagon, and a decagon.
Fifth drawer	This drawer consists of four quadrilaterals and one acute-angled scalene triangle. The four quadrilaterals are rhombus, parallelogram, a right-angled trapezoid, and an isosceles trapezoid.
Sixth drawer	This drawer consists of curved figures such as the curvilinear triangle, ellipse, oval, and quatrefoil.

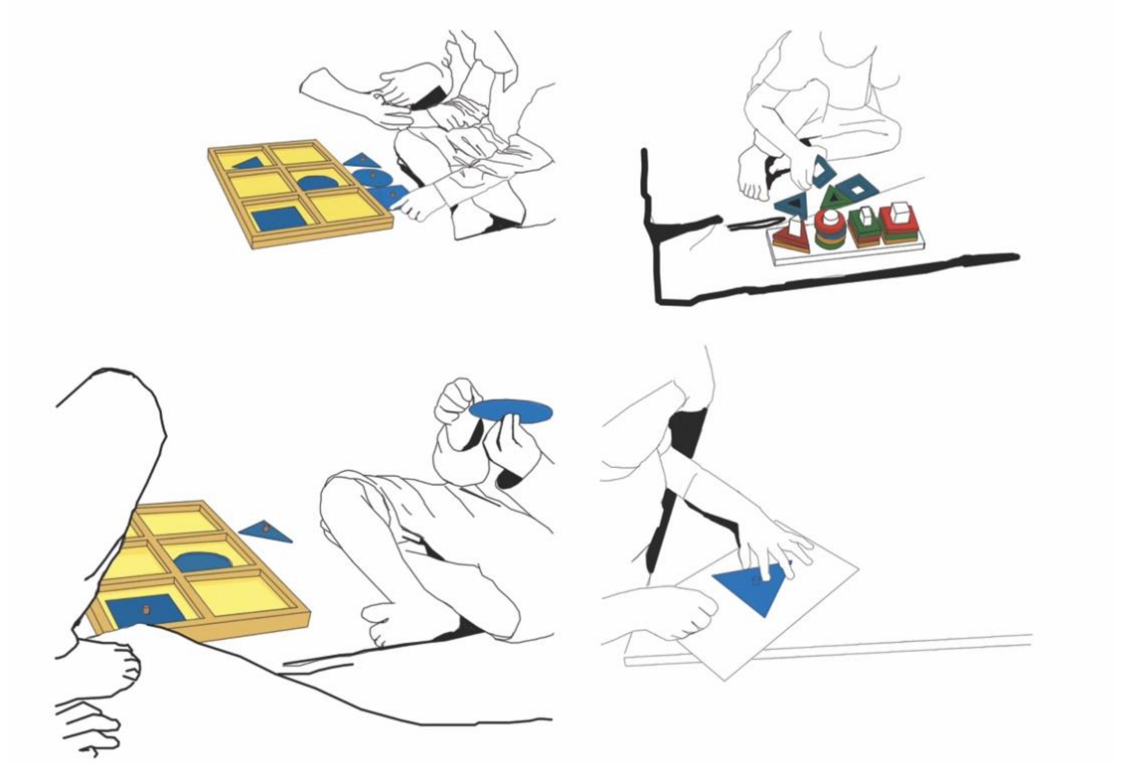

Figure 18: Captured interactions with Montessori's Geometric Metal Insets and shape materials

According to the Montessori method, children should be introduced to each shape inset systematically by progressing from one drawer to the next. As per the method, initially, children are introduced to all the shapes in the Geometric Cabinet. They begin by selecting a shape inset from a drawer, tracing the shape's form onto paper, and colouring inside the outline. Tracing shapes allows children to comprehend the differences in the physical form of each shape. They also trace the negative templates of each shape inset from specific drawers in the cabinet to familiarise themselves with the positive and negative spaces of each shape. Children are then encouraged to interact with two drawers at the same time, by placing all the shapes directly onto a mat and then tracing them. Next, they continue working with more drawers progressively, eventually increasing the number to six drawers during the activity.

The Geometric Cabinet also has accompanying visual cards in sets of three, with the outline of each shape printed on each card to match every shape found in the Geometric Cabinet. Activities designed to familiarise children with geometric shapes consist of matching shape cards to specific shape insets from specific drawers.

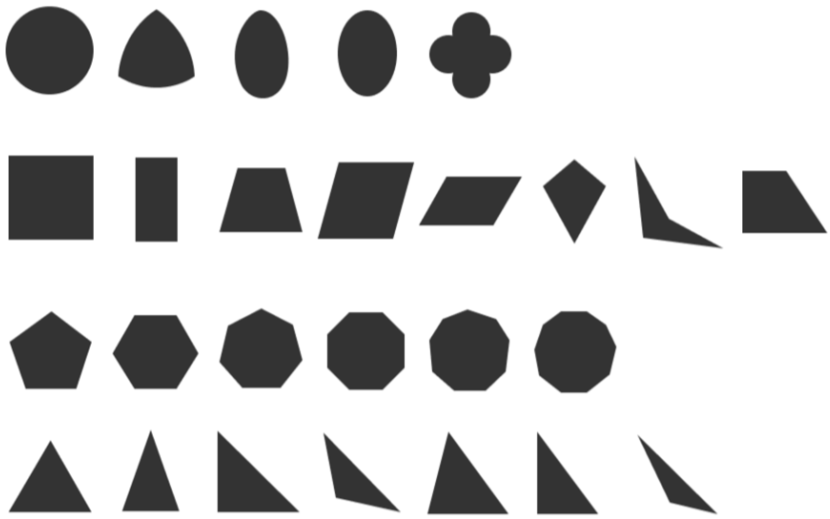

Figure 19: An illustration of all the shapes in Montessori's Geometric Cabinet

Many current Montessori schools encourage the use of pencils. Lillard (2005) argues that pencils are preferred as writing tools in most Montessori schools since they afford more tangible haptic feedback. According to Montessori, the intensity with which a child presses a pencil onto paper has visible consequences; a pencil tip will snap and break if pressed too hard and will not make a mark if not pressed with optimum pressure. Additionally, pencils allow shading and a key exercise with the Geometric Metal Shape Insets is to shade inside a traced shape, starting from the darkest shade to the lightest shade (ibid).

These shape insets in the Geometric Cabinet are constructed out of metal. Lillard (2005) notes that metal is an unusual choice for sensorial materials since it is cold to touch, unlike wood and other natural and haptically inviting materials that are more visible in other Montessori sensorial materials. However, metal's durability is advantageous in this activity as it does not get damaged or scratched through the use of pencils, while tracing.

Consequently, Geometric Metal Shape Insets are the first objects to which children are introduced while using real pencils (ibid).

Lillard (2005) explains that, in the Montessori curriculum, when children use the Geometric Metal Shape Insets, they are simultaneously learning to trace Cursive Sandpaper Letters with their fingers, by repeating the same path of motion, which they are introduced to while learning to write. The pedagogic argument that underwrites Montessori's distinctly designed sequence to develop writing skills is that, while children are introduced to tracing letters, they are simultaneously introduced to pronunciations of the phonetic sound associated with each alphabet. Eventually, activities designed to interact with the Geometric Metal Shape Insets and Sandpaper Letters integrate, where children (1) hold a pencil to paper while mimicking the same hand motions used to trace Sandpaper Letters, (2) read each alphabet out loud, and eventually (3) arrange these alphabets (Sandpaper Letters) together to construct words. Lillard's (2005) detailed descriptions of the Montessori method suggest that a Montessori school appears to be similar to an abstract and independent research laboratory, where children pursue their projects. The Montessori method encourages children to choose what they want to learn and select materials to aid their preferences (ibid), which leads to the child being perceived as what I refer to as a *motivated sensory doer*.

2.2.7 Sensorial exploration in the Montessori Method

Sensorial exploration in a Montessori school is based on interacting with objects designed for specific senses in a specific manner. As discussed previously, the addition of knobs in some of the sensorial materials to help children learn and align their hand movements towards the act of *picking up* an object are designed to make their affordance of *gripping the object by holding the knob* quite explicit. Sensorial materials such as the Button Frames make the affordance of attaching and detaching two cloth strips explicit, when the child interacts with the buttons stitched onto two separate cloth strips. Here, Montessori's sensorial materials are the ones with knobs on them and Button Frames, and the actions (affordances) are the ability to pick up, hold, and rotate the sensorial material while *gripping* the knobs, and the ability to attach or separate two pieces of cloth by *interacting* with the buttons on the frames (refer to Figure 20).

Figure 20: Montessori's Button Frames at the Montessori Congress in Berlin, 2016

The following table identifies some key affordances designed by Montessori in her sensorial materials, where each material aims at developing and training a specific sense in children.

Table 4: Affordances designed by Montessori in her sensorial materials

Senses identified by Montessori	**Designed affordances based on these senses**	**Examples of sensorial materials**
Visual	In materials designed to train the visual sense, a child learns how to visually discriminate and identify similarities or differences between objects.	Wooden Knobbed Cylinders, Pink Tower and Brown Staircase, Red and Blue Rods, Colour Tablets. Geometric Cabinet, Decanomial Cubes, Wooden Knobless Cylinders.
Tactile	These are materials designed to train the child's sense of touch (tactile sense). Montessori designed objects such as touch tablets and multi-textured fabric boxes to develop tactile sense in a child by sensitising their fingertips.	In the textured fabrics set specifically, Montessori designed three boxes which hold different qualities of fabrics. The first box contains pairs of natural fabrics (for example, silk, jute, and flax), the second box contains pairs of coarse fabrics (for example, corduroy and denim), and the third box contains pairs of fine fabrics (for example chiffon and satin).

Thermic	In materials designed to train the thermic sense, the child interacts with objects designed to cultivate a sense of temperature.	Montessori designed the Thermic Bottles and Thermic Tablets to train this sense. The Thermic Bottles are a set of bottles which can hold heated and cooled water at different temperatures. Thermic tablets consist of a box with six materials, which have different heat conducting properties. These materials are usually wood, felt, cork, marble, and iron.
Auditory	In materials designed to train the auditory sense, a child can discriminate between different sounds. Through designed activities to help differentiate between sounds, a child refines his or her sense of hearing.	Montessori designed the Montessori Bells and Sound boxes to train auditory sense.
Olfactory	In materials designed to train the olfactory sense, the child is taught to differentiate between different smells. Materials designed to work on the olfactory sense are meant to help the child distinguish between specific smells; potentially identifying pleasant smells from unpleasant smells and using them to make sense of their environment	Smelling Jars were designed to help develop this sense.
Gustatory	In materials designed to prepare the gustatory sense, a child is introduced to the sense of taste. It helps the child to distinguish between different tastes and flavours.	Tasting Bottles were designed to help develop this sense.
Stereognostic	This is an affordance where children learn to feel and recognise objects. Objects designed to stimulate the stereognostic/haptic sense utilise the body's muscular memory to remember impressions of those objects.	Sorting Trays, Sandpaper Alphabets Tiles, other textured sensorial materials.
Baric	Some materials are designed by Montessori to help a child feel the difference between weights and	Baric Tablets

	pressure of different objects by haptically interacting with them.	

Montessori's views on learning are not protectionist and so the materials she designed for play are not governed by the imperative to be *safe*. According to Montessori, children must have access to real tools. For example, blunt scissors make the task of cutting paper cumbersome and more difficult, and at times, more dangerous than using real and sharp scissors. According to Montessori, tools which do not work properly undermine the competence of the child. The Montessori method advocates competence and responsibility through design (in this situation, the opportunity to use real tools). Accessibility to sensorial materials is key to the design of her environments where children are able to find artefacts and based on their requirements, later put them away without help or any dependence on adults. This responsibility, Montessori argues, gives children more control over their environment, which in turn, instils responsibility and accountability in them.

Kennedy and Barblett (2010) echo Montessori's beliefs on *safe risks* in learning environments. As discussed previously in this chapter, the authors (ibid) have argued that providing challenging equipment and activities to help children extend their physical skills, while simultaneously being close by to monitor them and offer support, can encourage children to take safe risks.

2.3 Design principles of Montessori and Fröbel

Within the historical framework of playful learning, Fröbel and Montessori's research and theoretical contributions are limited to pedagogy. By re-reading their work as designers, we can recognise their contribution to the design of play-based learning environments and materials as visible in the twenty-first century. Both of them have contributed to the evolution of a play-based pedagogy by designing play systems, play spaces, and play objects (Zuckerman, 2010; Brosterman and Togashi, 1997). While Fröbel and Montessori's research share some similarities in their work, there are also distinct differences[31] in their design approaches.

31 These have been further discussed in Chapter Nine.

2.3.1 Colour coding materials

Montessori and Fröbel's designed materials are colour-coded for specific purposes. Specific colours assigned to specific Montessori materials add a layer of identification and differentiation between affordances of those objects, where each colour is selected to represent a concept, affordance, or quality. To illustrate, Montessori's Knobless Cylinders are colour-coded in four colours, where properties of each set are identified based on their specific colour. In the set of Yellow Knobless Cylinders, height and diameter of the cylinders decrease systematically. In the blue set, the height of the cylinders decreases as the diameter remains constant. In the green set, the diameter decreases as the height increases and, in the red set, the diameter decreases as the height remains constant. Within her mathematical material menu, for example, Montessori's Beaded Strings have specific colours which represent specific numbers (for example, her purple/lavender beads represent the number *six*). Similarly, in Fröbel's First Gift called Coloured Yarn Balls, the six yarn balls are segregated based on three primary (red, yellow, and blue) and three secondary colours (orange, green, and purple). These yarn balls are color-coded to introduce different colours, which eventually help familiarise a child with the rainbow colour palette.

2.3.2 Modular design and aesthetics

Both Fröbel and Montessori used bright and solid colours and materials that provoke a desire to touch, such as pinewood, soft wool, and yarn. Fröbel's Gifts and Occupations are modular in form to encourage interaction, exploration, and problem-solving. Fröbel's play materials are designed to afford being physically explored in an open-ended and experimental manner, which helps children ideate and try different configurations while allowing for innovative forms. Fröbel's designed artefacts encourage children to explore two-dimensional and three-dimensional constructions and eventually support the learning of concepts surrounding arithmetic, geometry, and counting.

In comparison, the Montessori method focuses on *self-correcting* (original emphasis) and specific interactions with her sensorial materials. These are designed for step-by-step engagement with her sensorial materials, to augment the learning efficiency of a particular concept. Combining arbitrary material sets or open-ended explorations is discouraged in the Montessori method. Her sensorial materials are designed to focus on singular and specific affordances. Her materials are not designed to imitate real-life structures or natural forms, but instead have a prearranged outcome. Similar to a puzzle, the Montessori method endorses the design of play activities and interactions that can only be undertaken in a step-by-step manner to reach a predetermined conclusion (Zuckerman, 2010).

2.4 Vygotsky, play, and design thinking

Lev Vygotsky (1896-1934), a renowned educational psychologist and pedagogue, was interested in the relationships and social interactions between children and their peers (Berk and Churchill, 1996; Berk, 2009). Vygotsky saw children as *active learners,* where their learning skills developed along with their ability to interact with others. He believed that the environment is the starting point of learning (Hall, 2007), and that it should be designed and equipped to support a child-centred perspective.

2.4.1 Imaginative play and the affordances of objects

Scharer (2017) argues that Vygotsky's cultural-historical theories position play as an integral part of Early Childhood Education (ECE), since they endorse social, cognitive, and emotional development in children. One of Vygotsky's (1978) central arguments is that through play, children become more competent in their language use and begin to regulate their thought processes.

According to Vygotsky (1967, 1978), all play creates imaginary situations and all imaginary situations also contain certain rules. Imaginative play as a premise affords decontextualization of meaning, during which a child can learn to imagine an object or a situation, even when it is not present or evident (Smidt, 2009, as cited by Scharer, 2017). Bodrova and Leong (2007) argue that Vygotsky's (1978) understanding of imaginative play focuses on play activities that (1) design an imaginary situation, (2) endorse the enactment of roles, and (3) follow specific rules imposed by these specific roles.

Scharer (2017) argues that imaginary or pretend play is designed through a composition of roles and rules, wherein roles are the characters children play, and rules are the set of behaviours proposed by either the role or play scenario. It is this relationship between the two that changes with different kinds of play (Connery et al., 2018). As an example, a large cardboard box as a play object can be transformed into whatever a child's imagination might want to experience. As an object designed to afford physical manipulation through its form, structure, material, and easy availability, a cardboard box is an ideal canvas to instigate imaginative play. Imaginative play in this situation can be introduced through redesigning the box as a tent or a castle, where a child crawls under it, or *doodles* towers, windows, and doors over it to resemble a castle. The box, therefore, becomes a canvas as well as an initiator of imaginative play and helps the child gradually understand the difference between what is real and what is imagined. By engaging with the cardboard box through imaginative play, the child begins to explore the object's physical properties and learns to symbolically represent them by designing narratives and rules of interaction. Here, the use of symbols is first supported by props (the cardboard box) and is eventually communicated to play partners through words and gestures (Scharer, 2017).

Re-reading Vygotsky as a design thinker reveals that imaginative play can be a suitable pivot to instigate language and cognitive development in children by introducing them to objects, play spaces, or activities designed to support imagination, symbolic representation, and self-regulation. This development occurs when children begin to conceptualise narratives, actions, rules, and voluntary intentions, and act out synopsis, while interacting with objects during play. Here, the Vygotsky's (1967, 1978) approach is compatible with Nicholson's (1972/2009) endorsement of designing adaptable learning environments. Additionally, Vygotsky and Nicholson criticise the design of overtly structured learning environments that dissuade imaginative play, and negatively affect the development of language and reasoning skills in children.

2.4.2 Vygotsky, ZPD, and mediator tools

Vygotsky's knowledge of social mediation and zone of proximal development (ZPD) is significant to understanding the intersubjectivity of play, creative processes, and shared meaning-making (Connery, et al., 2018). ZPD as conceptualised by Vygotsky (1967, 1978), is the distance or difference between a task the learner can perform without help and what the learner can achieve with guidance and encouragement from a more knowledgeable partner, adult, or peer, where *proximal* refers to the skill that the learner is close to acquiring. Vygotsky argues that in order to deliver the right amount of support, a learning environment must be designed to accommodate activities and expert individuals who can guide the learner and help him/her move to the next stage of development. His theories on ZPD draw upon the design of dimensional and spatial conditions in learning environments along with the design of supporting activities and materials (Hall, 2007; Taber, 2018) to further acquisition of new concepts.

Vygotsky (1978) categorises ZPD into four stages. Stage one is the assistance provided by More Knowledgeable Others (MKO) or capable peers, during which there is a continuous decline in the teacher's responsibility towards task performance and a complementary increase in the learner's responsibility, termed as the *Handover Principle* (Bruner, 1983). The teacher's task here is to provide accurate assistance to the learner by responding to the learner's endeavour and understanding the task goal. Dunphy and Dunphy (2003) suggest that activities designed for stage one can be completed when the responsibility for adapting the assistance, tailoring the transition, and completing the task, has been handed over to the learner by a MKO, with the help of mediator tools (Hall, 2007).

According to Vygotsky (1978), experts or MKOs engage with learners and employ mediator tools to facilitate learning during ZPD. Vygotsky refers to these mediator tools as "psychological" (1978, p. 53) as they are used to express thinking through the use of language, signs, symbols, texts, and mnemonic techniques. Vygotsky identifies *language* as the most significant psychological tool since it is vital to the development of a learner's cognitive functions (Hall, 2007).

Stage two is the help provided by the self. Vygotsky (1978) states that, during stage two, the learner works on a task without assistance. Here, control or assistance for the task is transferred from the expert (the teacher) to the apprentice (the learner). Tasks which were initially guided by others are now self-guided and directed by the learner (ibid). This is a transitory stage, where internalisation of mediator tools such as signs, texts, and mnemonic techniques occurs in the mind of the learner (Hall, 2007).

Stage three consists of automatisation through practice. Vygotsky (1978) discusses how at this stage, the activity is executed seamlessly, and the use of mediator tools (Hall, 2007) has been internalised by the learner. At this stage, assistance from the expert is no longer necessary, since it could be irritating and disruptive to task integration. Vygotsky (ibid) clarifies that, at this stage, the learner has developed new knowledge and can apply the recently acquired mediator tools in another activity. Stage four is re-automatisation; looping through the previous three stages (ibid).

Hall (2007) argues that psychological or mediator tools are employed throughout the learning stages of ZPD. First, experts use these tools to guide learners and mediate learning externally. This is followed by internalisation, during which learners begin to use these tools in other activities. This is where these mediator tools can help modify and transform the learner's thought processes (ibid).

Vygotsky considers the type of mediator tools, the teacher's expertise, and the context of the activity in which the tools and learners can interact with each other to design an *authentic* learning environment (Hall, 2007). By authentic, Vygotsky (1967) refers to the natural use of mediator tools such as languages, concepts, and symbols. Here, the activities designed for learning can be simple or complex based on the learner's competence and must employ authentic use of mediator tools. Vygotsky's perspectives on mediator tools help us comprehend the ways in which experts interact with learners. They begin by initially selecting specific tools and demonstrating how to use them, which eventually develops the learner's thinking.

Re-reading Vygotsky as a design thinker reveals how these transitory learning stages can be designed into the learning environment in order to develop agency and independent interactions for the learner to support internalisation of knowledge. Vygotsky as a design thinker further reveals the ways in which *ZPD*, as a design system, helps conceptualise authentic learning environments. Here, artefacts, activities, and environments are designed to provide specific levels of assistance by incorporating mediation, experienced others, and authentic use of mediator tools such as language, symbols, texts, and concepts (Hall, 2007); the learning environment is also flexibly designed to support both collaborative and individual learning.

2.4.3 Design of scaffolding systems

Vygotsky defines the assistance provided by a teacher or classmate in ZPD as "*scaffolding*" (Mooney, 2013, p. 84). Scaffolding is crucial to ZPD since it demonstrates one's ability to learn a new concept or even overcome fear, purely through interaction, or a *push/nudge*[32] from an adult or a friend/peer.

However, scaffolding is not just the act of designing or structuring a learning activity to offer support. Taber (2018) argues that, in order to scaffold learning, the task should be designed to achieve a specific learning goal that the learner has not yet achieved unaided. Vygotsky (1978) argues that scaffolding is affected and influenced by both social as well as cultural environments, rather than just physical factors and age. Mooney (2000) suggests that Vygotsky's theories appear to be flexible in their attempt to frame learning and development as a continuous process.

Re-reading Vygotsky as a design thinker reveals how scaffolding can be embodied in the design of learning activities, to specifically help the learner achieve a goal based on his/her competence. Vygotsky's theories on scaffolding guide teachers towards designing a curriculum that affords extending a child's knowledge. In the case of play-based learning, for example, examining scaffolding structures can help identify how facilitation is designed within learning frameworks to support knowledge comprehension.

Scharer (2017) argues that in case of ECE[33], teachers can find ways to engage in play at a higher level by differentiating between observations (what they see) and interpretations (what they think they see) of play. Vygotsky as a design thinker reveals that by engaging in informed observation of children's play, teachers can find multiple ways to design scaffolding structures in play processes.

Here, Vygotsky's understanding of informed observations draws parallels to engaging in design thinking (Brown and Kātz, 2009) by observing, analysing, and identifying design gaps and opportunities to implant scaffolding structures in play-based learning environments. Scaffolding can be integrated into learning environments by (1) providing ideas and themes, (2) choosing appropriate play artefacts, pivots, and props, (3) designing supporting plots and narratives, (4) integrating multiple themes, (5) dedicating sufficient

32 The term nudge in the context of this thesis has no bearing or association to the idea of Nudge Theory as compiled by James Wilk in 1995 and the act of the nudge by D.J. Stewart. In this thesis, the term nudge is used semantically to describe the act of a slight push, guidance, words of motivation or help given as a form of scaffolding, to help a child comprehend a new concept.
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time to play, and (6) introducing children to situations where their abilities and competence are stretched and challenged.

Play is an important component in the design of current learning environments such as maker spaces since it fosters engagement, creativity, and social participation (Marsh et al., 2019). Scaffolding in maker spaces can be embodied through themes, play tools, props, narratives, and multidisciplinary opportunities that challenge a learner's competency and encourage social participation. Based on a Vygotskian approach, these processes, when viewed through the lens of semiotic, symbolic, and multimodal communicative practices along with artefacts and tools, encourage creativity and intentionality in maker spaces (Marsh et al., 2019).

2.4.4 Vygotsky and play-tutoring

The meaning of objects and actions emerge during social play; hence, play is a consequence of the child's meaning-making, which develops during social interaction with others (Quilitch and Risley, 1973; Vygotsky, 1978). Vygotsky (1967, 1978) further argues that play for children is what leads to the development of abstract thought, as children gradually begin to negotiate the meaning of things and actions concerning specific rules and norms while engaging in play-based activities.

Play-tutoring, as introduced earlier in Chapter One, presents measures (play materials, play resources, play personnel, and play spaces) designed by adults to incorporate playfulness in children's learning environments (both formalised school spaces and cultural learning spaces) through categories[34] of play. Play-tutoring measures designed to encompass Vygotskian perspectives such as scaffolding and imaginative play enable children to submit to the premise of the play activity, when it is motivating and affords exploration of objects to discover their affordances and functions (Jahreie et al., 2011), while simultaneously engaging in inquiry-based learning.

2.5 Dewey, pragmatism, and design thinking

John Dewey (1859-1952) was an educational reformer and pragmatist in the early twentieth century, whose progressive ideas towards education revolutionised schooling

34 Introduced in Chapter One in a tabular format.

and remain fundamentally important in modern times (Mooney, 2013). Pragmatism supports interaction and integration, wherein theories must be linked to experience or practice (Rylander, 2012). Deweyan perspectives endorse pragmatist learning through a hands-on approach, where education is viewed experientially as a process of *learning-by-doing* (Hickman and Shook, 2009; Dalsgaard, 2014).

According to Schecter (2011), Dewey's views on education revolve around the focus of a child's growth serving as a guiding principle for knowledge acquisition. Mooney (2013) argues that Dewey's views on classroom education are grounded in democratic principles promoting equal voice amongst all participants in the learning experience (Hickman and Shook, 2009), where student experience inspires teacher instructions (Dewey, 1938).

Dalsgaard (2014) argues that Dewey's pragmatism offers a set of concepts and articulations that can aid the development of a design discourse by addressing key design issues. Dalsgaard (ibid) refers to issues such as (1) the relationship between theory and practice, (2) the relationship between designed experiments, techniques, and tools, (3) inquiry as a concept, and (4) the unfolding of design thinking in other human experiences, to illustrate convergences between pragmatism and design thinking.

2.5.1 Design as interventions

Intervention, as a key component of designerly inquiry, provokes change by developing and staging artefacts and environments which alter our perception and behaviour (Binder and Brandt, 2008; Johansson-Sköldberg et al., 2013; Dalsgaard, 2014). The interventionist agenda of design resonates with Dewey's pragmatist tenet of practice-based action taking precedence over theory, where concepts such as context, emergence, and interaction can be employed to understand both the design and users of interactive artefacts (Dalsgaard, 2014). This notion of design underpins Deweyan pragmatism, since it proposes that knowledge as an active experience is developed through experimental action.

2.5.2 Design is user-centred; play is child-centred

For Dewey (1897), "true education comes through the stimulation of the child's powers, by the demands of the social situation in which he finds himself" (p. 77-80). Mooney (2013) expands on the Deweyan perspective, wherein children interact and explore their environment in order to adapt and learn. Here, play's immediate educational value lies in its social attributes, since it helps children understand the world around them and how it functions (Dennis, 1970).

Re-reading Dewey as a design thinker reveals how his perspectives on pragmatism prompt us to consider children and teachers as useful actors, who, similar to designers, draw on interactive artefacts and systems to make sense of their world (Dalsgaard, 2014). Dewey argues that "the child's instinct and powers furnish the material and give the starting point for all education" (1897, p. 77-80). Dewey as a design thinker promotes user-centred perspectives; in the case of education, Dewey argues that a child's interests along with that of his/her group must be taken into consideration when planning and designing learning curricula and environments.

2.5.3 Dewey, inquiry-based learning, and experimentation

Dalsgaard (2014) argues that our past experiences with a situation determine our knowledge and habits; when our accustomed response doesn't lead to an expected outcome, we engage in inquiry. Hence, inquiry-based learning can be seen as a pragmatist concept to explore design challenges.

Inquiry-based learning is designed through (1) recognition of an issue or problem with an inexact situation, (2) motivation to transform that situation, (3) identification of a problem, and eventually (4) framing the boundary or parameters of an inquiry (Dalsgaard, 2014). Inquiry-based activities in play-based learning environments such as maker spaces in STEM and STEAM settings, when viewed from a Deweyan design perspective, reveal how an inconclusive and unexpected situation can be transformed into a new concept or solution by engaging in tinkering, hacking, exploration, and prototyping of play artefacts. Re-reading Dewey as a design thinker reveals how inquiry-based learning as a pragmatist concept affords the design process of problem identification, conceptualisation of ideas, formulating potential solutions, and testing them by engaging in experiential learning to transform the situation and, in turn, address the identified problem.

Experimentation, as another convergent theme in design and Deweyan pragmatism, demonstrates how intertwining iteration, reflection, and action can inform conceptualisation. Dalsgaard (2014) argues that experimentation affects entities that are both internal (the theme of an experiment) and external (the user) in an experiment.

Experimentation, in turn, mirrors design as an iterative process, within which one gains a better understanding of a problem through cycles of interventions and experiments. Re-reading Dewey as a design thinker reveals how experimentation is an essential affordance of play-based learning environments, since it helps evaluate potential situations and acts as a catalyst for knowledge acquisition. While referring to Dewey's work, Mooney (2000) states that an experiment can only be called educational if it is based on a child's insights and if it grows out of a child's existing knowledge and experience.

Dewey (1897) further explains it is the responsibility of the school to nurture and extend a child's value system that he/she develops at home. Here, one can draw parallels between Dewey's (1897) perspectives on social learning and Vygotsky's ideas of scaffolding (1978), where Dewey ascribes more responsibility to the teachers and educators. Re-reading Dewey as a design thinker reveals that his central ideas on educating children focus on a combination of iterative and experiential learning, which is backed by trusting the teacher's knowledge to nurture inquiry. According to Dewey (1897), the path to quality education is paved if the teachers know the children well, which helps in building on their experiences of past learning and being better organised in planning a curriculum based on their interests.

2.5.4 Dewey and Fröbel

Despite thinking highly of Fröbel's work, archived discussions on Dewey suggest that Dewey found inconsistencies in Fröbel's system of development (Dennis 1970; Dewey, 1974). Fröbel believes that power resides innately within the child and, by supplying a child with the right tools and material, this power will be liberated. Dewey, on the other hand, contradicts this theory, since his concept of personality is based on the socialisation of the child (Dennis, 1970). In his own words:

> *"The child is simply absorbed in what he is doing; the occupation in which he is engaged lays complete hold upon him. He gives himself without reserve. Hence while there is much energy spent, there is no conscious effort; while the child is intent to the point of engrossment, there is no conscious intention" (Dewey, 1974, p 145).*

For Dewey, playful learning is a process designed to further a child's knowledge (Mooney, 2013). Re-reading Dewey as a design thinker reveals his thoughts on *purposeful play* as a design measure to engage in inquiry-based learning. Where Fröbel's theories categorise play and work as two diverging elements (Sylva, 1990), Dewey's theories argue that play could eventually transition into work, through *tangible forms* and *conscious intent* (Dennis, 1970). As the child matures, he/she looks forward to greater visible achievements and rewards. Hence, Dewey suggests that play-based activities should be designed as evolutionary and purposeful, based on successive acts and steady progress, which leads to greater rewards for the child.

2.6 Chapter summary

As progressive educators, Fröbel, Dewey, Montessori, and Vygotsky advocate for the design of artefacts, learning spaces, and frameworks that recognise children as agents in constructing their own learning experience (Wood and Attfield, 2005; Hall, 2007; Dalsgaard, 2014; Scharer, 2017).

The aim behind re-reading Fröbel, Dewey, Montessori, and Vygotsky as design thinkers in this chapter is to argue that design thinking and design have historically been central to both play and learning environments. The four pedagogues discussed in this chapter contribute to an emergent language of play-based learning that bears its roots in design thinking. Re-reading their historical approach allows for an applied view of design's centrality to the evolution of play-based pedagogies and practices, which have bolstered, directed, and influenced the design of current play-based learning environments.

Table 5: Pedagogues and their relationship to play and design

	Fröbel	**Montessori**	**Vygotsky**	**Dewey**
Design inspired pedagogical perspectives	Supports the design of educational environments that involve direct interaction with materials.	Supports multi-age classrooms designed to create opportunities for independence, citizenship, and accountability through sensorial learning.	Supports the design of collaborative educational environments as they are fundamental for cognitive development.	Supports pragmatist education and learning by doing.

Approach to design and play-based learning	The Fröbelian approach examines play-based learning through objects designed as data gathering tools.	The Montessori method advocates for the need for carefully curated learning environments along with sensorial objects, designed with a structuralist footing.	Vygotskian perspectives reveal that learning structures and systems must be designed to support language development, collaboration, interaction, and social learning with peers and teachers.	Deweyan perspectives focus on pragmatism and affordances of purposeful play that make a curriculum meaningful.
Design of play artefacts, systems, spaces, structures	Gifts and Occupations, and the Kindergarten	Design of sensorial materials and furniture for Montessori classrooms.	Design of scaffolding frameworks, stages of ZPD, and learning structures to afford sociality.	Design of learning environments that afford hands-on learning, experimentation, and inquiry.
Advocating for categories of play	Child-led and instinctive play.	Sensorial, prescriptive, and imitative play.	Social and imaginative play.	Active, experimental, and iterative play.
Approaches to facilitating play-based learning	Child-led and open-ended play.	Independent and individualistic play that is supported by prescriptive facilitation.	Transitory social play that is supported by facilitation and help given to a child, based on his/her competencies. Additionally, imaginative play.	Progressive play that affords enquiry, interventions, and construction of concepts.

Re-read as design thinkers	Fröbel as a design thinker: Visualised the essential unity and compatibility of diametrically opposite forms through the design of his play materials.	Montessori as a design thinker: Designed modular, explicit, and specific learning play materials that focus on sensorial training and promotes uninterrupted and unmodifiable engagement with the prepared environment.	Vygotsky as a design thinker: Visualised the design of learning environments that are segregated into stages to help a child transition to their ZPD with the help of physical entities (artefacts, materials, spaces) and social entities (teachers, peers, facilitators)	Dewey as a design thinker: Supported the design of inquiry-based and iterative learning environments that dissuade structuralist and pre-set approaches to play-based learning.
	Fröbelian play perspectives embed design thinking by creating play materials and environments that afford intuitive exploration to further learning.	Montessorian play perspectives embed design thinking through the design of learning environments that afford prescriptive, sensorial and imitative learning.	Vygotskian play perspectives embed design thinking by endorsing the design of adaptable learning environments that afford imaginative play and embody scaffolding to help the learners achieve learning goals based on their competence.	Deweyan play perspectives embed design thinking as a pragmatist platform that affords a combination of iterative, interventionist and experiential learning, backed by trusting the teacher's knowledge to nurture inquiry.

This chapter summarises the fundamental premise of play, which focuses on the design and interaction with objects, structures, and environments to inculcate play-based learning. From Fröbel's kindergarten and *Spielgaben*, to Montessori's sensorial materials, to Dewey's formulation of pragmatism, inquiry, experimentation, purposeful play, and flexibility as essential affordances to support cognitive development, to Vygotsky's conceptualisation of ZPD, scaffolding, and imaginative play – all of these are identified as fundamental concepts of play-based learning, which, in turn, assert that design and design thinking are indisputable components of play's DNA.

Re-reading these pedagogues as design thinkers in this chapter has revealed that the theoretical and historical models of play are inseparable from design and design thinking. In order to develop an understanding of how design contributes to theoretical paradigms of play, there is a need to more fully explore and extract the ways in which design has been imagined as integral to the actions, identities, symbols, and spaces of play, both historically and within contemporary learning environments.

Informed by the connections drawn between design and play in Part One (through the work of Fröbel, Montessori, Dewey, Vygotsky and, STEM and STEAM paradigms) a conceptual model was developed to illustrates the relationships between the main theoretical concepts of pedagogy and design. This model visualises connections between design, pedagogy and play-based learning; some of which are explored further in this thesis, through on-site fieldwork and analysis.

CONCEPTUAL MODEL: Design embedded in play & learning theories

THEORIST/MODEL	LEARNING APPROACH/ METHOD	DESIGN / FORM	AFFORDANCE(S)	MODES OF PLAY	21st century learning
FRÖBEL	Data-gathering tools	Modular & abstract	Child-led, instinctive, artistic, explorative	Open-ended	Experimentation
MONTESSORI	Multi-sensorial learning	Modular & prescriptive	Imitative, gestural & prescriptive	Closed & linear	Sensorial & Kinaesthetic
DEWEY	Pragmatism	Experimental & hands-on	Active interactions, experimentation & iteration	Purposeful & pragmatist	Hands-on, experiental & adaptable
VYGOTSKY	ZPD & Scaffolding	Social & Interactive	Interactive & symbolic	Imaginative	Transitionary, flexible, collaborative
STEM/ STEAM	Exploration & Iteration	Hacking & tinkering	Multi-directional & interventionist	Experimental & inquiry-based	Material is immaterial. Focus is on the learning process.

Figure 21: Conceptual model – design embedded in play and learning theories

The thesis therefore now progresses to Part Two, which outlines the aims, theoretical framework, process, outcomes, and analysis of cross-cultural design ethnography (DE) of Montessori learning environments in Scotland and India.

Part Two

Part Two (Chapters Three, Four, and Five) examines the observation-based research method of design ethnography (DE). DE was undertaken in a cross-cultural capacity during this thesis to examine the contributions of design thinking and design in Montessori learning environments.

To begin the second section of this thesis, Chapter Three introduces DE as a research method within the gamut of ethnography.

Chapter Four presents the DE fieldwork undertaken across Montessori Schools in Scotland and India through on-site vignettes and notes. This chapter aims to present a detailed account of the Montessori method in practice, and how Montessori's universalised material menu has been designed and appropriated at a local level.

Chapter Five analyses and draws inferences from on-site DE data. It brings key design perspectives and affordances of the Montessori method to light, which endorse prescriptive learning and step-by-step interactions with her material menu. This chapter further identifies design gaps and design opportunities within the Montessori method to augment it to respond to the literacy needs of twenty-first century play-based learning environments.

Chapter Three:
Design ethnography (DE)

This chapter introduces DE as an observation-based research method that was undertaken to address the contributions of design thinking and design in Montessori learning environments.

As discussed in Chapter Two, the Montessori method as a system of play-based learning is guided by specific sensorial materials and accompanying activities. It argues that children learn most effectively when their surrounding environment aids their natural desire to learn. Montessori herself engaged in design thinking through ethnographic observations and design iterations while developing her material menu. She observed her materials in-situ, identified design gaps and pain points, and addressed them by constantly developing and iterating her sensorial materials. As a means to comprehending Montessori's rich design legacy of sensorial objects and the kinds of engagement her design language affords, cross-cultural DE was undertaken at Montessori schools in Scotland and India during this thesis.

Cross-cultural DE was selected as an observation-based research method instead of a more traditional method such as qualitative content analysis. Content analysis consists of analysing and interpreting information and its meaning (Schreier, 2012) by systematically collecting data from a set of written, oral, or visual texts and records. Content analysis is an effective method that quantifies the occurrence of specific information such as words, phrases, or concepts in historical or contemporary records, to help interpret their meaning and semantic relationships. In the context of this thesis, content analysis would have consisted of analysing the content of Montessori's written texts to uncover the potential use of words, phrases, and concepts similar to the ones used in design and design thinking; for example, the use of words and concepts such as tinkering, exploration, creativity, and so on.

Although content analysis is a trustworthy, wide-ranging, systematic, and transparent method apt for identifying correlations, patterns, preferences, intentions, and differences while communicating concepts, it tends to focus on words or phrases in isolation and can sometimes disregard the cultural context, ambiguity, and nuance; all of which are relevant to engaging in a critical and reflective ethnographic study. In the case of this thesis, the research aims and framework focused on the study and exploration of in-situ play-based learning environments, play objects, materials, and interactions as well as understanding the facilitation framework and play personnel involved in the running and operation of the learning environments. The interconnectedness of these factors lends itself to a study of ethnographic observations and site-specific design iterations. This made DE more relevant as a research method in this thesis.

This chapter begins by introducing ethnography and design ethnography as research methods. It continues to discuss explicit characteristics of ethnographic research such as the researcher's positionality, reflexivity, and observation formats. The chapter then ends with introducing the groundwork and preparation embarked upon before venturing on-site to undertake DE.

3.1 Ethnography

Reeves et al. (2008) maintain that ethnography is the study of social interactions, behaviours, and perceptions, which are codified by culture and materialise in clans, groups, teams, organisations, and communities. Reeves et al. (2008), referring to Hammersley and Atkinson (1994), argue that ethnography's roots can be traced back to premises of early anthropological studies of small, rural, and isolated societies from the early 1900s. Here, researchers like Bronislaw Malinowski and Alfred Radcliffe-Brown engaged with specific social settings for long periods, and documented the social arrangements and belief systems present in these communities through observations and involvement.

Ethnography grants detailed and comprehensive data on the views, lives, and actions of people, along with supporting factors such as sights and sounds of their habitats and environments, through a repository of documented observations and interviews (Reeves et al., 2008). The role of an ethnographer is to record and archive the cultural practices and perspectives of the people who are present in these settings. Ethnography aims to *dive in* or look at the world through the lenses of the people who inhabit these settings (Hammersley, 1992).

According to Hammersley and Atkinson (2007), during ethnographic research, participants are observed in their natural or everyday settings, instead of under experimental circumstances of an artificially structured environment. Data gathered during ethnography is obtained through methods such as participant observations and informal conversations, as they too comply with the research imperative of not disturbing naturalised settings (Hammersley and Atkinson, 2007).

3.2 Design Ethnography (DE)

Since the early years of the twentieth century, ethnography has become widely used across various disciplinary areas, which include but are not limited to design, sociology, education, and so on (Reeves et al., 2008). Ethnography has become central to design research because it allows the researcher to get *under the skin* of a specific social setting. Wasson (2000) argues that ethnography in design research helps investigate everyday behaviours of users[35] and what they actually do, highlighting the importance of learning about naturally occurring user practices. It helps designers immerse themselves in the environment of the user; where the design problem and all its associated issues occur. Through its application in varied disciplinary contexts, ethnography has become a highly mobile and flexible method that can be adapted to design disciplines.

DE is ethnographic research undertaken with a focus on informing and inspiring design processes. The principal advantage of DE is the ability to observe how the assemblage of artefacts, practices, and socio-cultural factors influence the ways in which users interact with their environment, and, more importantly, how these factors can be designed to bring about change through future objects, systems, and spaces.

DE recognises the influence of physical worlds on aspects that could potentially drive design change. DE allows the design researcher to interpret cultural systems and uncover complex and often invisible design problems through the study of artefacts, systems, and the environment of the research premise. Unlike traditional ethnographers who live with the participants and immerse themselves in their culture, design ethnographers are visitors who observe and document the environment they are researching. DE can help discover the hidden, implicit, and coded practices of everyday life, dispel preconceived assumptions about user behaviour, and help uncover unexpected design insights.

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35 The term ‘user’ in design ethnography is used to describe people who are the focus of the ethnographic study, where the design ethnographer studies how the users interact with a certain artefact, service, or environment, amongst others.

3.3 Documenting ethnographic observations

According to Hammersley and Atkinson (2007), the documentation of DE data is similar to traditional ethnography, and usually undertaken in an unstructured and open-ended manner. The authors (ibid) describe ethnographic research as having *porous boundaries*, wherein the rules set are not *hard and fast*, but more exploratory and flexible. In this way, it is responsive to potential threats, roadblocks, quirks, and unforeseeable circumstances.

Hammersley and Atkinson (2007) maintain that fieldwork in ethnography consist of "being there, and participating, overtly and covertly, in people's daily lives; it is inherently relational and therefore emotionally laden" (2007, p. 3). In this way, ethnographic research adds context and richness to empirical data. Based on the disciplinary context of the ethnographer, specific parameters can be arranged for the researcher, from considerations related to the physical proximity of the field to virtual environments.

The pre-set physical parameters of this thesis to undertake DE research, consisted of the actual geographical locations of the schools. Here, research was conducted in close physical proximity (sitting inside classrooms) of the Montessori schools. Based on on-site observations, DE fieldwork was documented as daily blogs, on-site notes, images, sketches, and video recordings[36]. It was further supported by informal conversations with the facilitators and staff.

Findings distilled from cross-cultural DE were then read against pedagogic theories discussed in the first two chapters. This synthesis of primary and secondary research is presented in Chapters Five and Nine, which reveal how design is implicated within Montessori play-based learning environments.

36 On specific sites where video recordings were allowed, consent was obtained beforehand from the relevant school authorities. Images and videos recorded in this thesis were completely anonymised and only focused on documenting hands-on objects interactions with the sensorial materials.

3.3.1 Participant and non-participant observations

Conventional outcomes of ethnography consist of verbal descriptions and explanations, which eventually lead to data analysis that could potentially be quantified to fit a variety of paradigms (Hammersley and Atkinson, 2007). The format of interviews in ethnography is described by Liamputtong and Ezzy (2005) as "comprehensive, focused and often unstructured" (p.332). Instead of using fixed questions, the researcher engages in conversations to elicit participant views and experiences. This style of interviewing compliments the participant observation method, where observations provide an overall insight to understanding daily life and interviews help with a more detailed articulation of everyday life instances.

Participant observation is a more active and immersive format of engagement with the in-study participants and requires the researcher to maintain equilibrium between embracing the role of an insider, while simultaneously continuing with his/her external investigations. Reeves et al. (2008) argue, that through participation, the researcher essays the role of an insider. Simultaneously, the researcher has to maintain a sense of objectivity towards participant observation by separating oneself from the group being studied.

In comparison, during non-participant observation the researcher goes with the flow of events, and the interaction and behaviour of participants within the research continues uninterrupted, almost as if the researcher is not present (Adler and Adler, 1994, p.81). During DE, I was allowed to observe the institutionalised learning environments of Montessori schools in silence, without interacting with the children or facilitators during their workday. As a result of this, non-participant observations were undertaken during the DE fieldwork, so as to not disturb or disrupt the learning processes at Montessori schools.

3.3.2 Reflections and research positionality

Reeves et al. (2008) argue that being reflective pertains to placing, recognising, and representing the researcher-self within ethnographic scrutiny. The authors (ibid) further argue that, while undertaking an ethnographic study, the collection of data is seen as a natural process, where the researcher watches a social phenomenon occur in its natural order. According to the authors (ibid), reflectivity involves considering oneself (the researcher) while planning and conducting an on-site ethnographic study. Reflective research practice specifies the consideration of the researcher's background, values, and history since it acknowledges that the researcher's experience will in some way affect the interpretation and reporting of social phenomenon.

Merriam et al. (2010) and Tillman (2002) argue that researchers undertaking cross-cultural studies are at an advantage if they are *insiders/natives*, where they share linguistic, social, and cultural characteristics with their research participants. From this point of view, familiarity or similarity with the participants and the field diffuses social, cultural, and linguistic barriers. Similarly, Birman (2005) argues that being a *cultural insider* has an added advantage, when the researcher is familiar with the language, local culture, and lifestyle of the community, which makes access to sensitive information much easier; unlike a *cultural outsider*, for whom this knowledge can be difficult to access, even if he or she is extremely culturally sensitive and aware.

During the initial stages of DE fieldwork in Scotland, I observed how my educational and cultural background influenced the ways in which I accessed, interpreted, and analysed data. Here, a lot of apparently well-known toys and teaching activities designed for children studying in a Scottish Montessori environment were unfamiliar to me. On the other hand, while being on-site in India, and being introduced to locally re-appropriated materials and activities within Montessori's universal curriculum, I was given an opportunity to recall and reframe some of my personal learning experiences as a young child growing up in India.

My research positionality was in constant flux due to the cross-cultural nature of this DE research. Due to my Indian heritage, while on-site at Indian Montessori schools, I was positioned as an *assumed* cultural insider. Paradoxically, with my residential status of a foreigner in the U.K, while conducting research in Scotland, I was positioned as an outside researcher. While on-site in India, even for the participants (school children and facilitators), my role would transition from an unknown outsider, who had just started visiting a school to observe its environment, to a known insider, who was at times entrusted to take story-telling sessions. The cross-cultural nature of the research sites made it interesting to constantly alter and adapt my positionality as a design researcher.

3.3.3 Awkwardness, reflexivity, and uncertainty

Koning[37] and Ooi[38] (2013) introduce the inherently identifiable occurrence of awkwardness and uncertainty within ethnographic research. Koning and Ooi (2013) argue that being overtly rational and individualistic can polarise an ethnographer's reflexivity. Here, while elaborating on the concept of un-paralysing reflexivity, the authors (ibid) describe how *awkward* refers to the less comfortable, non-rational, and un-coordinated aspects of an ethnographic experience, which may lead to generating unexpected insights. Even so, Koning and Ooi's (2013) emphasis on the reality of awkwardness sheds light on what could be seen as the "repressed and untold stories on the field" (p. 17). The authors (ibid) argue that reflexivity fails to take into account one's (here - the researcher's) emotions, and hence can become exceedingly rational and cognitive (within predominantly academic structures), where it fails to account for the researcher's mental state and thus becomes *paralysed* (Pillow, 2003).

Burkitt (2012) examines reflexivity as overtly rational and individualistic. Pillow (2003) argues that reflexivity is employed as a means to defend better research. Reflexivity incorporates dimensions such as fear, isolation, and embarrassment, which researchers avoid, as argued by Koning and Ooi (2013). The authors (ibid) further explain that researchers focus excessively on avoiding personal emotions, and are intent on feeling comfortable with reporting, expressing, and deconstructing research avenues. This impulse to remain unemotional and rational is in contrast to reflexive practices, which display real and everyday felt experiences (ibid). The authors (ibid) caution that revelations by the *research-self* might be considered as egotistical at times; however, these awkward experiences must be disclosed to make a *productive difference*, and to generate a richer understanding of human experience and meaning making.

Ethnographic fieldwork consists of sustaining harmony between the researcher's compulsion to become a part of the naturalised settings, and his or her commitment to keeping distance. There is a constant mechanism of negotiating with sentiments of *faith and apprehension* by both the researcher as well as the participant (Hume and Mulcock, 2004). Koning and Ooi (2013) suggest that, despite documents and publications on

37 Juliette Koning. She is a senior lecturer at Oxford Brookes University in Organizational Anthropology. Research focus: Ethnicity, gender, entrepreneurship, religion, and business in Southeast Asia.
38 Can-Seng Ooi is an Associate Professor from Copenhagen Business School. Research focus: Comparative ethnographic art world research in China, Singapore, and Denmark.

participant observation and reflexivity (Hume and Mulcock, 2004) being readily available and highly relevant to ethnographic researchers, there is less clarity on how these can be translated and analysed to present emotional dimensions of fieldwork.

It is a challenging task to bring hidden components such as awkwardness and emotions to light within mainstream design ethnographic research. However, it is the incomprehensible, unforeseen, quirky, uncomfortable, and often descriptive narratives that become a part of the awkwardness a researcher faces on-site. Awkwardness adds value to the rich fabric of narrating a *lived experience*, and makes it more honest, reflective and clarifies the researcher's position within the data.

Koning and Ooi (2013) suggest that awkwardness can often occur around issues of participant willingness to talk and be accepting of the researcher's presence. Such awkwardness, the authors (ibid) argue, can be ascertained through the tone of an encounter. According to the authors (ibid), when the researcher's tone is warm and amicable, it implies trustworthiness and sincere communication from the research participants. By highlighting these concerns in ethnography, researchers align with what has been described as a *reflective turn* (Clifford and Marcus, 1986), which embraces the subjectivity and intersubjectivity of the research process and the *ethnographic self* (Koning and Ooi, 2013).

3.3.4 Researching with children

Punch (2002) argues that much has been discussed about the differences between researching with children and researching with adults. Mandell (1991) suggests that the desired position of a researcher in a scenario involving researching with children is to adapt the *least adult role*, which acknowledges adult-child differences and suspends all adult-like characteristics except the physical. Some have criticised this claim, questioning whether this is desirable or even possible if one is an adult researcher (James et al., 1998). Christensen and James (2008) suggest that it may be more helpful to be an *unusual adult*.

Based on a theoretical understanding of the Montessori method[39], key areas were identified to focus on during the DE fieldwork, apart from preparing for open-ended and exploratory investigations.

39 Refer to Chapter Two.

3.4 Focus areas in the Montessori method

Play-based learning in Montessori schools and institutional settings is contingent on how play resources, learning structures, and facilitation frameworks are designed around Montessori's sensorial materials. Paying close attention to the *design language* of the Montessori environment during DE would help observe how the triad of play resources (play objects, tools, and spaces), play structures (activities, tasks, and themes), and play personnel (teachers, facilitators, and children) collaborate, and the kind of affordances that emerge from their interaction with each other and the learning environment.

Play activities that support interactions with sensorial materials are usually facilitated by trained or, in some cases, technically untrained but experienced facilitators (this existed as a very likely occurrence in India, where teachers who have years of experience and knowledge of working with young children might work in specialised schools, despite having no technical training in the method). Observing the *facilitation styles and frameworks* of various facilitators during DE would help identify how play activities designed by trained and untrained Montessori facilitators embody scaffolding to support knowledge acquisition in children (Vygotsky, 1978).

While observing the overall design language of the Montessori schools during DE, language acquisition as a subject from the Montessori method was identified as a specific area to focus on. As discussed in Chapter Two, language acquisition in Montessori schools is designed as an intricate and multi-sensorial process, where children are guided to transition from initially acquiring reading skills to eventually getting trained in writing skills. Theoretical accounts of the Montessori method have demonstrated that Montessori's language materials are designed to train vocal, written, and gestural domains by engaging in an elaborately designed play-tutoring format. Specific language materials are designed for children, which have knobs attached to their surface. These knobs are a typical design feature in some sensorial materials; they help develop the pincer grip to support a child's hand muscles and avoid muscle fatigue. Additionally, observing activities and sensorial materials designed for language acquisition at the Montessori schools[40] where multiple languages were taught would help highlight the

40 Multi-lingual modes of instruction are a prominent feature of Indian schools. While shortlisting certified Montessori school sites in India, it was interesting to note that most of them appeared to be located in southern India, especially in the city of Bangalore. Typically, most schools in southern India employ English as their language of instruction and also teach in one of these four southern Indian languages: Kannada, Tamil, Telugu, and Malayalam. I have native proficiency in only Hindi (a language

adaptation of Montessori's design language curriculum to local language materials and activities.

The above listed areas from the Montessori method were taken into account before undertaking DE, in order to address the first research aim of the thesis, which was to identify the contributions of design thinking and design in play-based learning environments (here, the Montessori method). Along with these areas to direct the DE fieldwork, open-ended observation-based research was also conducted to document awkward, unexpected, and surprising learning outcomes. Undertaking open-ended observations offered a way of comprehending invisible, intangible, and hidden affordances of Montessori schools in India and Scotland.

3.5 Preparation before going on-site

Before commencing with DE fieldwork, extensive preparation had to be undertaken to ensure that all the mandatory requirements and regulations specific to projects involving research with children were followed. In Scotland, researchers working with children are a part of the Protecting Vulnerable Groups (PVG) membership scheme, which is managed and delivered by Disclosure Scotland. The scheme has been designed to ensure that children are protected. It checks the suitability of adults working with children or other vulnerable adults. Before commencing with DE fieldwork across any school in Scotland or India, I enrolled myself in the PVG scheme in Scotland in order to be allowed to access school sites. Since Edinburgh Napier applied for my PVG membership as a research student, getting verified by the scheme was relatively simple.

After getting verified as a PVG member, formal approval had to be sought from Edinburgh Napier's Ethics Committee before contacting school sites for DE research. An ethics proposal along with clear project guidelines and copies of consent forms, was drafted and submitted to the university[41]. The proposal stated that any photography and

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spoken predominantly in northern India), as I was raised in north-western India during my formative years. The fieldwork included Montessori schools in Scotland, where it was safe to assume that Scottish Montessori schools would use English as their mode of instruction. This assumption was checked and confirmed by contacting various Montessori Schools across Scotland. Hence, during the DE fieldwork, some of the selected Indian Montessori school sites were multilingual, whereas the Scottish schools only taught in English.

41 The ethics form along with all the supporting documents can be viewed in the appendix section, at the end of this thesis.

video recordings would only be undertaken on-site after receiving written consent from the school administration and parents of the children. The proposal also specified that any visual documentation of the children while on-site would be entirely anonymised, with no visible facial or recognisable features of the children, in compliance with the PVG scheme.

3.5.1 Shortlisting research sites

After receiving a formal approval on the ethics proposal by the university, DE fieldwork could begin. Before going on-site, I also attended the Montessori Congress in Berlin in 2016. This congress was immensely helpful as I was able to converse with Montessorians from all over Europe. This helped me gain a more authentic understanding of the Montessori curriculum.

While initially shortlisting Indian schools and looking for contacts from the Indian Montessori Foundation (IMF), I came across schools which claimed to be ‘Montessori’ and used the term to brand the schools, without following any of the Montessori method prerequisites. In this way, schools were publicly misinforming parents with the pretext of being an authentic Montessori school. As I discovered later on, this practice was not new to the Indian educational system.

Although organisations such as AMI (Association Montessori Internationale) and AMS (American Montessori Society) have articulated the framework to regulate and set-up a Montessori school, any school is free to call itself a Montessori school, regardless of their accreditation. Due to a trademark dispute between AMS and AMI in 1967 over the use of the term ‘Montessori’, the US Patent and Trademark Trial and Appeal Board intervened and refused to grant licensed use of the term ‘Montessori’ to any one particular organisation. As a result, the term ‘Montessori’ has a generic and/or descriptive significance. Therefore, schools can have a traditional government-approved curriculum, but by adding a few Montessori artefacts within their learning spaces, they can call themselves a Montessori school too, without undergoing any checks or accreditation processes.

Since I was given the contacts to accredited Montessori schools in Europe through my involvement with the Montessori Congress, this issue was not encountered in Scotland. However, a more cautious approach had to be adopted in India due to the unchecked use of the brand Montessori. This meant that schools were selected on the basis of their collaboration or certification with either AMI (Association Montessori Internationale) or IMF (Indian Montessori Foundation). This helped filtering out schools which might be following a partial interpretation of the Montessorian philosophy.

Eventually, a few schools were selected and contacted in early 2017. After a few rounds of communication, negotiating research schedules, factoring in delays, and last-minute cancellations, one Montessori school in Scotland and two Montessori schools, across two different cities in India, were shortlisted. One of the schools was based in south India, while the other was based in western India. These regions in India are quite diverse in terms of culture, local languages, and socio-economic structures; therefore, collectively, they provided an interesting way of studying schools in two different socio-cultural landscapes within one country.

3.6 Chapter summary

This chapter has introduced DE as a research method, which supported an observation-based study of Montessori's designed materials, spaces, and systems in-situ, thereby making it relevant to this thesis. It has introduced characteristics of ethnography such as reflexivity, awkwardness, and participant and non-participant research, all of which helped guide the DE fieldwork during this thesis. This chapter further addressed the selection process of Montessori school sites across two countries as means of conducting cross-cultural DE research. This chapter commented on the decision to undertake cross-cultural DE research in order to observe the design localisms of Montessori's universalised menu. The next chapter, supported by on-site notes and vignettes, presents a comprehensive account of the DE fieldwork conducted across three certified Montessori schools in Scotland and India.

Chapter Four:

DE - Montessori environments in Scotland and India

As a means to comprehending Montessori's rich design legacy of sensorial materials and the kinds of engagement her design language affords, Chapter Four presents the cross-cultural DE study of Montessori schools in India and Scotland through on-site vignettes and notes. By presenting the empirical data, this chapter begins to make sense of the ways in which the Montessori method, as a universal system of education, has been designed, re-appropriated, and articulated at a local level. This chapter aims to highlight the common attributes as well as culturally relevant practices designed within the adaptation of the Montessori method across two different socio-cultural landscapes (Scotland and India). This is done to respond to the first research aim of identifying the contributions of design thinking and design in play-based learning environments (here: the Montessori method), which are further analysed and presented in Chapter Five.

Chapter Four is divided into two sections; Section One, which focuses on the DE fieldwork undertaken at one site in Scotland, and Section Two, which focuses on the DE fieldwork undertaken at two sites in India. In line with adopting a beginners' mindset (as discussed in Chapter One), each section is structured based on the main DE findings specific to each country. This chapter concludes with a summary of data gathered across all the three sites.

4.1 Why the Montessori method?

Play has become a global commodity and is informed by increasingly globalised professional networks. The global flow of design and play-based learning environments requires an approach capable of comprehending local adaptations of a globally designed yet distinctive play-based learning curriculum. The Montessori method was chosen because it provides opportunities to study cross-cultural play-based learning in Scotland and India. The Montessori method is now a globalised pedagogical product that is delivered through play-based learning environments across the world.

In comparison to other play-based learning environments such as Reggio Emilia, Steiner Schools and the Finnish education system, the Montessori method is one of the most intricately designed play environments of the early twentieth century. It boasts of approximately 4,000 certified Montessori schools in the United States and approximately 20,000 schools worldwide[42]. The method enjoys an elitist status evidenced by its endorsement by Google founders Larry Page and Sergey Brin (both former students at Montessori schools who credit Montessori's self-directed learning process as a positive influence on their work). Will Wright, a video game pioneer and the creator of games such as the SimCity and Spore, also credits the Montessori method for teaching him the joy of discovery, which he has later adopted as an affordance within the design of his video games.

Pedagogues such as Pestalozzi, Fröbel, Dewey, and Montessori started to design educational programs in Europe with an international reach, which eventually influenced the early childhood curriculum in the United States. In Italy around 1916, Maria Montessori began promoting her educational method for children, who were at that time, considered cognitively defective, and lived in acute poverty in Rome. In generations of pedagogical theorists and practitioners to follow, the design of educational programmes had an increasingly international reach, beyond national education systems.

According to Snyder (1972), many of Fröbel and Montessori's early theories were put into practice and altered by educators such as Margarethe Shurz, who was credited with building the first kindergarten programme in the United States, Patty Smith Hill who also actively campaigned for kindergarten education and Elizabeth Peabody, who promoted the philosophy of Fröbel and was involved in the American kindergarten movement across the country. Goffin and Wilson (2001) review that the Montessori method continues to expand globally, usually among middle-and upper-class communities, as a home-schooling method as well as an academically focused approach in private schools.

In 1939, the Theosophical Society of India invited the 69-year-old Montessori and her son Mario to the country. Montessori and Mario were restricted from traveling out of India due to the outbreak of World War II, and as a result ended up staying in India between 1939 and 1947. Montessori lived in Adyar in Chennai (southern India) and began to train educators around the Indian subcontinent in the Montessori method (Montessori-India.org., 2016). Here, Montessori offered Indian educators their first experience of play-based learning through AMI (Association Montessori Internationale) courses. Initiated

42 These figures are based on research conducted by the North American Montessori Teachers Association. http://www.montessori-namta.org/

into the first year of the course in 1939, Gool Minwalla, Tehmina Wadia, and Khurshed Taraporewalla later became eminent Montessorians (ibid).

Wilson (1987) argues that, although the Montessori method was foreign at the time it was introduced to Indian educators, its adoption coincided with a critical period in India's history. The method's emphasis on liberty and the development of independent thought and action appealed to certain aspects of the growing Indian nationalist movement (ibid). Wilson (ibid) further explains that the Montessori method was regarded as modern and innovative and was embraced with enthusiasm from those seeking progress in what was still a very traditional society.

The story of Montessori's engagement with India and with the Theosophists is documented in Rita Kramer's biography on Montessori, (specifically on pages 341-348). One of Montessori's most seminal works, *The Absorbent Mind*, presents accounts of Montessori's work which was undertaken during her time in India. While focusing on the content of her work in India, Kramer (1976) discusses that Montessori was influenced by observing the development of babies in Indian families; where they were stimulated by being at the center of attention in families and were constantly seeing, hearing, touching, and interacting with things. These ideas were then worked out by Montessori and later documented in the book *The Absorbent Mind*.

The discussion above evidences the existence of an undeniable influence and reciprocal relationship between Montessori's work on early childhood education systems in India as well as the cultural influence of India on Montessori's work. This further bolstered the incentive to study Montessori's universalised pedagogy at a local level, specifically across two distinct socio-economic landscapes of Scotland in the global north and India in the global south.

4.2 Section One: Scotland

Scotland currently has around 10 Montessori schools and nurseries that are affiliated to the AMI's UK subsidiary, along with other accredited Montessori training programmes in Scotland such as the Montessori Partnership (based in Edinburgh). An independent body called the Scottish Montessori Collective is also run in collaboration with some Montessori schools in Scotland and the Montessori partnership programme. They organise training workshops, conferences, and development sessions for Montessori schools, facilitators, and parents in the U.K.

4.3 DE fieldwork: Scotland

The first site chosen to undertake DE fieldwork in 2017 was a Montessori school in Scotland, hereby known as M.S.1.0[43]. While on-site at M.S.1.0, I was permitted to sit inside the learning spaces of the three mixed-age cohorts at this school. These cohorts were called the following:

- Infant Community (zero to three-year-olds)
- Children's House (three to six-year-olds)
- Elementary (six to twelve-year-olds)

DE fieldwork essentially consisted of recording activities of everyday school life along with what Hammersley and Atkinson (2007, p.3) describe as "watching what happens, listening to what is said…".

4.3.1 Reflexive ethnographic encounters in Scotland

Awkward ethnographic encounters experienced throughout the fieldwork in Scotland mainly arose from adherence to the school's very specific rules and guidelines, which became a part of the DE fieldwork's research framework.

My position as a researcher was complicated by the limitation that I was not allowed to converse with the children at this school and parallelly ensure that children did not speak to me during their regular school hours. These restrictions were given a very visual form by a lanyard that I was asked to wear when on-site. The lanyard displayed a graphic of a person holding their index finger on their lips, to symbolise silence. Essentially, the lanyard avoided the necessity to repeatedly explain to children that I was not to speak with them.

The children were also aware that I was wearing a lanyard that visualised a *do not disturb* sign around my neck when I was on-site. Initially, I observed (especially during the first

43 The name of the school is anonymised in compliance with Edinburgh Napier University's data protection policies .

two sessions on-site M.S.1.0, both at the Children's House and Elementary learning space) that the children appeared to be curious about me and my role in their classroom, since I was not behaving like a facilitator or engaging with anyone. Some of them from the Children's House cohort even came up to me once, peeked over my shoulder, and smiled. Unfortunately, since I had to work within the predefined framework of a silent researcher, I could not interact with them or put their confusion to rest.

These restrictions made the on-site study difficult and awkward, as all the transcribed data was captured through passive encounters unfolding in front of me, instead of direct interactions, which I might have had with the children. As a researcher, I was permitted to sit in one corner of their learning space. I was not allowed to move around the learning space to observe interactions between the children and the facilitators as they engaged in their play activities. This often limited my on-site research, as I was unable to observe a few interactions up close. However, I often chose a well-located spot in the learning space as my vantage point, from where I could clearly observe and document on-site interactions with the sensorial materials.

An additional aspect that added to the awkwardness of my presence as an on-site researcher, was that I was not also supposed to engage in eye contact with the children, as it might also distract them and disturb their learning flow. Avoiding eye contact and not smiling at the children was uncomfortable. It was difficult for me to ignore their presence when they tried to get my attention or looked at me. Being unperturbed or blank also worried me, since I assumed that the children might see me as an unpleasant entity in their learning space, which might disrupt the naturalised setting, despite taking all precautions.

After discussing reflexive ethnographic encounters met in my fieldwork, I present the following findings from the DE fieldwork, which are organised based on the three cohorts, to elaborate on the similarities and differences in the designed affordances and adaptations of the Montessori curriculum at M.S.1.0.

4.3.2 Infant Community (M.S.1.0)

The early years curriculum at this school is based around the Montessori translation of the Pre-Birth to 3 and Scottish CfE (Curriculum for Excellence) framework. Daily sessions at the Infant Community programme consist of sensory play, art, free play, circle time, songs, sing-alongs, games, and Practical Life activities, after which the children sit together and eat in a communal dining space.

4.3.2.a Design: Learning zones

The following vignette illustrates how the design of the indoor space at Infant Community affords agency and independent movement.

Vignette 1 | M.S.1.0 | January 2017

> *"The furniture and shelves in this section of the learning space are smaller than the rest. The room is dotted with lots of small benches, a little staircase that leads to a quiet corner on top of the room, ramps, dollhouses, blocks, play dough, and the Pink Tower blocks. Smaller seats and Montessori bells are scattered around the room. Some children are busy exploring sensorial materials and playing, while others are sitting in a quiet corner of the room, stringing beads, interacting with play dough, or setting up a doll house."*

As seen above, the spatial design and layout of the learning space encouraged free movement. Here, children were able to exert agency over their surrounding space by freely walking in the room or picking up sensorial materials as per their preference.

4.3.2.b Design: Practical life activities for imitative play

At M.S.1.0, domestic chores were given prominence and were a part of the programme's Practical Life curriculum. Here, activities from everyday life are designed as object play sessions for the children. The Practical Life material menu is inspired from commonly available household objects, and is designed to give children an opportunity to learn life skills through activities such as using brushes and dusters to clean, watering plants, arranging flowers in a vase, learning how to pour liquids and so on.

In the Infant Community programme, Practical Life activities are designed as transitory object interaction sessions, which eventually help children transition into the next cohort of Children's House. Since the Infant Community is an introductory programme in the Montessori curriculum for children, facilitators from this cohort insist that even children as young as three years of age are introduced to cleaning their space after playing with an object or after completing an activity. The following vignette illustrates this.

Vignette 2 | M.S.1.0 | January 2017

> *"Children in this cohort tidy up constantly. The room is dotted with posters on topics such as movement, self-discipline, communication, and independence. Each child has a dedicated coat hook on the common rack, and a little plastic tray under it with his / her photograph and name.*
>
> *... Initial training for independent movement and the need to clean up after finishing an activity is probably introduced from this cohort at the school."*

4.3.2.c Design: Affordances of furniture

At M.S.1.0, Montessori furniture was designed for comfort and offered appropriate ergonomic support to children and adults. The modernist dictum of *form follows function* is relevant here, where the affordance of the furniture, which is to be comfortable, yet light and mobile, had been successfully translated into its design. Mobile furniture units (such as chairs, tables, stools) are designed with grooves and handles (for support and grip) to help children pick them up and carry them with relative ease. Since the furniture is designed at a scale that speaks to the ergonomics of children's physicality and perspective, it affords playful interaction and instils independent movement.

The absence of grooves and handles in the furniture would make moving the furniture difficult, and children might end up dropping it more often and eventually hurt themselves, which would dissuade them from being independent. The Montessori method, thus, includes a design language of scale and tactility that affords a sense of independence, agency, and responsibility. The design of the furniture also affords taking *safe risks*[44] (Kennedy and Barblett, 2010), which allowed children at M.S.1.0. to shift the furniture around and curate their learning space as per their preference.

4.3.3 Children's House (M.S.1.0)

At the Children's House programme at M.S.1.0, children were introduced to themes such as Practical Life, Cultural Curriculum, languages, mathematics, and creative arts. Similar

44 In the classroom, safe risks refer to the design features of handles and grips, which encourage the act of picking up the furniture without dropping it – thereby encouraging children to be independent and take safe risks.

to Infant Community, the spatial layout of their learning space was designed to afford agency and independent movement.

Figure 22: Vantage point from where I sat. Children's House learning space (M.S.1.0)

4.3.3.a Design: Practical life activities for imitative play

As observed during DE fieldwork, sensorial materials (for example, artefacts such as kitchen sets, garden sets, cleaning equipment and so on) and activities in the Practical Life curriculum for this cohort, were designed to afford imitative object interaction

Figure 23: Practical Life activity corner. Children's House learning space (M.S.1.0)

While on-site, I observed that the design and layout of the learning space also afforded independent movement and self-reliance. Complimentary to this was the requirement to clean up after finishing a Practical Life activity. As discussed previously, the Practical Life curriculum was introduced during the Infant Community programme of the school and taken forward in the Children's House programme. The following vignette visualises the layout and design of the Practical Life learning zone in the Children's House space.

Vignette 3 | M.S.1.0 | January 2017

> *"Today I am sitting in a different section of the Children's House learning space. It has tables and chairs along with extra shelves with Montessorian sensorial materials. These materials are a part of the Practical Life curriculum, which consists of small cutlery sets, ceramic water jugs, miniature versions of woodworking and carpentry tools, mortar-pestle sets, folded tea towels, tablecloths, and floor cloths. This room has been designed to resemble a living room, which has typical artefacts, and objects one would use and display at home."*

Practical Life activities at M.S.1.0 were designed to afford mimetic object interactions, where children were often observed imitating facilitators engaging in a domestic chore, through step-by-step and ceremonial interactions with sensorial materials. Similar to the design language of the Practical Life curriculum, the spatial layout of the Practical Life learning zone was designed to afford systematic interaction with objects, where everything was arranged in a specific order and placed on a specific shelf. It could be argued that the Montessori learning zones, which are designed to support a play-based learning curriculum for young children, in reality resemble a gallery space or a living room, which displays expensive objects (that are protected and arranged in a specific place).

4.3.3.b Design: Cultural Curriculum

Montessori's Cultural Curriculum introduces a range of tools and activities designed to develop a child's understanding of the wider world; puzzle maps, globes, picture and object boxes, and activities built around themes such as global cultures, people, plants, animals, and natural environments. While observing the arrangement of the Cultural Curriculum learning zone at M.S.1.0, I noticed that the signature Montessorian design feature of a wooden knob was visible on most cultural sensorial materials.

Figure 22: Dedicated space for Cultural curriculum in Children's House cohort (M.S.1.0)

4.3.3.c Design: Language and mathematical sensorial materials

The learning zone for languages in the Children's House programme resembled a library space, with a reading corner and books arranged on low-lying shelves. The bookshelves were designed as open shelves which were low in height. These shelves were designed to afford independent movement and agency in children, where children could easily access books. To support activities for language acquisition, all the language materials were placed next to each other, and that space eventually guided children towards the reading area, where they were encouraged by the facilitators to sit and read. Similar to the language learning zone, the mathematics learning zone was also designed to afford independent movement and easy access to all mathematical materials, where all the artefacts, activities, and books on mathematical learning were arranged next to each other on low-lying shelves.

Figure 23: Language tools and reading corner in Children's House learning space (M.S.1.0)

Montessori's sensorial materials are a part of the sensorial zone in the Children's House learning space. It was interesting to observe that, here as well, Montessori's prescribed methods of playing with a specific material in a *Montessori manner* were illustrated and displayed as posters. These posters functioned as instructions and silent cues for the children. The facilitators would point towards the posters, especially when they observed any child interacting with a sensorial material in a *non-Montessori manner*.

Figure 22: Sensorial materials and posters on display at Children's House (M.S.1.0)

4.3.4 Elementary programme

The Elementary programme is closer to a *regular* school syllabus, with more prominence given to subjects such as science, mathematics, languages, world geography, history, and cultural studies. Since this programme consists of children between the age groups of six to twelve-year olds, learning is focused on knowledge acquisition through the use of Montessori's sensorial materials, along with traditional subject materials and assignments.

Similar to Children's House, the Elementary learning spaces have dedicated zones based on subjects and themes taught within the curriculum. The open layout of the Elementary learning space at M.S.1.0. was designed to afford easy access to all the subject zones in the room. Nothing was obstructing, blocking, or isolating any of the zones in this room. Similar to Children's House, this learning space fostered a sense of independence, and children could walk around, pick up materials as per their choice, and settle somewhere to work based on their preference.

The following vignette illustrates how the Elementary programme had a more formal schedule as compared to Children's House. In this vignette, the younger children in the

Elementary programme are sitting as a group with a facilitator and working on a science experiment. They are interacting with general lab experiment tools such as beakers and water jars, instead of engaging with specific Montessori sensorial materials.

Vignette 4 | M.S.1.0 | January 2017

> *"It looks like the children are really excited about this science experiment. Today, they will be learning about the ways in which plants consume water. Their facilitator discusses the phenomenon of how plants "drink" water and asks the children about who waters plants in their houses. She tells them to write down a question this experiment will help answer today, which is "How plants drink water?". The facilitator then picks up a book, holds it in front of the children, and shows them visuals of how this experiment will be conducted. She then requests three children from the group to get glass beakers and fill them with water.*
>
> *The facilitator holds up a board with the question written in block letters to help children copy the question in their worksheets. She shows them carnations and explains that all kinds of flowers would work in this experiment as long as they were white. She then hands out individual carnations to the entire group. Then, she points to the beakers full of water and food colouring and questions them about why one would need food colouring in this experiment.*
>
> *The younger children are drawing their equipment visuals onto their worksheets. They are discussing the colours used in the beakers for the flowers and waiting for the rest of the group to be done with their sketches.*
>
> *The facilitator then discusses the 'method' of conducting the experiment. Each child chooses a flower stem and selects a specific coloured water beaker to place the flowers in. The children discuss their colour preferences amongst themselves. Then, they write and draw the process of conducting the experiment in their worksheets. The facilitator asks one of the girls if she should show them how to write the process on a small whiteboard. The girl agrees, saying that this might help everyone. The facilitator then writes the method on the whiteboard, using bold, block-letter handwriting and gives it to the girl to be used as a reference. The children continue to observe the flowers. The facilitator slices a stem in half and asks the children what would happen if she places this split stem in two different coloured water beakers?*

As illustrated in the vignette above, despite not using any specifically designed sensorial materials in this scenario, the facilitator guided the children through a step-by-step process of preparing an environment to begin the experiment and then conducted the experiment with the children. The facilitator encouraged the children to ask questions so that she could address their queries and doubts about the experiment.

The Elementary programme adapts characteristics of a traditional Montessori school curriculum, and also integrates elements of traditional schools and teaching methods. The facilitator in this cohort embodied the role of an instructor and teacher (as seen in the vignette), where she instructed children throughout the experiment, instead of letting the children engage with the activity independently.

4.4 A summary of DE findings: Scotland

On-site DE fieldwork at M.S.1.0 in Scotland revealed how play-based learning sessions and learning activities are designed to support a prescriptive play-tutoring format by providing access to suitable tactile props and artefacts (puzzles, colour, natural materials like water, clay, and matching pattern games, amongst others) to engage in object play. The following section presents a summary of DE findings at M.S.1.0.

4.4.1 Facilitation formats

Montessori, in her work *The Absorbent Mind* (Montessori, 1969), elaborates on the role of a Montessori-trained facilitator. As per the Montessori method, a Montessori facilitator must prepare the play environment for inquisition and independence to help the children transition from one activity to another. The facilitator must give the children space and opportunity to learn from their own discoveries and outcomes. Montessori (ibid) also argues that a Montessori facilitator must focus on an individual child as an individual, instead of planning daily lessons and syllabuses for the entire cohort, since the interests of the child might change based on mood and behaviour, which is more relevant and necessary for a facilitator to keep track of.

Facilitators at M.S.1.0 school were constantly transitioning between roles of a guide, a teacher, a problem-solver, and an observer. At this school, children were comfortable while interacting with their facilitators. It was observed that, whenever children needed the help or guidance of one of the facilitators, they could walk up to the facilitator and place their hands on the facilitator’s shoulder or touch their arms lightly, instead of calling out to them. This gesture got the facilitator’s attention, and the children would receive the necessary assistance.

4.4.2 Language acquisition

Fieldwork at M.S.1.0 showed no collective demonstration or presentation of Montessori materials for language acquisition. Instead, most children were individually working with language materials, often in complete silence. However, activities were designed within the curriculum during *circle time* for children to practice communication skills collectively with the help of poems and rhyming exercises.

4.4.3 Circle time

During circle time, children and facilitators sit in a circular formation. This gives the children an equal view of each other and the person leading the circle, and simultaneously gives the person who leads the circle a complete view of all the participating children. Circle time at M.S.1.0. consisted of activities such as poem recitation, sing-alongs, discussions about the daily schedule, sharing information, reading books, and so on. Since this was the only time when children collectively engaged in a discussion, recited poems, and communicated with each other, it could be argued that circle time additionally afforded speech and language development. Circle time was also designed for musical training in the Infant Community cohort, where children and facilitators sometimes sat together and played musical instruments. Circle time at the Elementary programme was designed as a common platform, where the facilitators and children would sit together and plan their schedule for the day.

4.4.4 Geometry material menu

While on-site M.S.1.0, I was informed by one of the facilitators that specific play activities in the geometry material menu are designed to help children discriminate between different forms of geometric shapes by affording the training of visual and tactile senses. Additionally, play activities from the geometry material menu also prepare children for mathematical exercises to help them progress to older programmes such as Elementary.

Figure 23: (L to R): Geometric Solids and Geometrical Cabinet (M.S.1.0)

Vignette 5 | M.S.1.0 | January 2017

> *"A child is trying to build a structure out of triangle solids and plains from the Blue Geometric Solids set. He tries to interact with the solids by engaging in block play. It looks like he is interested in designing a structure of some sort using these solids but looks unsure about how to proceed.*
>
> *He seems to be having an internal conversation with himself while trying to understand why his structure is not able to stand. He walks towards the geometry shelf and starts to arrange the blocks back on the shelf very carefully. The shelf also consists of stands designed to specifically place the curved solid materials such as the sphere and oval, without them falling off. It seems like the child appears to view these sensorial materials as expensive artefacts that need to be displayed systematically on the shelf."*

What was compelling about the interaction mentioned in this vignette was that the child was very cautious while trying to build a structure out of the sensorial materials. The interaction with the geometry materials was short-lived, as the child only constructed a structure to a certain extent, before giving up. It wasn't apparent if the child had understood the differences between the different visual forms and shapes of the structure designed by him before giving up and placing the solids back on the shelf.

It could also be argued that what dissuaded the child from engaging in exploratory object play with the geometry materials was their high price value, which led to the cautious and almost distant engagement with the materials. On-site observations at M.S.1.0 revealed that the children were constantly reminded to not *ruin or break* the sensorial materials. On-site fieldwork and observing interactions with the geometry materials demonstrated that activities designed to interact with these materials did not evoke social play, engagement, focused object play, experimentation, or elicit any inquiries from the children.

4.5 Section Two: India

According to Wilson (1987), the Montessori method had been largely promoted by affluent and urban elite educational groups in India who could afford her expensive sensorial materials. However, in India, Montessori was urged by Mahatma Gandhi to design materials based on the socio-economic conditions of villages in India (ibid). Gandhi's request sought to ensure that the Montessori curriculum made preschool education available to the majority of Indian children. This took place during the period when *pre-basic education* was promoted in rural parts of India, largely through voluntary effort. Wilson (ibid) argues that, despite having spent a few years in India while developing her method, Montessori appeared to have given little consideration to its application amongst India's low-income population groups[45].

Kaul and Sankar (2009) argue that influenced by Montessori's visit and based on her designed curriculum, Gijubhai Badheka and Tarabai Modak established Preschool Education centers across the state of Gujarat, in India.

The current landscape of play-based learning has garnered a lot of popularity within the Indian education system, especially in southern India, where a lot of certified Montessori Schools have recently emerged. Advertised as being progressive, play-based, and child-centred, the Montessori curriculum appeals to the middle-class aspirations of urban India.

4.5.1 Play legacy of Arvind Gupta in India

The current landscape of early childhood education in India is generally working towards incorporating play-based learning as a pedagogic method. Arvind Gupta, an India toy inventor with an engineering background, has revolutionised play-based teaching in India by introducing his repository of toys designed from readily available play materials to teach children basic scientific concepts. Gupta has also adapted the design language of Fröbel and Montessori, along with employing his engineering education skills to design affordable play artefacts and toys for children.

45 Maria Montessori's journey through India and her influence on the Indian education system has been extensively discussed in Montessori in India by Caroline Elizabeth Wilson (1987).

According to Gupta (n.d.), a good toy affords construction and dismantling; "being taken apart and put back together". He has adopted principles of STEAM and engineering with a constructionist approach to teach children scientific concepts by constructing toys; for example, a simple periscope constructed out of a cardboard box (Silverberg, 2011).

Gupta[46] has conducted play workshops with children and teachers across India, and introduced his toys and play materials on international platforms such as TED Talks and at the LEGO Idea Conference in Billund in 2018. Gupta believes in a constructionist approach to imparting knowledge on scientific concepts. According to him, "All children love toys, so they are motivated to make them. Most of them pick up the skill quite quickly. Others learn by seeing their friends" (Gupta, as transcribed by Silverberg, 2011). Gupta's work is relevant to understanding pedagogical play in the Indian educational landscape, as he employs methods of designing and constructing playful tools using cheap, affordable, and readily available materials to incentivise schools to adopt multi-sensorial, engaging, active, and accessible approaches of play-based learning.

4.6 DE Fieldwork: India

For the DE work in India, on-site fieldwork was undertaken at two Montessori schools. The first school is a relatively new Montessori School based in Bangalore, southern India. Moving forward, it is termed as Montessori School 2.0[47] or M.S.2.0. The second school is based in Pune, in western India. It is hereafter known as Montessori School 3.0[48] or M.S.3.0.

The following sections on my DE findings from India first introduce the differences between M.S.2.0 and M.S.3.0. After discussing reflexive ethnographic encounters met in my fieldwork, I discuss the similarities and differences in fieldwork findings between M.S.2.0 and M.S.3.0 in terms of daily curriculum and learning zones, spatial layout of the learning space, affordances of kinaesthetic learning, Montessori and Non-Montessori artefacts, and language materials.

46 Arvind Gupta's work of designing around 700 different models of toys from trash, is available as free access on his website: http://www.arvindguptatoys.com/
47 The name of the school is anonymized in compliance with Edinburgh Napier University's data protection policy.
48 The name of the school is anonymized in compliance with Edinburgh Napier University's data protection policy.

4.6.1 Montessori School 2.0 (M.S.2.0)

M.S.2.0 is based in Bangalore and has a student community of around 90 children. They run four programmes at this school:

- Nido or the Infant/Young Toddler programme (children between the ages of twelve and twenty-four months).
- Pre-Casa Toddler programme (children between the ages of eighteen months and three years).
- Casa or the pre-primary programme (children between the ages of three and six years).
- Lower Elementary (children between the ages of six and nine years).

I completed two weeks of on-site fieldwork at M.S.2.0; six days observing the Lower Elementary learning spaces and three days with the Casa cohort. My fieldwork at the M.S.2.0 primarily consisted of observing learning spaces in progress throughout the week for two weeks. While on-site, I would sit in any unoccupied section of the learning space, and record observations in the form of written descriptions, photographs, and sometimes video.

Interestingly, at M.S.2.0 I was allowed to take some photographs and record videos of the play-sessions, while following strict guidelines of Edinburgh Napier's research framework and ethics committee. In the rare case that I recorded videos or took photographs, consent was approved beforehand, and the children were anonymised. The photographs and videos were also framed in a way where they only focused on the hand movements and gestures of the children interacting with the sensorial materials. At M.S.2.0, I was allowed to walk within the learning spaces and could keep changing my position to sit closer to activity zones, as long as my presence did not disturb the classroom activities.

4.6.2 Montessori School 3.0 (M.S.3.0)

M.S.3.0 is based in the city of Pune and runs a single Montessori programme for children between the ages of two and six years. At M.S.3.0, I had to occupy a non-intrusive position and was not allowed to move within the learning spaces. Similar to M.S.1.0, this limitation led to difficulty in accessing specific activity zones within the learning space and observing play sessions. M.S.3.0 did not allow photography, video recordings, or any forms of technology (iPad, laptops, mobile phone, or cameras) in the learning spaces during school hours. However, I was allowed to take some photographs on my first day, before the school sessions began.

I was initially allowed to undertake fieldwork for two weeks at this school, which was then suddenly reduced to a week at the request of the school administration. Subsequently, I spent a week at this school, during the morning sessions, and was allowed to sit in two of the Casa learning spaces for two days each and spend one day with the Nido cohort.

Both the Montessori schools (2.0 and 3.0) are recognised by the Indian Montessori Foundation. On further on-site fieldwork at these two schools, I observed that there were striking differences in the way Montessori's curriculum and theories had been adopted in comparison to M.S.1.0. in Scotland. The next section is an account of the fieldwork undertaken at M.S.2.0 and M.S.3.0 in India.

4.6.3 Reflexive ethnographic encounters in India

An uncomfortable and awkward situation arose at M.S.2.0 when I was trying to dissuade children from interacting with me during their play sessions. At M.S.2.0, some children were excited to see a new member in their learning spaces, which fed their curiosity and sometimes disrupted their play sessions. One child in particular would often run up to me when the facilitator wasn't looking and peek over my shoulder, poke me, sometimes pick my notebook up, and see what I was doing.

This added to my awkwardness and discomfort as I did not want to cause any disruption in their school schedule. I was also worried that this might lead to the school administration cancelling my on-site fieldwork at their school in order to avoid disruptions in their classrooms. As a result, despite the child's insistence that we chat and talk, I tried my best to ignore the child during school hours. However, I did interact with the child and ask about their favourite play activities at school during their break time. I engaged in an informal and friendly conversation with the child, hoping that I was not perceived as a negative and unfriendly presence in their learning space.

4.6.4 Design: Daily curriculum and learning zones

In the following section, I have elaborated on the nuances and reciprocity of syllabus, schedule design, and spatial layouts of Montessori Schools India.

At M.S.2.0, every hour at the school was planned and scheduled for specific activities. While this school followed the Montessori curriculum of introducing sensorial materials in a prescriptive manner, the choice to work with a specific material or on a specific theme was decided by the facilitator and not the children. At this school, all the cohorts (except for the Nido programme, which was also a nursery) followed a curriculum calendar that was a combination of outdoor play, physical education (PE), presentation time in learning spaces, and time slots for self-study. Unlike the theoretical Montessorian approach as introduced earlier in this thesis, learning spaces and the curriculum at M.S.2.0 did not afford independent movement, and freedom of activity or object selection, by the children.

Each week before the school began, the facilitators would plan activities for the children. The curriculum for each day (9 am to 3 pm) was divided into various themes. Children would usually arrive at M.S.2.0 between 8.30 am and 8.45 am, where they would await further instructions from their facilitators and meanwhile play at the jungle gym (constructed within the boundary walls of the school, see Figure 27). Then, by around 9 am, the children would be instructed to form a queue and systematically taken to each of their learning spaces, led by the head facilitator, and a few assistants and helpers.

Morning sessions began from 9 am every day, where the children typically spent about an hour practicing alphabets through phonetic songs. This was followed by poem recitation and stretching exercises till about 10 am. After this, time was allocated for revision of spellings, phonetics, and mathematics. At 10.30 am, presentation time of materials would begin. Here, the facilitators would prepare the play space for the activity; they would systematically arrange the sensorial materials on cloth mats and ask the children to sit around them in a semi-circular formation. After the presentation of sensorial materials, the children would be divided into groups and given individual sensorial materials to interact with. The facilitators led these sessions and the schedule was devoid of any free time.

Figure 24: Outdoor gym and play-area (M.S.2.0)

After presentation time, children would have a snack break and then move on to learning languages (Kannada and Hindi), colouring, art and craft, or PE till about 1 pm (depending on the day of the week). After their lunch break at 1:30 pm, cultural activities or story-telling sessions would be organised till 2:45 pm, after which the school session would come to an end. The last fifteen minutes or so after the end of a formal school day were allotted for free play, where the children could access the small jungle gym.

At M.S.3.0, I was on-site from 8.30 am to 11 am for five days. Here, I observed that the daily curriculum of M.S.3.0 was relatively free, compared to M.S.2.0. At M.S.3.0, children would walk up to a shelf in their learning space and pick up a material, or a group of two to three children would pick up an activity. Unlike M.S.2.0., every hour was not planned for an activity at this school. At M.S.3.0, the facilitators were not as involved or in sync with how the children were interacting with the materials. Often, the children were left alone to interact and play with the materials without any guidance or involvement of the facilitators.

4.6.5 Design: Spatial layout of the learning space

At M.S.2.0, I had the opportunity to observe two different cohorts within the school; the Lower Elementary and the Casa cohort. The school itself was built inside a residential bungalow which had been redesigned to function as a formal learning space.

The spatial layout of the Casa and Lower Elementary learning spaces at M.S.2.0 was designed to afford functionality, frugality, and space management, unlike M.S.1.0 in Scotland (see Figure 28). The Lower Elementary and Casa learning spaces were designed to allocate space for presentation time and circle time activities. Maximum free space was allotted in the middle of each room for the children to bring their mats forward and arrange the sensorial materials on the floor over a mat during individual material interaction time (which was, again, pre-decided by the facilitators). Both the learning spaces of the Lower Elementary and Casa cohorts had low-lying shelves which displayed the sensorial materials.

Figure 25: Layout of the Casa learning space (M.S.2.0)

Smaller individual tables (called *chaukis* in Hindi) were stacked on top of each other and arranged in one corner of the learning spaces. A facilitator once mentioned that children had a tendency to write on these tables, which is why all the tables were covered with newspapers to protect them. Apart from the smaller tables, a few larger tables and chairs were arranged along two corners of every room to provide additional space for children to read books or work in groups. There were wooden baskets in each room to hold all the Montessori mats which were used during presentation time. These learning spaces (in terms of basic layout and arrangement) resembled standard classrooms of a functional lower primary school.

Unlike M.S.1.0, the learning spaces here were not segregated into specific thematic zones such as sensorial, mathematics, languages, and so on. All the materials were arranged next to each other in a very space efficient manner.

Figure 26: Elementary learning space (M.S.2.0)

The learning spaces at M.S.3.0 were named after flowers such as *Marigold, Iris, and Tulip,* and their internal layouts resembled the learning spaces at M.S.1.0 in Scotland. The learning spaces at M.S.3.0 were large rooms with learning zones designed for specific themes such as sensorial learning, mathematics, Practical Life, and so on. The room itself was divided into sections with shelves acting as enclosures for these specific zones. The spatial layout of the learning spaces at M.S.3.0 afforded independent movement for children, similarly to M.S.1.0. Sensorial materials at M.S.3.0 were arranged to afford easy access on open-shelves and children had the freedom to pick-up any material to engage with, similar to what was observed at M.S.1.0.

Figure 27: Learning spaces at M.S.3.0

4.6.6 Design: Affordances of kinaesthetic learning

At M.S.2.0, in both Casa and Lower Elementary cohorts, I observed that phonic songs, poems, and circle time activities were crucial to introducing an element of playfulness and engagement for the children. Every morning, an hour was spent reciting the phonic alphabet song, and a series of other poems based on themes like happiness, learning about animals, and word associations.

The morning alphabet song or the *“Aa, Ba, Ca, Da…”* song was designed to introduce alphabets as phonic sounds to the children. Often during the recitation of this song, a few children would be asked to come to the front of the class and conduct the song along with the facilitator, while the rest of the children would sit in a semi-circular formation and repeat the song. The facilitator would write the alphabets on a whiteboard in English, which the children would follow as they sang the song.

After reciting the alphabet song a few times, the children would then sing this poem called *A Beautiful World* by Jack Hartmann. This poem was written in a manner that introduced new words and their meanings to children. Words along with their meanings and supporting hand gestures were introduced to the children in a rhythmic sequence during this song, which helped them memorise new words and their meanings (for example, the use of sentences to describe typical characteristics of specific objects such as the following: “guitars are strumming, tails are wagging…”). This poem was recited everyday by the facilitators and the children together.

At M.S.2.0, while introducing mathematical concepts such as addition to children, the facilitators would employ the term *“along with”* and simultaneously bring their hands together to signify addition and unification. Another example was while introducing the concept of *greater than-lesser than numbers,* where the facilitators would create a hand gesture using their thumb and index finger that resembled the sign ‘<’, while simultaneously employing it in this narrative: “let’s visualise a crocodile with its mouth wide open eating a larger number; where the shape ‘<’ of the crocodile’s mouth signifies the greater than sign in mathematics”.

At M.S.3.0, the facilitators would often sing folk songs, poems, and patriotic songs with the children. I was familiar with some of these patriotic songs as they were taught at my school during my formative years in India. Most of the patriotic and national songs convey a historical account of India’s struggle with the British Empire and the eventual war for India’s Independence. Children across all Indian national and regional schools are usually introduced to these songs and poems to introduce them to India’s history.

Based on on-site observations undertaken at M.S.2.0 and M.S.3.0, it can be acknowledged that poems and songs appeared prominently at these Montessori schools. As playful and active learning approaches, these poems and songs afforded narratives and story-telling, which helped children learn new words, word associations, and also be introduced to India's history (here, referring to the patriotic song sessions at M.S.3.0). Facilitators often employed hand gestures and playful imitations during these songs and poems to visualise some of the lyrics, which afforded kinaesthetic learning to support acquisition of new words and concepts.

4.6.7 Design: Montessori and Non-Montessori artefacts

Conventional Montessori sensorial materials such as the Pink Tower, Brown Staircase**,** Smelling Bottles, Binomial and Trinomial Squares, Red and Blue Rods, Decanomial Squares, Knobbed and Knobless Cylinders, Abacus Kits, and Spelling Boxes were visible at both the Indian Montessori schools, and children spent time interacting and playing with them. Additionally, locally adapted and locally designed Montessori materials were also visible at both these schools.

Apart from Montessori's sensorial materials, artefacts such as workbooks, diaries, colouring material, videos, maps, globes, puzzles, and games were also employed during presentation time at these schools. At M.S.2.0, I observed the use of LEGO Duplo[49] bricks to teach mathematical equations such as *greater than-lesser than*. Play objects such as soccer cones, footballs, tennis balls, hoopla rings, and so on (which are not traditional Montessorian artefacts) were a part of the PE curriculum.

At M.S.3.0, I observed the use of locally designed sound toys and shaker toys, which were a part of the music section in some of the learning spaces. These artefacts were not Montessori's sensorial materials, but a part of specific music activities.

49 LEGO Duplo bricks are a subset of traditional LEGO bricks. They are double the length, width, and height of traditional LEGO bricks. Their larger size makes them easier to handle and safer to play with (as children are less likely to swallow them). Despite their size differences, these bricks are designed to be compatible with traditional LEGO bricks.

Figure 28: Traditional shaker toys (M.S.3.0)

While conducting on-site research at M.S.1.0 in Scotland, I had initially come across Montessori artefacts such as jugs, jars, and kitchen utensils to help children develop their gross and fine motor skills during Practical Life activities. These activities were a part of the Indian Montessori school curriculum as well. At the Indian schools, traditional kitchen utensils were employed to recreate the activity of pouring liquids from one container to the other, while avoiding spillage, to develop motor skills. Instead of the glass tumblers, jugs, milk pots, and wooden spoons seen at M.S.1.0., utensils such as copper and steel coffee tumblers (iconic to south Indian kitchens) and brass pots were visible at M.S.2.0 and M.S.3.0 (see Figure 32). Instead of sand, lentils and semolina were used to design sensorial trays for children to practice writing alphabets during language sessions.

It could be said that a *vernacular language of play* occupied the same space as the formalised language of Montessori's sensorial materials. Here, non-Montessori materials were designed and collectively adopted within Montessori activities, to create hybrid forms of play.

Figure 29: Locally adapted Montessori tools (M.S.2.0 and M.S.3.0)

4.6.8 Design: Language materials

Unlike M.S.1.0 in Scotland, where English is the main language of instruction, children in Indian schools are taught other languages. The first language of instruction is often English, the second is usually Hindi (if the school is located in the central, northern, or western regions of India), or Kannada, Tamil, Malayalam, or Telugu (if the schools are based in southern regions of India). Apart from these languages, children often speak an additional language at home, which might be regional, based on where the children's families have grown up, or what religion they practice at home. These could range from other Indian national languages like Marathi, Gujarati, Punjabi, and Bengali to regional dialects. As a result of this, Montessori materials for language study in India have been redesigned to be compatible with the written scripts of a variety of Indian languages.

At M.S.2.0, children could learn either Hindi or Kannada as a second language. The Lower Elementary cohort had language sessions twice a week, where they could choose to learn either of the two languages (both verbal and script). Here, it was observed that Montessori's Sandpaper Letters and Knobbed Alphabet Insets were redesigned to comply with the Hindi and Kannada script (Hindi and Kannada use different written scripts). At M.S.2.0, Hindi was taught in a manner similar to traditional Indian schools. Children would be asked to recite alphabets and repeat pronunciations with a facilitator, and then learn common words through themes such as colours, times of the day, numbers, and so on.

Figure 30: Montessori's language tools adopted for Kannada and Hindi (M.S.2.0)

Some of the facilitators who organised the Kannada language sessions at M.S.2.0. explained that similar to Hindi, Kannada is a phonetically constructed language. Both Hindi and Kannada work in compliance with the Montessori curriculum as they focus on sounds and phonetics instead of letters. As a result of this, children learn the second language with relative ease, as they are taught to write and spell sounds in an integrated manner to avoid confusion. They are taught to deconstruct spellings based on sounds, which helps them memorise, and learn how to spell and write, words.

Unfortunately, I was unable to sit in any of the language sessions at M.S.3.0 due to my restricted seating arrangements while I was on-site. However, based on overhearing some of the presentations across the learning spaces while I was on-site, I was able to deduce that this school also taught languages such as Hindi, Marathi, Gujarati, and Tamil to the children. I once overheard a facilitator reciting a poem to some of the children in Hindi, and then repeating each sentence of the poem in Gujarati, Marathi, and Tamil to illustrate the differences between each of the languages.

4.7 A summary of DE findings: India

4.7.1 Facilitation formats

Montessori, in her accounts of expected behaviour from the facilitators, insists that the facilitator should be very careful as to not disturb the child when he or she is deeply engaged in interacting with a material. However, based on Montessori's prescribed framework, it is also important to guide or direct the child if he or she is not interacting with a material in a manner prescribed in the Montessori method.

Facilitators at M.S.2.0 had to essay the role of an instructor and a disciplinarian, as well as an activity coordinator. They were involved in every aspect of scheduling a cohort's activities for the day. They had to prepare for presentation time before every scheduled interaction with the cohort and follow the interactions prescribed in the Montessori method. They were also assigned with the role of guarding the sensorial materials at all times, not allowing for any independent interaction with them. The following vignette illustrates this observation:

Vignette 6 | M.S.2.0 | July 2017:

> *"This learning space functions as a 'typical' school, with a clear divide between the roles of the facilitators being knowledge-givers and children being the knowledge-receivers… Material allocation depends on the facilitators. Children cannot choose a sensorial material and engage with it independently."*

M.S.2.0 also had a few children with special needs who were enrolled in their learning programme. Some of the facilitators were trained nurses, who were brought onboard to supervise and help these children. However, they were trained as medical professionals and had little to no knowledge about the Montessori method. During a conversation with one of these trained nurses at M.S.2.0, I was informed that some of the children with special needs were lacking in their developmental stages, and it was difficult for them to even hold and handle the sensorial materials, let alone engage in active interactions with them. The facilitators were worried that these children might need specialised schools and more focused help, which the current learning framework was unable to provide. The lack of specialised Montessori facilitators trained to guide children with special needs made it challenging to focus on their interactive, learning, and sensorial needs.

At M.S.3.0 school, apart from the main counsellor and a few senior facilitators, none of the other facilitators were trained in the Montessori method, despite the fact that this was a certified Montessori School. It was visible how different levels of the facilitator's training produced different relationships with the sensorial materials. When a facilitator was not knowledgeable about the Montessori method, or was unaware about the affordances of the sensorial materials as defined in the method due to lack of training, it affected the way children engaged with the sensorial materials. The following vignette from the on-site notes illustrates my confusion over the way this school was managed:

Vignette 7 | M.S.3.0 | July 2017:

> *"The difference between a school with trained teachers and a school with untrained teachers is highly noticeable. There is an overall lack of understanding of the materials, and how they are supposed to be presented or introduced to the children as per the Montessori method. I notice that children are often interacting with a material aimlessly. There is a lack of purposeful play. There is independent interaction, but the use of most materials is not self-evident to the children, which might hinder their learning curve. I can also notice that no one documents their work or completed tasks, unlike the previous sites."*

4.7.2 Language acquisition through multisensorial play

Similar to the discussion at M.S.1.0, time constraints made it difficult to observe language acquisition from start to finish at the Indian schools. However, since I was observing schools that were teaching multiple languages, it was interesting to see the adaptation of Montessori's language acquisition method for English for other languages.

In the following table, Montessori's language materials are initially evaluated by outlining which of her designed tools and activities were observed in use across all the three sites:

Table 6: On-site DE interactions with language materials and activities (here active use is highlighted in grey)

Language tools and activities	**Montessori School 1.0**	**Montessori School 2.0**	**Montessori School 3.0**
Cursive Alphabet Tiles	■	■	■
Object Box and Picture Cards	■		
Word Cards	■	■	■
Spelling Hangman	■		
Poems and Sing-Alongs	■	■	■
Phonic Alphabet Songs		■	■
Nursery Rhymes	■	■	■
Phonetic pronunciations		■	■
Learn Spellings with Phonetics		■	■
Hindi Alphabet Tiles (with Knobs)		■	■
Hindi Activity Book		■	■
Kannada Alphabet Tiles (with Knobs)		■	
Pink Language Series		■	
Activity Sheets Puzzles		■	
Name, Place, Animal, Thing – A scaled-down farm model		■	
Story Time		■	
Blue Series (Blends) With Object and Picture		■	
Large Movable Alphabets	■	■	
Sketching alphabets on a Semolina Tray		■	
Sandpaper Alphabet Tiles	■	■	■

On-site fieldwork across all three sites revealed active interaction and object play with Montessori's language materials such as Cursive Alphabet Letters, Object and Picture Boxes, Large Movable Alphabets, and Sandpaper Letters. While children at M.S.1.0 would engage with these tools individually or along with a facilitator, children at M.S.2.0 and M.S.3.0 were introduced to these tools as a collective cohort during a time slot (predefined in their daily schedule) dedicated to language acquisition.

During presentation time at M.S.2.0, facilitators would introduce language materials such as Object and Picture Boxes to match spellings to visuals or introduce Montessori's Large Movable Alphabets to teach children basic spellings in a step-by-step manner. While introducing these language materials, facilitators would reiterate specific phonetic sounds based on the chosen alphabets to help children associate these sounds to specific visuals (see Figure 34). Facilitating children in a large group instead of giving individual attention to each child is not prescribed in the Montessori philosophy. However, when facilitators did present language materials to a cohort, they followed the Montessorian prescribed step-by-step process of introducing a specific sensorial material or activity through presentation time.

Figure 31: Guided and individual interaction with language materials after presentation time. (M.S.2.0)

As illustrated in the following vignette at M.S.2.0, while practicing their handwriting skills, children always chanted phonetic pronunciations of alphabets and referred to the phonetic alphabet song.

Vignette 8 | M.S.2.0 | July 2017

> *"They are learning words with "sh" (pronounced as 'sha'). Here, the spelling of the word 'fish', for example, is broken into three sounds and read as "pha - eee - shhh - fish". The facilitator passes a sheet of paper with some words to the children, requests children to recite a specific spelling using phonemic sounds and helps them when they seem to be stuck."*

Here, the facilitator led the activity and the cohort essayed the role of an audience, where each child would be subsequently assessed while working on the same activity individually. The facilitator led the session within a designed play environment with the help of language materials, which the children were not allowed to touch or interact with during presentation time. Once the presentation ended, children were allotted separate materials and allowed to engage with them.

As mentioned earlier in this chapter, I also had an opportunity to observe how other national languages such as Hindi and Kannada were taught in a Montessorian manner at M.S.2.0, and was able to document interactions with language materials designed exclusively for Hindi and Kannada based on Montessori's design framework. In the following vignette, I discuss how Hindi was taught to children from the Lower Elementary section at M.S.2.0.

Vignette 9 | M.S.2.0 | July 2017

> *"Children are introduced to the 'Varna Mala'- a list of Hindi alphabets. A second facilitator comes into the classroom and helps the head facilitator with this lesson. They proceed to teach numbers in Hindi and then introduce words about human anatomy. The method of teaching Hindi is similar to how all children are taught Hindi in any conventional school in India. This is how I was taught Hindi in school as well. The head facilitator teaches children basic sentences in Hindi and asks them to respond in Hindi. They then move on to learning about the names of colours, known as 'rang' in Hindi. The facilitator uses an activity book to help children identify these colours and associate them to their Hindi translations. She then recites the names of the colours in English and the children repeat after her by translating the words in Hindi.*
>
> *They move on to writing and practising alphabets in Hindi. Some of them sit on the bigger tables while a few choose to sit down with individual tables. They are practising the Hindi alphabet 'E' (pronounced 'iii').*
>
> *The children begin the activity by tracing the form of the alphabets on pre-printed sheets and then write them on a blank sheet of paper, mimicking the hand movement of tracing the letter earlier. Here, they begin to memorise the movement required to write that specific alphabet. The children start talking in 'Hinglish' in this class on purpose since they can use newly learned words in Hindi and add them to familiar, commonly spoken English sentences."*

Figure 32: Montessori's Sandpaper Alphabet Tiles designed to teach Hindi. (M.S.2.0)

As mentioned earlier in this chapter, I was informed that Hindi and Kannada were taught in a similar manner. M.S.2.0 had access to materials designed to replicate the affordances of Montessori's tactile language materials; Sandpaper Letter Tiles for Hindi and Wooden Alphabet cut-outs with knobs for Kannada. Along with Montessori's language materials, activity books, activity sheets, and alphabet charts were employed to support the learning process. Here, facilitators presented the step-by-step process of interacting with the language materials. They began by tracing their fingers on the rough texture of the Sandpaper Alphabets and repeated the same movement on semolina trays. This tactile interaction with the language materials was undertaken simultaneously while reciting each alphabet phonemically.

This interaction was followed by practising writing skills on semolina trays (to trace letters with their fingers in metal trays filled with semolina; semolina resembles sand texturally) to comprehend the visual form of the alphabets. After engaging in tactile interaction with the semolina trays, the children would progress to reading skills at the end of each presentation time slot.

Despite designing language acquisition activities for a large cohort of children (a non-Montessorian practice), instead of engaging with each child individually, the presentations themselves were highly defined and designed to follow Montessori's process of language acquisition. Sensorial materials such as the Sandpaper Letter Tiles and Wooden Knobbed Alphabets guided the activity of introducing the children to languages, where they could engage in object play and interaction with the language tools, before documenting their learning outcomes in activity books. Repetitive phonemic recitation of every alphabet while physically tracing the alphabets on semolina trays and then engaging in object play with other language materials helped the children memorise the sound of the alphabets and associate them with their visual form (refer to Figure 35).

4.7.3 Kinaesthetic learning and circle time

As discussed earlier in the chapter, DE fieldwork also brought to light the reliance on kinaesthetic stimuli by the facilitators to support presentation time. Mimetic hand-gestures were adopted during presentation time. Facilitators would enunciate slowly and use hand-gestures to teach concepts.

Circle time is a prominent feature of the Indian Montessori curriculum. While active participation was observed during circle time**,** there were no sensorial materials in use. During circle time, learning took place through diverse modes of engagement through collective tasks, interaction with peers, and active participation (dancing, socio-dramatic play, playful hand gestures, high pitched voices while singing). Lack of visual and tactile interaction with objects and sensorial materials was compensated by singing and talking in unison.

Figure 33: Kinaesthetic learning (hand gestures) during circle time. (M.S.2.0)

Activities such as circle time were designed with a framework that encouraged active participation and communication through affordances of sociality (Warren, 1982; Gaver, 1996), where the prepared environment[50] presented opportunities for social interaction and simultaneously developing language skills. Circle time, despite its clear order of play (the facilitator led each circle time session in a step-by-step manner), also extended agency towards the children as it requested their involvement. Children had a voice and could freely discuss any issues, concerns, and clearly state their opinions to their peers and facilitators during circle time. The designed structure of circle time afforded trial and error (tinkering in the semantic sense) and manipulation of its content and context, based on day to day demands of the school's schedule, unlike any other activity designed within the Montessori curriculum at the Indian schools.

50 Prepared environment in this case consisted of children and facilitators sitting in a circular formation and being able to interact with everyone collectively.

4.7.4 Geometry material menu

During DE fieldwork across the Indian sites as well, I observed limited instances where children were interacting with the Geometric Cabinet and Geometry solids. In comparison to the language acquisition activities, the Geometric Cabinet and Geometric Solids were not as popular or engaging as sensorial materials with the children. The following vignette demonstrates the monotonous and passive quality of these activities, where two children try to add an element of playfulness and absurdity by troubling the facilitator who is supervising them.

Vignette 10 | M.S.2.0 | July 2017

> *"Here, the facilitator shows them to use the pincer grip (middle and index finger with thumb) to pick each shape inset up and then place it back. She constantly calls the child's name to get his attention, but he looks completely distracted. He eventually catches up, traces the negatives of the shape inset and picks each shape using the pincer grip, while trying to say each shape's name. While another child is trying to work with the shapes, the first one seems to be constantly disturbing the process.*
>
> *Sometime later…*
>
> *The two children are still working with the shapes. One of them often likes to skip the step of tracing a shape and directly likes to insert the shape into the frame. The facilitator keeps stopping him so that he completes all the steps. He laughs loudly when he skips a step, and enjoys seeing the facilitator laugh and shake her head when he skips a step on purpose."*

As observed on-site, activities designed to engage with the Geometric Metal Shape Insets or other shape materials did not incentivise playful exploration and ideation, despite being designed to potentially enrich a child's understanding of differences in geometric forms and spatial knowledge. Unlike language acquisition, which was designed as a multi-sensorial design process to afford object play, social play, and sensorial training, activities designed to support acquisition of geometry lacked that depth of exploration and design thinking.

4.8 Chapter summary

DE research was undertaken across three different Montessori schools in Scotland and India to gain both global and local understanding of Montessori's play-based curriculum. Montessori's global menu is common to India and Scotland, and a comparative analysis was logical to draw parallels across Montessori's culturally adapted learning environments. By observing educational experiences in-situ, and specifically the ways in which learning through play relates to objects, spaces, and structures of play, cross-cultural DE helped capture the ways in which distinct Montessori learning environments afford distinct modes of play.

A dominant observation during DE was the universalised design language of prescription and specifically structured play activities across all three schools. Despite the differences in facilitation frameworks and the design of schedules across all schools, reliance on prescriptive interactions was apparent. There were limited sensorial materials that were culturally adapted or altered to suit local needs; they mostly consisted of language tools or activities in the Practical Life curriculum, which could be a part of that country's way of life; for example, the use of locally available cutlery and utensils to train motor skills in children, where the activity essentially remains the same, but materials or 'props' used to support that activity differed from place to place.

In order to further examine the implications of design and design thinking in the Montessori environment, the next chapter presents an analysis of on-site DE fieldwork presented in Chapter Four.

Chapter Five:

Design Ethnography - Analysis and Inferences

Chapter Five aims to analyse the findings from the DE fieldwork in India and Scotland (discussed in Chapter Four) as a means of bringing to light the implications of design thinking and design in Montessorian play-based learning environments. This chapter introduces new design terminology and concepts that have emerged while observing the Montessori method through the lenses of design thinking and design. This chapter then reflects on adapting a multimethod research approach (Morse, 2003) within this thesis, where the identification of design opportunities and gaps within the Montessori method through DE research influence the development of RtD as the second qualitative research method.

5.1 Ceremonial guided play

As discussed in Chapter One, play-based learning falls somewhere between *free play* (where children can play independently, without any interruption) and *didactic learning* (where a teacher directly instructs the child) (Chaiklin, 2003; Lillard, 2013; Wood, 2013). This balance of self-regulated play and supported learning can be understood through Lillard's (2013) concept of *guided play*. Here, the facilitator leads the child to discoveries through a dialogic exchange of inquiries and conversations, while interacting with play materials (Lillard, 2013). In this way, the open triad of interaction between play materials, the facilitator, and the child follows a pace of learning through play set by the child.

In contrast, didactic learning is associated with what we might call *closed play*, where the facilitator prescribes both the pace and interaction with the materials. Both open play and closed play are structured through interactions with play materials. The rituals of open play are more exploratory and dialogic, and afford agency of the child, whereas the rituals of closed play are more instructional, mimetic, and didactic. These concepts can be applied to my observation in Montessori schools.

Montessori's curriculum is designed to support a ritualistic and process-oriented format of guided play. While conducting DE across the three sites, it became evident that this format of guided play is prominent in her curriculum. However, the term *play* is more mutable in this context. If one was to look at playing as a participatory activity involving *interaction with a play artefact or toy*, then one could say that the children were *playing* at these schools. However, if one were to associate emotions such as fun, exploration, joy, and freedom with play as an experience, this form of guided interaction with objects could be described as *play-adjacent*, instead of being playful.

This format of guided play as observed on-site was prescriptive and *ritualistic*. It wasn't just the facilitator guiding the child through an activity; instead, each step of the prescriptive activity was giving equal time and importance. It was ritualistic, where the interaction with a specific sensorial material was deconstructed into various steps (here, one did not skip through steps in order to continue playing). I refer to this format of guided play as *ceremonial.*

Ceremonial guided play, in the context of the Montessorian method, is a term I suggest to describe a format of direct instructions and closed play that restricts and constraints embodied interactions with Montessori's sensorial materials.

When analysed from Deweyan perspectives of recognising iterative play as a key component of designerly inquiry, it can be argued that Montessori's ceremonial guided play was not iterative in nature; it was not designed for exploration of objects through trial-and-error and experimentation. Ceremonial guided play**,** as a play-tutoring format, was designed to sustain prescriptive and non-critical object interactions with sensorial materials**.**

Ceremonial guided play did not afford independent interactions with sensorial materials (in contradiction to the Montessori method's theoretical framework which supports independent interactions and agency of the child). However, the format of ceremonial guided play, as observed during on-site DE, was consistent with Dewey's design principle of knowledge acquisition through hands-on learning (Rylander, 2012) and engaging in active interactions with sensorial materials.

In order to support this observation, I refer to an interaction observed with Montessori's Yellow Knobless Cylinders at M.S.1.0. These specific sensorial materials are designed to stimulate sensorial extensions and visual variations of objects and shapes. The cylinders are called *knobless* because, in comparison to some other Montessori materials which have a wooden knob attached to their surface to help lift the object using a pincer grip (thumb and index finger), Knobless Cylinders have a smooth surface. In Montessori's prescriptive interaction designed for these sensorial materials, the largest cylinder from the set is placed right next to the smallest cylinder in the set. Children are sometimes blindfolded while being introduced to variations in the height and diameter of these cylinders. Here, they are asked to haptically engage with the sensorial materials and assess their physical form, while being unable to *see* them. The prescriptive interaction with these cylinders is designed to help children decipher the physical and tactile differences between the sizes of each cylinder in a set by running their hands over the pre-arranged set (largest to smallest cylinders; typically arranged outside their storage box, in an ascending row). In the following vignette, a facilitator demonstrates how to assemble Montessori's Yellow Knobless Cylinders in an ascending order of height and diameter to a child.

Vignette 11 | M.S.1.0 |January 2017:

> *"A facilitator shows a child how to assemble a set of Yellow Knobless Cylinders in an ascending order of height and diameter. She, very slowly, picks out each yellow cylinder from the box and arranges them in front of the child (an almost Japanese tea ceremony-inspired object interaction; slow paced and ritualistic). Then, along with the child, the facilitator puts the cylinders back in the box, again, in a slow-paced, step-by-step manner."*

As demonstrated in the vignette above, the facilitator prepared an environment to embed ceremonial guided play within the activity by means of specific rules and rituals to interact with the cylinders. Instead of allowing the child to open the box and interact with the cylinders based on his/her preference, the child was instructed to haptically[51] engage with each cylinder. The facilitator interacted with the Yellow Knobless Cylinders as though they were precious artefacts rather than play materials that are designed to be explored by children. The facilitator slowly and deliberately selected one yellow cylinder at a time and arranged it in front of the child. After arranging all the cylinders, the facilitator returned them to the box, repeating the slow ceremonial pace of giving an order to the materials. By instructing the child how to *order* the cylinders rather than *play* with them while engaging in hands-on interaction, the facilitator restricted the child's capacity to explore the cylinder's form and discover new affordances.

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51 In this scenario, the child was instructed to touch, hold, and rotate the cylinder, and then place it in a specific box.

Slow pronunciation of words, embodying specific hand gestures and actions to visualise concepts, modulating voices, and getting the children to repeat them were designed within the ceremonial guided play and introduction to sensorial materials. This distinctive technique of ceremonially introducing children to sensorial materials depended on each facilitator's individual play-tutoring style.

As discussed in Chapter Four, presentation time was crucial at M.S.2.0. Unlike M.S.1.0 in Scotland, where children could select a sensorial material as per their preference, at M.S.2.0, the presentation of sensorial materials was pre-decided by facilitators. Here, the facilitators would present a specific sensorial material to the entire cohort at the same time. What was interesting about the ceremonially guided presentation of these sensorial materials was the embedded hierarchical structure within the order of interaction.

Figure 34: Presentation time with Elementary and Casa cohorts (M.S.2.0)

At M.S.2.0, the facilitators would prepare the environment to present sensorial materials through a series of steps to a cohort of children, while ordering them to sit around the selected sensorial materials, and observe the presentation quietly and passively. The facilitator, while presenting the selected sensorial materials, would instruct the children to not touch or play with the materials. However, instances were observed where, despite being instructed not to**,** children would try to covertly touch and play with the sensorial materials when the facilitator was looking elsewhere. There were repeated efforts by children to *interrupt* the predefined order of play and *disregard* prescriptive interactions.

5.2 Shepherding

While on-site, I observed various instances that seemed to contradict the pedagogic values of the Montessori method, specifically the emphasis on independent interactions and agency to explore objects through touch. At M.S.1.0, I observed a specific activity designed to teach children how to balance objects.

Vignette 12 | M.S.1.0 | January 2017:

> *"A child picks up a small brass bell from one of the shelves and starts ringing it suddenly. The facilitator asks the child to show her the bell. Once the child gives the bell to the facilitator, the facilitator starts to walk in a slow place in the learning space, while holding the bell, without ringing it. As the facilitator is cautious and taking measured steps across the learning space, the bell in the facilitator's hands stays still and does not ring once…. Then, the child tries to mimic the facilitator and walks around the learning space with the bell. But the child is not successful in walking quietly as the bell chimes constantly. I understand what the point of this exercise is when the child places the bell on the shelf and starts to carry a jug of water, in slow measured steps, mimicking the facilitator. This activity is designed to teach children to learn to walk carefully, in slow measured steps, which will help them avoid spilling any liquids or dropping things when they carry furniture/ materials around the learning space later."*

This activity was designed to teach children to walk slowly, and avoid spilling any liquids or dropping sensorial materials on the floor (again, to reinforce the idea of *protecting* the sensorial materials from damage). In the vignette above, a bell was employed as a prop, which the child was not allowed to ring. Instead, the child was supposed to walk while holding the bell carefully to avoid making any sound. In this activity, the bell's essential and immediate affordance (which is its ability to *ring* it and make a sound) was cancelled. Based on the on-site observations, the child seemed to be confused by the activity, as he/she had picked up the bell to ring and play with it, but the activity curtailed this instinctive interaction.

I refer to this format of object interaction as *shepherding*, a term I employ to describe specific activities observed on-site, where children were ordered to imitate a facilitator's interaction with sensorial materials through mimetic object play. In the context of the DE fieldwork, I refer to shepherding as a facilitation format designed to specifically guide children into mimicking a facilitator's interaction with a chosen sensorial material where the level of support a child actually needs or the competency or interest of the child is not taken into consideration.

As observed on-site during DE, shepherding, similar to ceremonial guided play, embedded a hierarchical structure within the order of interaction. It ~~and~~ was undertaken in a manner where interaction with the sensorial materials was pre-decided by the facilitator. Herein, the facilitator would interact with the sensorial materials in a specific manner and the child would be gently instructed to mimic it.

Shepherding can be compared to Vygotsky's (1978) theory of scaffolding. According to Vygotsky (ibid), interaction is a major influencer in a child's cognitive development. Scaffolding is guided by social and cultural environments, physical development, and age, which Vygotsky (ibid) recognises as the support or assistance provided by a teacher or MKO to further learning. Vygotsky (ibid) argues that scaffolding structures are meant to consider the level of competence a child already has along with a specific learning goal that the child cannot achieve unaided. In terms of practice, scaffolding guides teachers to design and plan a curriculum that extends a child's knowledge and *scaffolds* their learning by introducing them to situations where their abilities and competencies are stretched and challenged. In the Montessori school sites, however, I observed how shepherding (repetitive and mimetic play with sensorial materials) was not designed to be critical, flexible, and consider a child's competence. Instead, shepherding discouraged intuitive exploration of sensorial materials.

5.1.1 Order in play-based learning

Based on DE observations discussed previously, it can be argued that the order of play in learning environments such as Montessori schools performs a crucial role in the design of the play activities. As discussed in Chapter Two, Fröbel, as a progressive educator, shares his ideas with Dewey and Vygotsky, where all three support the design of child-centred, play-based learning environments, which focus on the agency, development, and needs of the child. While discussing the theoretical work of Montessori, affordances such as agency, independent interactions, and self-regulated play emerge as key concepts. However, while observing instances of ceremonial guided play and shepherding across the three Montessori school sites during DE, the order of play that emerged in various levels across various activities was usually facilitator-led or facilitator-initiated. Here, the needs and agency of the child took a backseat, and *correct, mimetic,* and *prescriptive* interactions with the sensorial materials along with ensuring the materials are protected and taken care of, took precedence.

5.1.2. Affordances of ceremonial guided play

Montessori's format of ceremonial guided play appeared to work positively when children were being introduced to formal subjects such as mathematics and languages. At M.S.2.0 children were introduced to concepts such as addition and subtraction in mathematics with the help of LEGO Duplo bricks. This activity afforded ceremonial guided play, where solving a mathematical equation on paper was instead deconstructed into interactive object play with sensorial materials.

During another presentation time activity designed to compare numbers at M.S.2.0 (here that six is bigger than five), a facilitator demonstrated object play with the help of LEGO Duplo bricks. In this activity, she designed two LEGO Duplo brick towers to represent the numbers five and six by stacking five bricks to design one tower and six bricks to design the second tower. The facilitator then visually compared the heights of both the towers and evidenced this physical difference by counting the LEGO bricks on each tower. Sets of LEGO Duplo bricks were then handed out to children to engage in the same activity. Here, the children engaged multiple senses to aid the learning process (physically holding, stacking, and counting each brick, and visually comparing the stacked brick towers to see which tower is the tallest. Refer to Figure 38).

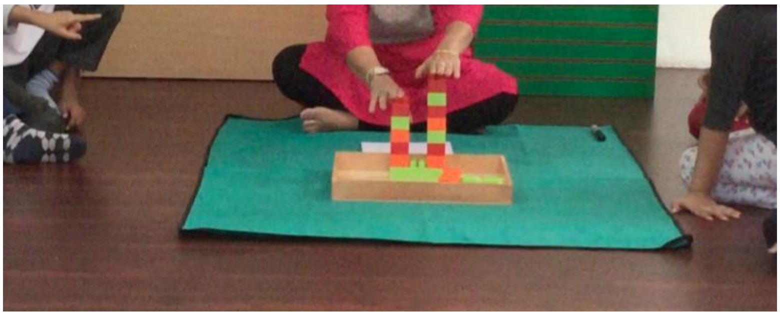

Figure 35: Ceremonial guided play to engage in addition (M.S.2.0)

The next vignette illustrates this argument more prominently.

Vignette 13 | M.S.2.0 | July 2017

> *"A child is engaging with the Blue and Red Rods to learn about numbers, while trying to place each numbered tile next to the correct rod. The tiles seem to be bigger than the space allocated to them, and the child seems confused… or maybe he/she is thinking about which number to place in front of the correct tile."*

Figure 36: Blue and Red Rods and Number Tiles (M.S.2.0)

(After a couple of minutes …)

The child has solved the problem of setting up the board! – I was mistaken, it is not horizontal, but vertical placement of the numbered tiles against the Blue and Red Rods. The facilitator is pleased with the child and congratulates him/her. The child then starts to deconstruct the numeric arrangement and places the tiles back in their box. This child is working silently and alone, unlike the rest. The child rearranges the Blue and Red Rods along with the number tiles in the box and moves onto equations."

Figure 37: Systematic interaction with Blue and Red Rods to learn addition (M.S.2.0)

Here, a child interacted with Montessori's Blue and Red Rods[52] to identify numbers and associate the correct numeric quantity to the correct rod (by placing a numeric tile in front of the rod). The child verified the answer by loudly counting the blue and red rectangles on each rod to match the correct numeric tile. The child was also able to add two values using the rods, and could visualise larger and smaller numbers by arranging the rods next to each other, weighting them by engaging the stereognostic sense (feeling the form of the object by holding it in their hands and identifying the difference in weight) and visually assessing the difference in length (refer to Figures 39 and 40).

52 Blue and Red Mathematical Rods are a sensorial material designed for mathematical learning in the Montessori method.

On-site fieldwork at the three schools revealed that, while ceremonial guided play with specific sensorial materials can help children explore a concept holistically (as evidenced through the two vignettes before), in most cases, this constrained design framework can also inhibit a child's learning process and hinder conceptual thinking. This is more likely to occur when comprehending new concepts that require iteration and exploration to create or discover new affordances.

It is essential to elaborate on a few instances where this ceremonial guided play became inhibitive and anti-intuitive. The following section elaborates on this argument with the help of on-site vignettes and illustrations.

5.3 Hacking ceremonial guided play

Zuckerman (2010) compares Montessori's prescriptive interactions to solving a puzzle that can only be configured in a particular manner. As discussed earlier, despite promoting active engagement with her designed sensorial materials, in practice, Montessori's designed activities do not support exploration and iterative learning.

Figure 38: Non-prescriptive interaction with Yellow Knobless Cylinders (M.S.2.0)

The Montessori method encourages children to independently play with objects (Lillard, 2005). Paradoxically, on-site fieldwork revealed that constant vigilance was practiced by Montessori facilitators, a pedagogic relationship I refer to as *helicopter facilitation*. The term helicopter facilitation is inspired by the term *Helicopter Parent*[53] that describes overprotective parents. Helicopter facilitation describes the facilitation style of Montessori teachers ("hovering over children in classrooms, similar to a helicopter"). Helicopter facilitation was observed on-site across all the school sites.

Montessori facilitators are trained to gently discourage the misuse[54] of a sensorial material. While on-site, I observed a few situations where children *hacked* the prescriptive learning process while interacting with sensorial materials, to engage in intuitive and exploratory play. *Hacking* is a term I suggest to describe the act of manipulating, disrupting, or re-interpreting prescriptive activities by children, as observed during the DE fieldwork at Montessori schools, that disrupted Montessori's ceremonial guided play. The idea is to reflect on the concept of going against prescription, and engaging in intuitive and iterative play with the sensorial materials, which can sometimes lead to discovering new affordances.

As discussed in Chapter Two, scaffolding structures, when designed to challenge the learner's competency and encourage social participation, contribute to collective meaning-making and creativity in learning spaces (Marsh et al., 2019). On-site DE observations revealed that, while hacking the ceremonial interactions at Montessori schools, children would challenge the predefined rules of prescriptive interactions and ceremonialism, and instead engage in social and collaborative play. They provoked change by hacking, iterating, and staging sensorial materials to engage in exploratory play-based learning, thereby adopting intervention as a key component of designerly inquiry. By hacking interactions with sensorial materials**,** their learning process was in fact enriched by the sense of increased freedom. In the following vignette, hacking the prescribed interaction led a child to go beyond the predefined outcome of interacting with the sensorial material and acquire new knowledge.

Vignette 14 | M.S.2.0 | July 2017

> *"A child chose to play with Montessori's Colour Tiles – here, one is supposed to match two tiles with the same colour and arrange them as pairs. Instead of just matching each colour with its partner tile, this child referred to the paintings of*

53 The term 'Helicopter Parent' was originally coined in the book written by Foster W. Cline, MD. and Jim Fay in 1990, titled Parenting with Love and Logic: Teaching Children Responsibility.
54 Here 'misuse' refers to interacting or playing with Montessori objects in a non-prescriptive manner.

rainbows that were glued to the walls of their learning space and arranged the tiles in a rainbow pattern, entirely on his own."

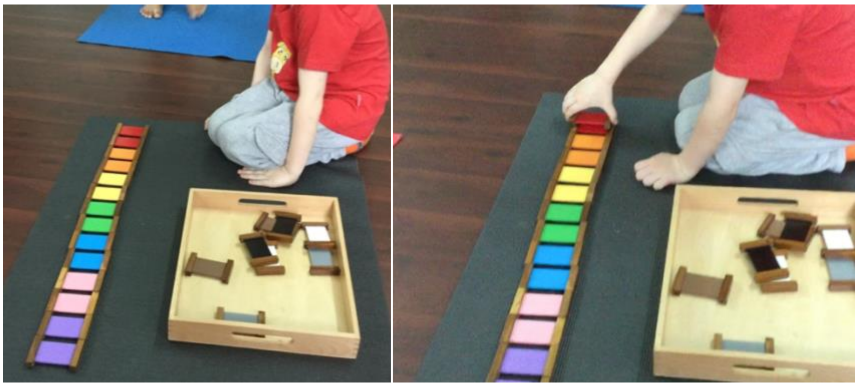

Figure 39: Non-prescriptive interaction with Montessori's Coloured Tiles (M.S.2.0)

In this vignette, the child was known to disrupt presentation sessions during school hours. During this particular incident, this child was given Montessori's Coloured Tiles during the last hour of their school day. The child seemed to be enjoying playing with these Coloured Tiles and no one was helicopter facilitating him. Interestingly, the child engaged with the Coloured Tiles for a long time and started to freely explore them. The child arranged the Coloured Tiles in a rainbow palette (see Figure 42), inspired by all the drawings of rainbows pasted on the classroom walls. The child then presented his *tile arrangement* to the facilitators. This child was very excited by the fact that, instead of reprimanding him, the facilitators were very pleased with him.

As seen in this vignette, the child was able to hack the prescribed interaction by engaging in intuitive and exploratory play. By hacking prescriptive play, responding to environmental cues, and then engaging in a dialogic exchange with the facilitator to explain his design rationale, this child discovered a new concept through iterative interactions with the sensorial material. Instead of using the Coloured Tiles to group similar colours together (which is the Montessorian way of interacting with them), the child rearranged these tiles to create a rainbow-inspired colour palette, thereby discovering a new affordance of using these tiles as art materials to visualise a rainbow. He was further rewarded with positive feedback from his facilitators, who were otherwise accustomed to constantly reprimanding him for disruptions in the classroom. Experimenting with sensorial materials and lack of helicopter facilitation in this scenario led to focused and motivated object play by the child, along with positive feedback and response as rewards.

The following section focuses on three sensorial materials that are iconic to the Montessori method and have been designed to specifically train the visual sense. These are the Pink Tower, Brown Staircase, and Knobless Cylinder sets. Fieldwork from observing interactions with these sensorial materials revealed an interesting pattern, where children across all three schools engaged in exploratory play with these sensorial materials by disrupting and hacking prescriptive activities.

5.3.1 Pink Tower and Brown Staircase

Montessori's Pink Tower and Brown Staircase are sets of modular blocks. Their multiplayer quality, simplicity, and affordances of designing structures make them engaging and popular with children.

The Pink Tower is a set of ten pink wooden cubes, in the size range of $1cm^3$ to $10cm^3$. By stacking these cubes in a progressively decreasing order of size, interactions with the Pink Tower are designed to teach concepts of visual discrimination, coordination, and precision, which also prepares the ground for the child's later comprehension of cubed roots in mathematics. However, interactions with the Pink Tower are designed to be irrefutable, where the child is meant to systematically and ceremonially place the cubes in a decreasing order of size, while concentrating and ensuring that the tower is *visually harmonious*. This visual harmony, as defined by the Montessori method, can only be achieved by arranging the cubes in a systematic tower of their sizes, with the biggest cube stacked at the bottom, leading to the smallest cube on the top.

The Brown Staircase**,** similar to the Pink Tower, is a set of ten brown cuboids of the same length, but with varying height and width, ranging from 1 cm to 10 cm. The Brown Staircase is meant to be arranged in decreasing order of thickness, in a systematic step-by-step manner, to help the child grasp visual discrimination of dimensions as well as prepare for future mathematical lessons.

Both these sensorial materials are meant to be interacted with in the prescribed Montessori manner. However, during the DE fieldwork, I observed how children would mix the two sets, and use them to construct towers, bridges, and anthropomorphize the blocks to resemble the form of dragon or a warrior, amongst others. These hacked interactions would typically take place when the facilitators were busy attending to other children.

Vignette 15 | M.S.2.0 | July 2017

> *"A child is playing with the Brown Staircase materials in a non-Montessori manner. He keeps alternating the directions of the blocks as he stacks them, which makes the structure stable and visually dynamic at the same time. He begins to colour one of the stacked brown blocks with a crayon and is immediately stopped by a facilitator. The block structure is dismantled, the materials are taken away, and he is asked to stand in a corner as punishment since he has 'spoiled the sensorial material'…."*

In the vignette above, a child was reprimanded in front of all his colleagues, while trying to hack the interaction with the Brown Staircase blocks. Through helicopter facilitation, the child was immediately asked to stop, dismantle the construction, and carefully place the Brown Staircase tool set back on a shelf.

The child appropriated these Brown Staircase blocks as a surface to sketch and colour with crayons, which is a *non-Montessori* way of interacting with them. The facilitator reprimanded the child through helicopter facilitation to discourage non-prescribed interaction with the sensorial materials, which, in this case, was exploring the Brown Staircase blocks as a surface to sketch on. In this incidence, the fear of *ruining or spoiling* the Brown Staircase blocks was given more importance than the process of acquiring new knowledge and discovering the affordance of visualisation by sketching on a three-dimensional surface of the brown block.

This incident also served as a reminder to the younger children in the cohort who watched this event unfold that the sensorial materials in their learning space could not be played with in a manner of their choosing. Children were meant to interact with these apparently *precious* sensorial materials with extreme caution, instead of freely playing and exploring them. Prescriptive interaction with the Brown Staircase blocks in the above-mentioned vignette, for instance, discouraged sketching on its surface, which the facilitator justified as the reason for the child being punished.

Both the Pink Tower and Brown Staircase sensorial materials are designed as blocks and have plain surfaces without the signature Montessori *knob* attached to them. Their structural design and smooth surface quality afford innumerable possibilities of positioning and placement. This, in turn, provides children with opportunities to experiment with the physical properties of the materials such as stacking them on top of each other, exploring principles of mass and form, and discovering how the blocks can be arranged and balanced. When children engaged in open and exploratory play with these blocks by hacking the prescription on-site, they were *intuitively responding* to the block's physical affordances.

The following images (see Figure 43), as illustrated during the DE fieldwork, capture some more of these hacked interactions. On-site observations of these interactions revealed that these sensorial materials, when hacked, were far more engaging and enjoyable to the children. Here, children were stacking the sensorial materials in odd combinations, discovering new spatial arrangements, and engaging in imaginative play by symbolically representing these constructions through narratives within their conversations (such as "I have made a castle"). Children were also engaging their stereognostic (haptic) and baric (weight) senses by discovering physical principles such as weight and mass of the sensorial materials, which govern how their design structures are balanced. This form of hacked play also exhibited joyous social collaborations and learning as children would come together to build new structures.

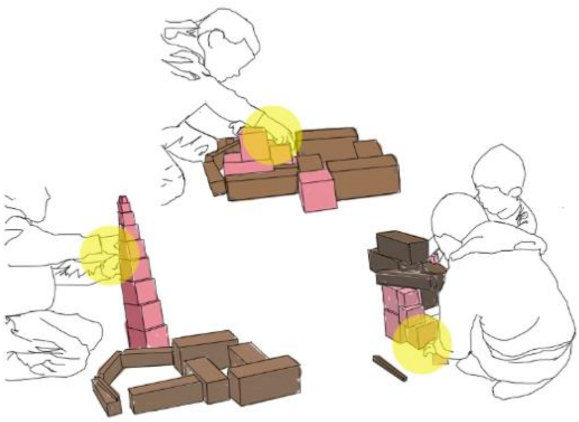

Figure 40: Exploring the Pink Tower and Brown Staircase objects (M.S.1.0)

5.3.2 Knobless cylinders

Montessori's Wooden Knobless Cylinders are four sets of ten cylinders. As discussed in Chapter Two, each set is coded in a primary colour, where properties of each set are identified through their specific colour. The storage boxes of each of these cylinder sets are also constructed to only allow arrangement of specific cylinders in an ascending or descending order.

Knobless Cylinders are meant to be played with prescriptively to allow children to comprehend differences in the visual dimensions of each set. However, while onsite, the opposite was observed. Children were combining the cylinder kits, rolling them on the floor, and stacking the smallest cylinder at the base of a structure while precariously balancing their constructions, before nudging the structure to fall over the classroom floor. Children were exploring the physical properties of the cylinder (differentiating between the curved and flat surfaces of the cylinder) by rolling the cylinders between their palms, letting the cylinders slide off an incline, tilting them at odd angles, and constructing *visually dynamic* towers. Hacking this sensorial material also incentivised collaboration with other children, and encouraged exploratory play and socialisation, as children formed groups of two to three to play with these Knobless Cylinders. Eventually, hacking was curtailed through helicopter facilitation and, in some instances, the children were reprimanded for *mistreating* these sensorial materials.

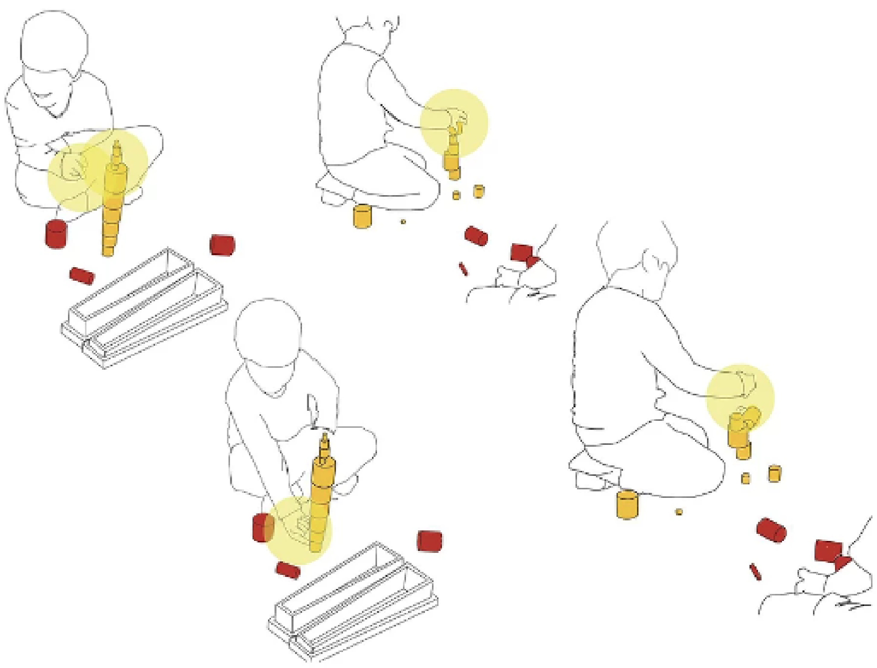

Figure 41: Exploratory play with Wooden Knobless Cylinders (M.S.2.0)

5.4 Design affordances of ceremonial guided play: constructive and adverse

Based on all the vignettes and observations discussed in the earlier sections, two kinds of responses to Montessori's ceremonial guided play were observed. With subjects such as language acquisition and mathematics, guided play activities were designed to afford exploring multiple senses simultaneously. Activities such as addition with Montessori's Blue and Red Rods were designed to embody purposeful object play along with training the auditory and phonemic senses (by reading each number out loud while haptically interacting with the tiles) to guide a child through the process of learning a new concept. Activities such as circle time, which afforded a dialogic exchange of ideas between the facilitators and children through gestural learning and poem recitation, helped with language acquisition, afforded agency of the child, and led to social play. These activities underpin Dewey's design principles of being *purposeful* and *playful* at the same time.

Some sensorial materials in the Montessori material menu are designed with specific constraints and functionality, which leads to lesser possibilities of exploration and interaction. To further explain, while referring to sensorial materials which are designed with knobs on them (such as Knobbed Wooden Cylinders, Knobbed Alphabet Tiles, and Knobbed Geometric Insets), the knob (which acts as a hook or a clasp) is designed with specific functionality, which is to help develop the pincer grip in a child. The knob, hence, has a specific affordance within the sensorial material. In the case of Knobbed Wooden Cylinders, for example, these cylinders cannot be stacked on top of each other due to the presence of knobs on their flat surfaces**.** The knob is a design constraint that does not afford the ability to be stacked. However, the knob does afford the ability to develop a child's pincer grip.

On the other hand, with sensorial materials such as Pink Tower, Brown Staircase, and Knobless Cylinders, ceremonial guided play was often hacked and reinterpreted. On-site observations with these sensorial materials, as discussed in the previous section, demonstrated instances of hacking and disrupting prescriptive interactions to engage in intuitive, social, and exploratory play.

Elaborating on the affordances of play objects such as blocks, bricks, and planks, Ness and Farenga (2016) refer to Vygotsky's (1933/1969) emphasise on situational and environmental constraints, and their effect on how children play with objects. Ness and

Farenga (2016) revive Vygotsky's (1933/1969) and Lewin's (1935) arguments that objects (in this case: play materials, toys, pedagogic tools) impose rules on how children must engage with them. To illustrate, Ness and Farenga (2016) use the example of LEGO minifigures, which are designed with a clear set of constraints, inasmuch as they can only be played with in certain ways (for example: LEGO minifigures arranged inside or over a LEGO vehicle). As the LEGO minifigure is designed to be played with in a specific context, it has a specific affordance, where the player clearly understands how to engage with it (ibid). In comparison to a LEGO minifigure, a wooden block, for example, is simply a square or rectangular cuboid; here, its structural constraints are ambiguous, thus it exhibits more possibilities of interaction and cognitive demands for a child (ibid).

Based on on-site DE data and Ness and Farenga's (2016) reasoning, it can be argued that the constrained design language of some sensorial materials influenced the way they were interacted with. Here, sensorial materials such as Pink Tower, Brown Staircase, and Knobless Cylinders**,** based on their less constrained design structure, afforded more opportunities of iterative and exploratory object play. Comparatively, sensorial materials such as Knobbed Wooden Cylinders, Knobbed Alphabet Tiles, and Sandpaper letters**,** due to their constrained design language, afforded fewer opportunities of hacking and exploratory play.

5.5 Chapter summary

By observing play-based learning through the design filters of play resources (play objects, tools, spaces), play structures (activities, tasks, themes), and play personnel (teachers, facilitators, and children) across all three sites, cross-cultural DE helped identify, analyse, and compare the theoretical underpinning and foundation of the Montessori method to its practical applications. Within the Montessori environment, there is a normative tendency to create order. Being *play-driven without being playful* seems like an unlikely combination in a play-based curriculum, yet it aptly describes the Montessori environment at the school sites in India and Scotland.

5.5.1 Prescription, hacking, and iteration as affordances

On-site DE fieldwork demonstrated that the institutionalised Montessori method did not encourage exploratory and iterative play with the sensorial materials**.** This was observed across all three sites. However, exploratory play was accommodated in the curriculum through some children hacking prescriptive interactions.

Examining the affordances of some sensorial materials also revealed the influence of a constrained design language. As discussed through the arguments put forward by Ness and Farenga (2016), sensorial materials such as Pink Tower, Brown Staircase, and Knobless Cylinders**,** based on their less constrained design language, afforded more opportunities of iterative and exploratory object play.

While hacking the prescribed interactions of sensorial materials such as Pink Tower, Brown Staircase, and Knobless Cylinders**,** children engaged in design thinking by constructing models, prototypes, and discovering the reciprocity between play criteria and constraints for design challenges (Kelly and Cunningham, 2017; Li et el., 2019). Children provoked and challenged their designed structures by staging and arranging the blocks (Dalsgaard, 2014) in a way that made sense to them.

Hacking prescriptive activities and participating in explorations led to children engaging in interventionist play, which is a key component of designerly inquiry. The design capacity of the blocks to be rearranged and reorganised, even if a structure falls or disintegrates due to external physical pressure, led to more intuitive and iterative explorations with these materials. Hence, hacked play with some of the sensorial materials allowed the children to challenge the learning frameworks along with engaging in cognitive and spatial learning through the structures they created; these can be foundational to future studies such as architecture and engineering.

Socialisation was an additional appropriated affordance (Flint, 2016) that emerged while hacking prescriptive play. Here, by means of hacking, some children disrupted the prescription learning framework as endorsed by the Montessori method, which encouraged the rest to hack as well. Hacking of prescriptive interactions, while encouraging imaginative, experimental, and iterative play, also initiated a dialogue to exchange ideas and engage in conflict resolution.

5.5.2 Absence of designing new play materials and opportunities

In relation to the prevailing emphasis on STEAM, DE fieldwork demonstrated that there were no opportunities to construct new materials or avenues for children to create new play artefacts to foster their learning process. Tinkering and prototyping were not encouraged at any of the schools. As opposed to current play-based learning environments, which are striving to adapt tinkering as a twenty-first century literacy skill (Yakman, 2008, 2010; Bevan et al., 2014), these Montessori schools did not adopt an evolutionary approach to play-based learning. Only prescriptive and predefined activities to engage in play-based learning were provided and, if a child would hack a sensorial material, he or she was immediately interrupted, or, specifically in the case of the Indian Montessori schools, reprimanded in front of the cohort.

Some of the key design features of the prescriptive Montessori framework that were identified during the course of DE fieldwork were *ceremonial guided play* as a play-tutoring format, *shepherding* as a facilitation format, and *helicopter facilitation* as an affordance of shepherding.

New ways of exploring sensorial materials are discouraged by traditionally trained Montessori facilitators, who document *wrong/misplaced* interactions with the Montessori materials and intervene during the interaction to *correct* them. By engaging in helicopter facilitation and intervening to correct the interaction with materials, the Montessori method prevents discovery, collaboration, and iteration. Over-prescribed and excessively codified interactions ensure there is no space to discover hidden or new concepts during object play.

Nevertheless, codification of materials is vital to the ways in which children navigate the opportunity for play. For instance, every Montessori object and piece of furniture has supporting grooves or indentations to help children pick them up and carry them easily. Ergonomic comfort is given primacy in the language of play. The tools and furniture have been designed for ergonomic comfort and stability. However, while observing this growing dependence on the design language of Montessori's sensorial environments and ceremonial guided play, which embody scaffolding through the acts of shepherding, ceremonial guided play, and helicopter facilitation, a criticism of non-challenging and non-iterative design begins to emerge.

5.5.3 Multimethod approach: From DE to RtD

As introduced in Chapter One, multimethod research (Morse, 2003) as a methodological approach was selected to gather primary data during this thesis. DE (design ethnography) undertaken in India and Scotland demonstrated that, despite incorporating engaging and interactive play artefacts in Montessori schools, Montessori's curriculum hinders intuitive exploration of these artefacts, and discourages questioning their affordances and challenging interactions coded by the curriculum within the object's form. On-site fieldwork revealed that, within the current landscape of play-based learning, Montessori's restrictive material pedagogy is counterproductive to learning through intuitive processes of exploring or creating something (Ackermann, 2001).

Despite being an extensively designed and design thinking-driven (Brown, 2009) method of play-based learning, the Montessori method reveals itself as rather outdated in its lack of twenty-first century literacy skills (Yakman, 2008, 2010). The Montessori method does not accommodate constructionism, tinkering, prototyping, iterative learning, or contextual inquiry, which most contemporary pedagogies hope to formally incorporate. A common observation throughout the fieldwork was that of children *hacking* Montessori's prescriptive interactions with the sensorial materials. Empirical data reveals that intuitive play is designed out of the curriculum and instead treated as an error that is summarily corrected by facilitators. In this way, the Montessori curriculum gives children no space to hack and tinker or scrutinise a play activity, and limits exploratory and intuitive play.

Parallelly, on-site observations of ceremonial guided play for language acquisition, mathematics, and, at times, cultural studies also demonstrated that these subjects employ sensorial materials that are designed with more constraints and specific affordances (Ness and Farenga, 2016). Their constrained design language along with elaborate multi-sensorial and purposeful guided play activities led to fewer instances of hacking or re-interpreting their interactions.

However, there are opportunities to design affordances of experimentation, iteration, exploration, and conceptual thinking within Montessori's sensorial material menu. Analysis of on-site DE data gathered during this thesis argues that Montessori's rich, yet static, design language of modular sensorial materials and prescriptive activities can be broadened and adopted to accommodate twenty-first century literacy skills (Yakman, 2008, 2010).

Montessori's curriculum, which embodies a multifarious repository of tried and tested knowledge through the design of sensorial materials, affords possibilities of designing systems inspired from it to support comprehension of STEAM themes in a play-based setting. As Montessori's curriculum and designed materials inherently focus on the development of mathematical, art, and science skills that are key to STEAM learning, it is plausible for Montessori and STEAM environments to incorporate each other's strengths.

To support this argument in this thesis, Part Three introduces and explores the method of Research through Design (RtD), during which dynamic play objects and activities inspired from Montessori's geometrical menu and presentation time format were conceptualised and introduced to children between the ages of eight and twelve years.

Part Three

Part Three (Chapters Six, Seven, and Eight) examines the participatory and improvisational method of research through design (RtD). To begin, Chapter Six introduces RtD as a practice-based research method within the gamut of design research. This chapter introduces participative play workshops that were designed as a research method to undertake RtD. It examines CLEs such as museums and public galleries as play environments, which were selected to conduct a participative play study through workshops. It also addresses the shift in the researcher's positionality, from a passive observer in DE to a curator, designer, and workshop facilitator during RtD.

Next, Chapter Seven presents on-site observations of the participant's interactions and experiences in the play workshops through thirteen workshop diary narratives, supported by images and observations. These diary narratives are segregated into specific sections to present a detailed synopsis of designing and facilitating play workshops to conduct RtD.

Chapter Eight then analyses and draws inferences from the diary narratives to bring key design perspectives and affordances from the play workshops to the forefront of this thesis. This chapter examines how the RtD play workshops were designed to afford twenty-first century literacy skills (Yakman, 2008, 2010) such as prototyping, inquiry-based learning, iteration, and experimentation.

Chapter Six:
Research through Design (RtD)

The aim of this chapter is to address how design thinking and design have contributed to play-based learning's migration beyond formal classroom environments in the twenty-first century. This chapter begins by introducing RtD as a participative research method, within the gamut of design research, and discusses its relationship to design and play. RtD is crucial to this thesis, since it allows the study of play-based learning in a participative format through the design and testing of play materials in-situ at informal CLEs.

This chapter then addresses the relevance of *workshops designed as a research method* to undertake RtD. The chapter continues on to examine the relevance of CLEs as sites that offer opportunities to design experimental play-based learning programs (Andre et al., 2017). This chapter focuses on the shift in the researcher's positionality (from inactive observer to active designer and facilitator) and its relevance to this thesis, where, in order to examine the implications of design thinking and design in the play workshops, the researcher essays multiple and transitory roles. Findings from the RtD workshops are further discussed in Chapters Seven and Eight.

In the wider context of the thesis, this chapter takes on an additional level of relevance in relation to pedagogy, play, and design. As argued in Chapter Two, RtD is discernible in Vygotsky, Fröbel, Montessori, and Dewey's views of materiality, interaction, and creative play. In this sense, Chapter Two has argued that these pedagogical theorists can be re-read as design thinkers. RtD is therefore significant as both a method in the development of the wider exploration of play-based learning and as a way of conceiving the pedagogues responsible for establishing play-based learning approaches across the world.

6.1 Research through Design

According to Godin and Zahedi (2014), RtD is embedded within the design process, where its main concern is not just to inform the research question but to also transform the end product of the design. The authors (ibid) argue that RtD has migrated from the field of human-computer interaction and developed into a comprehensive practice-based research method that could be applied to any field.

As a prominent pedagogue within art and design education, Frayling's (1993) identification of three kinds of design research has been instructive across the discipline. He describes the three kinds as research *of* art and design, research *for* art and design, and research *through* art and design. Research *for* design focuses on guiding and developing design practice, where the processes and concerns of designers and their practice are documented as objects of study. Research *of* design, as a more academically inclined research method, documents objects, phenomena, and the history of design (ibid). Research *through* design (RtD), as a practice-based method, is most similar to design practice, where design by creation is established as research. Designers and/or researchers employ RtD by designing new products, tools, processes, or by experimenting with new materials (ibid).

According to Frayling (1993), RtD as a practice-based method provides a more holistic and all-encompassing understanding of complex and often future-oriented design issues by gathering processes to produce unique insights. RtD supports constant readjustment and construction of artefacts to tackle complex design problems through trial and error (Toeters et al., 2013). Godin and Zahedi (2014) argue that, by testing designed prototypes in a participative site-specific approach, RtD supports and recognises design practice's contributions to knowledge. Furthermore, RtD as a pragmatist, practice-based method, associates itself to the *present* or *reality,* instead of focusing on stated truths or points of view.

Godin and Zahedi (2014) examine multiple perspectives of RtD to help understand it as a distinct approach. They refer to Bowers (2012), who underpins Frayling's (1993) claims of artefacts embodying multi-faceted and heterogenous design thinking. Godin and Zahedi (2014) also borrow from Zimmerman (2010) to describe RtD as a process of iteratively designing artefacts in order to creatively investigate potential futures. Here, Godin and Zahedi (2014) consider the shared goals of Bowers (2012), Zimmerman

(2010), and Jonas (2006) while discussing RtD, which collectively focus on establishing aspects of research done by undergoing an iterative design process, and which leads to a tangible or intangible end result.

Unlike research *for* design and research *of* design, which rely on the research traditions of other disciplines, research *through* design (RtD) is an open-ended and exploratory model that needs an aggregation of various points of view to present a more holistic picture of the method. Koskinen et al. (2011) argue that construction takes centre stage as a means to creating knowledge in RtD.

6.2 Workshops designed for RtD

Ørngreen and Levinsen (2017) argue that a workshop refers to an arrangement where a group of people come together, form a community, gain new knowledge, and engage in creative problem solving based on a specific issue or subject. Ørngreen and Levinsen (2017) argue that workshops designed to undertake research allow us to iterate, refine, and moderate our designs over a period of time and in different contexts, thereby supporting design inquiries by affording flexibility and creative problem-solving.

Similarly, Ahmed and Asraf (2018) see workshops as a promising data-gathering tool. The authors (ibid) argue that workshops foster engagement through collaborative and constructive communication between participants and the workshop facilitator. The authors (ibid) further argue that facilitation and interaction with participants can help build trust which, in turn, makes participants feel valued and more willing to share information. Workshops as meeting spaces are a common avenue for participants interested in a particular topic, which helps the researcher elicit rich information through a shared collaborative experience (Ørngreen and Levinsen, 2017; Ahmed and Asraf, 2018).

Ahmed and Asraf (2018) argue that workshops allow for both internal and external research. Here, the researcher has the opportunity to initially engage and create a rapport with the participants. This can help the researcher become a part of the participant community and comprehend participant behaviour in various contexts within the workshop space. Later, the researcher can distance himself/herself from the workshop context and analyse the gathered data. Hence, the researcher embodies dual roles during workshops; that of an *insider* who can engage in participation, observation, and active engagement initially, and later of an *outsider* who analyses acquired data.

While unpacking the duality of a researcher's role during workshops, Ahmed and Asraf (2018) refer to Spradley (1979), who emphasises a third role of the researcher, that of a "*research instrument*" (p.56, original emphasis). Researchers become a research instrument when they actively participate in the workshop, and ensure that other participants feel comfortable and safe in the workshop space. This, in turn, incentivises participants to discuss their perspectives and give feedback to the researcher (Ahmed and Asraf, 2018).

6.2.1 Workshops as a research method

Ørngreen and Levinsen's (2017) perspectives on *workshops as a research method* focus on the study of specific themes designed within the workshop format. On one hand, the workshop is an authentic environment that aims to fulfil the participant's expectations to achieve something related to their interest. On the other hand, the workshop satisfies a specific purpose and produces valuable data on a particular topic (ibid).

RtD workshops in this thesis were designed as flexible learning environments (Nicholson, 1972/2009), which supported play-based learning by embodying the following design affordances:

- Hands-on object play
- Construction of models and prototypes
- Tinkering and iteration of play materials and construction processes
- Inquiry-based learning
- Exposing participants to challenging situations, where their abilities and competence would be stretched and challenged
- Reflecting on learning outcomes

RtD workshops as a research method allowed the testing of adaptive play materials designed with a specific learning objective, which was to integrate Montessori's static design language with STEAM learning in a participatory format. Simultaneously, workshops as a research method also allowed design and curation of participatory play-settings to test play materials.

In the context of the workshop, it is important to understand the convergence of different types of *participation*, specifically *participatory prototyping* and *participatory design* (van Waart et al., 2015). Binder et al.'s (2008) argument on participatory design is relevant to this thesis, where it considers the foundations of participatory design as a critical response to conventional design approaches that ignore the voice of the end-user. Binder et al. (2008) refer to Brereton and Buur's (2008) "ethos of participatory design" (p.79), where boundaries of participatory design projects are blurred in certain contexts, and participation strives to strike a balance between reflexivity and pursuing predefined goals.

Brereton and Buur (2008) discuss the shift in taxonomy shift from "participatory to user-centred design" (p. 80). According to the authors (ibid), *participatory design* refers to seeking continuous interaction from stakeholders and practitioners, and *user-centred design* portrays humans in a more performative manner. The authors (ibid) argue that participatory design should afford iterative and experimental explorations in order to provide essential understanding of complex contexts and practices. They further argue that adapting participatory design as a measure to engage in continuous iterative prototyping and research can lead to the inception of new types of participatory relationships, which bring the researcher closer to members of the participant community.

As a part of the primary research that contributes to this thesis, RtD play workshops were designed to adopt an immersive and participative format of play-tutoring. This format supported key components of design thinking such as flexibility, collaboration, iteration through tinkering, and creative problem-solving. Designing workshops as a research method revealed the ways in which scaffolding could be designed to support an authentic learning environment through the design of natural mediator tools, play materials, play activities, and facilitation frameworks that consider a child's competencies (Vygotsky 1978; Hall, 2007).

6.2.2 Cultural Learning Environments (CLEs) as RtD workshops sites

CLEs are seen as informal learning spaces that consist of rich artefacts and hands-on materials to support children's learning through interaction and inquiry (Andre et al., 2017). As discussed in Chapter One, play-based learning has evolved and transitioned beyond formalised learning spaces of schools to CLEs such as children's museums, public libraries, maker spaces, and tinkering studios.

Mayfield (2005) argues that play is the raw material of knowledge in CLEs. Play can be introduced and brought forward through hands-on learning and interaction with materials in exploratory and sensorial environments. In comparison to formalised learning spaces like schools, where learning typically is undertaken in a scheduled, time-bound, state-mandated, compulsory, and law-binding framework[55], learning programs organised at CLEs offer informal and free-choice learning.

Learning undertaken at CLEs is qualitatively different from that offered in schools. Findings from research undertaken at schools cannot be transferable to museum learning. Within the context of this thesis, selecting CLEs as sites to undertake play workshops supported RtD's informal and iterative research format. As a workshop facilitator, CLEs allowed me to design improvisational and adaptive techniques to engage in play-based learning. Undertaking RtD through workshops at CLEs was also practical and convenient in terms of logistics during the thesis, as there was no risk of disrupting school-based curricula. To summarise, in comparison to Montessori schools chosen as sites to conduct DE, CLEs such as children's museums and public art centres were chosen as sites for RtD workshops.

6.3 Shift in the researcher's positionality

As discussed in Chapter Four, a highly prescriptive and formalised format of play-tutoring was observed and analysed during the cross-cultural DE fieldwork at the three Montessori schools. During on-site DE research at Montessori schools in Scotland and

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55 Current primary school education across the globe focuses on establishing fundamental literacy and numeracy skills in children, along with developing their understanding of the world. Since these skills have been recognised as necessary for life in the modern world, primary education is compulsory and provided by the state in most countries around the world. More information can be accessed on https://ourworldindata.org/primary-and-secondary-education.

India, I engaged in non-participative observation-research. This format of research was silent and non-intrusive, where I would quietly sit in an allocated space at the school-sites and observe the institutionalised Montessori learning environments, without interacting with the children or facilitators during their workday. This format was undertaken to not disturb or disrupt the learning processes at Montessori schools.

However, while designing play workshops as a research method, my research positionality underwent significant change vis-a-vis participants and the explicit control of the research environment. Within the framework of RtD, I became the designer, curator, and facilitator of RtD play workshops. Undertaking RtD through play workshops allowed me to adopt multiple roles (Ørngreen and Levinsen, 2017; Ahmed and Asraf, 2018), which are as follows.

1. An *inside researcher*, who could engage in participation and observation.

2. A *research instrument*, who could incentivise other participants to share their feedback and perspectives by designing a safe and comfortable workshop environment.

3. An *outside researcher*, who could step away from active participation later on and analyse the gathered data.

Undertaking RtD through play workshops also resulted in the duality of me embracing the role of an actor and researcher at the same time. Here RtD, as an active research method, also encompassed ethnographic research; where it allowed me to simultaneously engage in active participant-observation through design ethnography (DE) as well as embrace the role of an actor (as a workshop facilitator).

Unlike DE conducted earlier during this thesis, which was silent and non-participative, conducting active participant observation during RtD meant that I could engage in active conversations and interactions with the participants. This also meant that I had to maintain equilibrium while embracing the role of an *inside researcher* (actor or facilitator), and parallelly, while embracing the role of an *outside researcher* (ethnographer), to continue with external investigations. The argument presented by Reeves et al. (2008) in Chapter Three is crucial to comprehending the duality of being an actor and researcher during the play-workshops. Reeves et al. (ibid) maintain that through participation, the researcher essays the role of an inside researcher, which is advantageous as the researcher is able to become a part of the participant group as well as experience what the other participants are experiencing. This is particularly useful where trying to gain an empathetic understanding of the challenges and difficulties faced by the participants and maintain transparency between the researcher and participants. Simultaneously, Reeves et al. (ibid) also argue that while engaging in the research as an outside researcher, the researcher has to maintain a sense of objectivity towards participant observation, by separating themselves from the group being studied.

Therefore, during RtD, while I was facilitating the workshops and conducting the play sessions, I was also engaging in active DE research, where I was constantly observing the participants and their engagement with the workshop premise and materials.

Initially, I was nervous about my role as a facilitator for the RtD workshops. I anticipated a complex scenario where I might have both less control over my data-gathering process and more influence over the learning environment. In preparation of RtD and to test the design and facilitation of play workshops, I conducted a mini-pilot play workshop at the Counterplay Conference[56] in Aarhus.

6.3.1 Play experiences at the LEGO Idea Conference

I attended the LEGO Idea Conference in Denmark during April 2018. It was based around the themes of child-centred play and learning environments. Here, I had the opportunity to participate in a tinkering workshop on cranks and contraptions organised by the Tinkering Studio[57]. This workshop was called *Cranky Contraptions and* was designed to encourage participants to construct various movable cranks and contraptions devised from everyday art material.

56 Discussed in the Introduction Chapter of this thesis.

57 The Tinkering Studio is a creative and immersive play-based activity studio at the Exploratorium in San Francisco. Its design and aesthetics are inspired by kindergartens, play workshops, and tinkering garages. Here, museum visitors can participate in various activities designed to stimulate learning in a fun, exploratory, and play-based manner. More information about the Tinkering Studio's ideology, projects, and collaborations can be accessed at https://www.exploratorium.edu/tinkering/projects

Figure 42: Cranky Contraptions atelier at the LEGO Idea Conference, Billund, 2018

The play materials for the Cranky Contraptions workshop were arranged on individual tables. Predesigned samples of a few movable contraptions were also a part of the material atelier. Workshop participants were encouraged to play and interact with these predesigned samples, before devising their own contraptions. The sample contraptions were constructed out of wood blocks, craft foam, and craft wire, and the same materials were made available to the participants. The contraptions were designed as skeletal samples, which made their *movable mechanisms* visible. One could comprehend how the mechanisms can be designed by observing and interacting with the sample contraptions. Additionally, samples designed by previous workshops' participants were also displayed on the tables, for the new participants to see and play with, or even to inspire ideas.

Observing and participating in the Cranky Contraptions workshop with the Tinkering Studio evolved into an iterative design session. This helped me devise a play-tutoring format for the RtD play workshops that focused on hands-on learning and object play through exploring, engaging, and tinkering with adaptive play materials developed by me.

6.4 Putting ethnographic findings to work: Design of play workshops

While designing the RtD workshops, I wanted to embrace uncertainty and be prepared for unforeseen circumstances with children as participants. Preparing for uncertainty and contingency meant ensuring that the needs and competencies of the participants were taken into consideration; this, in turn, supports Nicholson's (1972/2009) and Vygotsky's (1978) perspectives on designing adaptable and flexible child-centred learning environments. These unforeseen circumstances could range from language barriers, the participant's potential disinterest in the activity, the possibility of abandoning the workshop mid-way, distraction from other factors present in the CLEs, disappointment, boredom, inability to comprehend the workshop's intention, and potential interruptions from accompanying parents, younger siblings, or guardians.

I envisaged the participants (children) having agency over which play materials they wanted to select and how they wanted to engage with them. As observed during DE at Montessori schools, an inflexible and prescriptive play-tutoring format often led to monotonous and repetitive object play. As a result, affordances of design thinking such as iteration, tinkering, inquiry-based learning, and exploration were designed out of the learning experience.

Most instances of ceremonial guided play, helicopter facilitation, and shepherding, as observed during DE, did not account for uncertainty, competencies, and interests of the child. The hierarchical order structures adopted through ceremonial guided play, as observed during DE, led to an absence of agency, exploratory play, and discovery for the child. Based on these insights acquired during DE, I consciously decided against interrupting play sessions by being a helicopter facilitator,[58] and instead designed a facilitation framework where I could guide the participants through the workshop premise and respond to their queries.

6.4.1 Affordances of research spaces

Chesworth (2018) addresses child-friendly research methods in her work on embracing uncertainty while researching with young children. The author (ibid) talks about navigating unanticipated challenges and opportunities encountered while researching *with* children. Chesworth (ibid) cites Deleuze and Guattari's (1987) studies on *smooth* and *striated spaces,* while speculating on ever-changing ideas on researching with children. Deleuze and Guattari (1987) identify *smooth spaces* as "an amorphous collection of juxtaposed pieces that can be joined together in an infinite number of ways" (p. 476). Smooth spaces can be identified by the non-linear, random occurrences that evolve and unravel through interconnected encounters (Chesworth, 2018). Hohti (2016, as cited in Chesworth 2018) puts forward the following affordances of smooth spaces:

58 Helicopter facilitation was observed during ethnography at Montessori schools. This concept has been elaborated upon in Chapter Five.

1. In these spaces, action and interaction is ongoing and in constant flux.

2. Instead of following a fixed sequence, these spaces afford multiple possibilities.

Striated spaces as described by Hansen et al. (2017, as cited in Chesworth 2018) are seen as structured spaces or practices that are restrained and regulated by predesigned research frameworks, prescriptive actions, and prescriptive aims or contexts. Deleuze and Guattari (1987) visualise smooth and striated spaces as interdependent, interchangeable, and reciprocal, where the space can evolve from striated to smooth, and reverse.

Based on the arguments made above, it could be said that Montessori environments, as documented during my DE fieldwork, fall into the category of striated spaces (Hansen et al., 2017). Montessori environments follow a prescriptive approach to play that is based on a predefined curriculum and insists on specific outcomes and training of specific senses. Chesworth (2018) argues that a researcher, while engaging with children, might decide to intentionally set up an open-ended workspace (Gallacher and Gallagher, 2008) and operate nomadically in a smooth space (Deleuze and Guattari, 1988).

While preparing for my role as a facilitator and designing the RtD workshops, I hoped to incorporate a *smooth-striated workspace* which would oscillate between being purposeful (by following the step-by-step process to acquire a foundational STEAM concept) and being exploratory. Here, the participants would be incentivised to take control of their design process, and encouraged to experiment with materials and narratives by engaging in tinkering, and iterative and exploratory object play. These affordances, in turn, would support RtD and design thinking.

6.5 Play-based learning and RtD

Deweyan and Vygotskian perspectives on design thinking help perceive the link between play-based learning and RtD. As discussed in Chapter Two, Dewey, as a design thinker, advocates for pragmatist learning by endorsing hands-on interactions that support design thinking by exploring, tinkering, and iterating with materials and activities (Dalsgaard, 2014). Vygotsky, as a design thinker, endorses the design of play-based learning environments that challenge a learner’s competency and encourage social play. Both

Dewey and Vygotsky, as progressive educators, focus on active engagement, inquiry, and the design of play-based learning environments that support children's interests, while simultaneously considering and challenging their competencies.

Deweyan and Vygotskian perspectives on pragmatism and design thinking blur the lines between the roles of a researcher, a designer, and a facilitator, when engaging in RtD. In the context of this thesis, it can be argued that Vygotsky's and Dewey's play theories on active engagement, social play, inquiry-based learning, and experimentation resonate with RtD. In this thesis, RtD through play workshops offered a platform to design and test play materials with children that were conceptualised to consider their competencies, interests, and agency. Simultaneously, these workshops were designed to incentivise them to engage in hands-on learning through collaboration, interventionist play, and social play (Vygotsky, 1978).

Design of the play workshops also embodied perspectives on scaffolded facilitation (Vygotsky, 1978), pragmatist learning (Dewey, 1897), and Nicholson's (1972/2009) theory on loose parts. Here, the premise of the play workshop included studying the nature of a problem, reflecting on its requirements and needs, planning alternatives, construction and building prototypes, experimenting, modifying, tinkering, and hacking play materials, which necessitate the design of flexible and adaptable learning environments.

6.6 Design blueprint of the play workshops

The workshops were designed to encourage children to inquire, challenge, and experiment with play materials while simultaneously introducing them to STEAM themes such as spatial comprehension, movement, and mechanisms. Play materials designed for these workshops were inspired by Montessori's modular geometry palette, the presentation time format, prepared environments, and the LEGO Cranky Contraptions workshop.

6.6.1 Workshops and the affordance of tinkering

As discussed in Part One, when activities that afford tinkering and iterative play are incorporated within play-based learning environments, they encourage the adoption of a creative and innovative palette of play materials, concepts, and frameworks. In contrast to prescriptive play-tutoring as observed on-site during DE at the Montessori schools that did not factor in rearrangement or refurbishment of materials, tinkering as a twenty-first century literacy skill (Koupf, 2018; Bevan et al., 2014; Yakman, 2008, 2010), due to its exploratory attitude towards knowledge acquisition, embraces iteration and creativity[59]. Tinkering as an adaptable design affordance supports design thinking, since it allows for rearrangement and swapping of materials, which encourages iterative and inquiry-based exploration of concepts. This, tinkering with play materials was a key affordance designed within the play workshops.

6.6.2 Geometry to inspire STEAM comprehension through play workshops

When children are exposed to geometric shapes, it gives them an opportunity to mentally manipulate spatial data (Satlow and Newcombe, 1998; Cross et al., 2009). Resnick et al. (2016) argue that the identification, visualisation, and manipulation of geometric shapes creates a foundation of STEM concepts such as *measurement*, *composition*, and *decomposition* in children. Resnick et al. (ibid) acknowledge that an understanding of spatial knowledge and geometry is vital to preparing for school-based curricula. Montessori, in her curriculum, factored this as well, which is visible from her understanding of geometry and the design of her sensorial menu as discussed in previous chapters. Montessori's geometry tools and activities are designed for prescription. Simultaneously, the geometry tools and supporting activities are supposed to cater to children's spatial and mathematical learning outputs as they progress through each cohort.

Resnick et al. (2016) argue that it can be challenging for children to grasp geometric forms until they are older. The authors (ibid) argue that the time children dedicate to spatial learning and geometry is often focused primarily on identification of shapes, and not on understanding the core properties of shape categories (Sarama and Clements, 2004). Consecutively, play-based learning environments are a promising format to grasp geometrical forms since there is a potential of interaction with pedagogic materials and activities for children to learn in a dynamic and multi-sensorial manner.

59 Examples of CLEs that support tinkering include the Tinkering School and Exploratorium in California, the Institute of Imagination in London, and Brightworks in San Francisco, as well as the Learning through Play approach adopted by the LEGO Foundation in Denmark. These CLEs have been inspired by the progressive pedagogies of educators such as Jean Piaget, John Dewey, Johan Pestalozzi, and Seymour Papert.

Resnick et al. (2016) insist that materials that aid shape learning essay an important role in the development of spatial understanding in children. Within the current context of school curricula, Resnick et al. (ibid) identify shape learning materials such as books, shape sorters, and apps to aid spatial acquisition. In their study of shape materials presented to preschoolers, Resnick et al. (ibid) cite three enquiries, which are as follows:

1. Which shapes are introduced to children?

2. How are these shapes depicted?

3. Is there any additional information provided on the presented shapes that might aid the children's learning process?

Examining how geometrical comprehension occurs in children is relative to how they are exposed to geometrical shapes, and in what manner the learning environment and learning materials support their knowledge acquisition (ibid).

Resnick et al. (2016) argue that shapes can be presented in various formats, such as (1) in isolation through line drawings (for example, the line drawing of a triangle), (2) embedded in everyday objects as an isolated image (for example, as an image of a circular bottle cap), or (3) ingrained in a scenario (for example, a bottle of cola with a circular lid on a square table). However, the authors (ibid) also clarify that the ability to identify shapes from a complex scenario can be difficult for young children. The authors (ibid) explain that children will resist learning new shape names (for example, a square) from everyday objects that already have a label (for example, a box will not be called a cuboid).

Resnick et al. (2016) suggest that studying children's exposure to geometric forms through their interaction with shape sorters and shape materials (as observed during DE) is crucial as an initial step to spatial comprehension as it highlights opportunities for children to develop geometric and spatial skills. These skills help create a foundation that can support the development of STEAM-related competencies.

During DE, I observed interactions that cohere with Resnick et al.'s (2016) argument. The Geometric Cabinet is designed to provide children with an extensive palette of shapes and introduce them to geometric principles. The shape insets are designed and arranged to transition from symmetrical to non-symmetrical forms. The shape insets are flat in structure (resembling ceramic tiles), have knobs attached to their surface, and come prearranged in drawers. These drawers are designed to only allow one specific shape to fit into a specific cavity designed for that shape. As observed on-site during DE, the overall physical construction of the shape insets and activities designed to interact with them were limiting. These prescriptive activities only allowed children to trace the shapes from the shape insets onto paper and arrange them back into their drawers.

On-site vignettes of children interacting with the Geometric Cabinet revealed that play activities designed to interact with these sensorial materials, along with helicopter facilitation, did not afford opportunities for experimentation or iterative play. Here, I refer to Ness and Farenga's (2016) arguments on a constrained design language leading to fewer possibilities of exploratory play. In the case of the Geometric Shape Insets, these materials and their supporting play activities were designed with more constraints (knobs on the surface and a flat structure), which led to fewer instances of exploratory and iterative play. In short, there was limited scope to manipulate and hack these materials in order to engage in inquiry-based learning. As a result, children would often end up engaging in *repetitive* and *monotonous* play with the geometry materials.

In comparison, the play workshops were designed to encourage children to tinker and experiment with materials, try a few variations, and construct fun and innovative movable artefacts that could then be taken home by the participants. Play materials and activities for the RtD workshops were designed to be adaptive, dynamic, hackable, exploratory, and interchangeable. These materials and activities for the RtD workshops supported design thinking through affordances of tinkering, exploration, experimentation, inquiry, intervention, and hands-on learning, while simultaneously focusing on the acquisition of STEAM concepts.

These affordances were designed to allow children to explore various aspects of geometry, that would help them construct prototypes by using different geometric shapes. To integrate play-based learning and STEAM comprehension through tinkering, experimentation, exploration, and inquiry-based learning, *automata as a design idiom* were incorporated as a theme within the workshops.

6.7 Automata as a design idiom

The history of automata is closely connected to the history of movable toys, kinetic sculptures, theatrical devices, engineering, and traditional robotics. Race (2014) defines *automata*[60] as objects that move themselves where the term automata could be applied with reference to objects to illustrate only mechanical movement. According to Race (2014), automata is commonly used to define movable mechanical devices, which typically intend to function as toys for play or entertainment. The author (ibid) adds that the term automata is used to describe an aesthetic, specifically, that which imitates the action of a living body performing a routine task (for example, toys often depict repeated movements such as cows grazing, sheep bobbing their heads, and birds pecking at their food).

With their background in Montessori education, computer science, and engineering, Ibes and Ng[61] (2011) argue the Montessori method can be expanded to suitably adapt engineering and STEM education. The Montessori method, due to its holistic nature, initiates learning through initial experiences (presentation time) followed by hands-on engagement and interactions (play activities) with sensorial materials. Ibes and Ng (ibid) argue that STEM themes such as engineering can offer a practical and hands-on approach to designing activities and materials for the Montessori curriculum that help access deeper concepts embedded within lessons.

Ibes and Ng (2011) argue that it is important to identify areas and themes that cross-pollinate engineering principles with the Montessori pedagogy. They discuss how exposing children to experiencing, constructing, and analysing physical phenomena from a younger age could help in future comprehension of engineering concepts. Given the emphasis upon sensorial experiences and physical interaction with materials within both the Montessori method and STEM and STEAM themes, it seemed that automata as a design idiom could provide an accessible and adaptable medium to amalgamate these domains.

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60 Automata is plural for the word Automaton (which bears its roots in Greek)

61 Ibes and Ng (2011) co-developed a MSTEM (Middle School Science, Technology, Engineering, and Mathematics) program for in-service Montessori educators at St. Catherine University in Minnesota, as a means to enrich existing Montessori content in Science, Technology, Engineering and Mathematics (STEM) subjects.

6.7.1 Geometry and engineering through automata mechanisms

In the following section, I refer to the work of North (2015), an automaton-maker and enthusiast, while introducing foundational automata mechanisms. Within the context of RtD play workshops, automata mechanisms were deconstructed and simplified into buildable prototypes that are inspired by North's (2015) work. By interacting with specially designed play materials and geometric shapes, children could build a movable automaton in the RtD play workshops.

North (2015) explains the concept of *cams* that is central to studying mechanisms in automata. Cams can be defined as geometric shapes that *remember a movement* (act as the memory) and allow a mechanism to repeat the same movement continuously through external force (either manual or motorised). However, North (ibid) specifies that cams cannot function in isolation. Cams are paired with a component known as the *cam-follower* that helps translate the shape (geometrical form) of a moving cam into the desired motion. The next section introduces specific geometric cam shapes and their accompanying cam-followers, which are commonly used to design basic movable mechanisms in an automaton.

6.7.2 Movable geometry: Form and shape of cams and cam-followers

According to North (2015), a *plate cam* (or a *disk cam*) is a circular disk shape, which is anchored to a rotating *axle* or *shaft* (a rod that passes through the cam). The cam-follower is designed as an extension that moves along the edge of a cam. A typical automata contraption will also have a component called the *bearing* or *guide*, which is the gap through which the rod attached to the cam-follower will slide through (ibid). Consequently, when the *axle* is rotated, the cam and the cam-follower rod rotate parallelly.

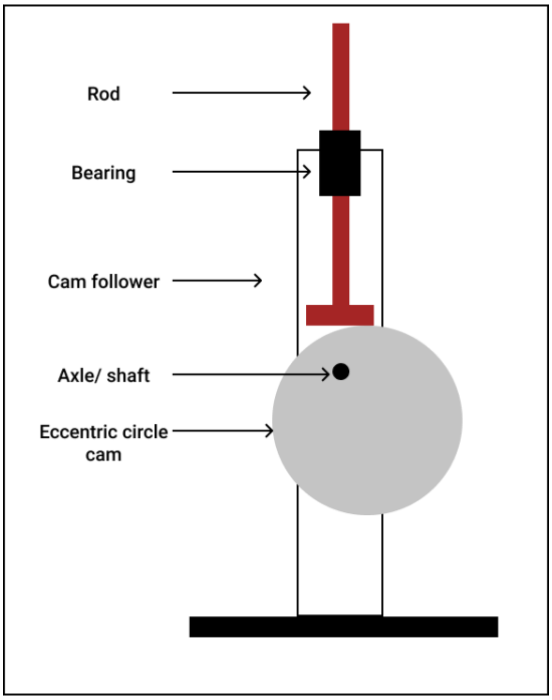

Figure 43: Illustrating a basic automaton mechanism

Cams act as gears in an automaton and are arranged to create continuous and/or repetitive movements like oscillations, rise-and-fall, tremors, shakes, and rotations. The geometrical form of a cam will define the kind of movement the cam-follower will create. Changes in the diameter of the cam (relative to the geometric form of the cam) will lead to changes in the way a cam-follower moves.

Different geometrical shapes create different movements. The following section refers to some popular cam and cam-follower combinations that North (2015) refers to in his work. Some of these cam shapes were later adapted as components in the material atelier for the RtD play workshops (see Figure 48).

1. **Drop cam:**

   A cam resembling the shape of a water droplet. This cam creates a specific movement of *bobbing* or *skipping up and down*. Usually, a cam-follower with a flat or disk base is paired with the drop cam. According to North (2015), a disk-based cam-follower is not very precise, and the size of the disk can also add to the time of contact between the cam and the cam-follower.

2. **Apostrophe or Snail cam:**

The geometrical form of an apostrophe or snail cam resembles the shape of an apostrophe or a snail and is designed to create the movement of slow rise and sudden fall. The rise-and-fall movement generated by an apostrophe cam is unidirectional, where the movement will only occur if the axle is rotated in one direction. According to North (2015), this cam should have thicker edges, and must not be very intricate or sharp-edged, as the cam-follower's edge might get caught in the cam's contours. The snail cam is not used in automata very often, since the constant movement wears both the cam and the cam-follower down (North, 2015).

3. **Splash cam and rounded-edge cam-follower:**

The *splash cam* is also called a *flower cam* since its geometrical form resembles a four-petaled flower. The geometric form of a splash or flower cam is designed to have wide and smooth depressions and contours, so that the cam-follower can drop into any depression with relative ease, without causing any wear and tear. North (2015) clarifies that, if this cam shape has sharp depressions and tight contours, the motion of the cam-follower will not be translated accurately. North (2015) suggests a rounded-edge cam-follower to accompany the splash or flower cam shape. This cam-follower can also be designed as a simple dowel with smooth and rounded edges, which can glide effortlessly along the contours of this cam shape.

North (ibid) argues that, with cams and cam-followers, friction is a regular issue. To counter the wear and tear caused by friction, sometimes the cam-follower is also designed with a wheel attached on the end interacting with the cam (also called a roller cam). With this geometric form, the wheel at the end of the roller cam can spin along the edges of the splash cam with minimum effort. Such cam-followers are also functional when the load attached to the cam follower is heavy.

4. **Cams arranged to create singular rotation motion:**

North (2015) explains that flat and wider cam-followers can be adopted to create a rotational movement. In order to achieve this movement, the cam-follower's shaft must be offset so that one edge of the cam can be in constant contact with one side of the cam-follower. Hence, a round cam in continuous contact with the flat edge of the cam-follower will end up producing a movement of continuous rotation. A cam that is arranged in a lop-sided manner (also known as an eccentric cam), on the other hand, will cause a periodical rotation or lift based on how it is closely positioned to the cam-follower.

5. Cams for dual rotation motion:

North (2015) explains that, with *dual cams*, back and forth rotational movement is the most popular mechanism in automata devices. In this contraption, two cams are attached to a common axle and a flat cam-follower is paired with them to create an alternative rise-and-fall motion.

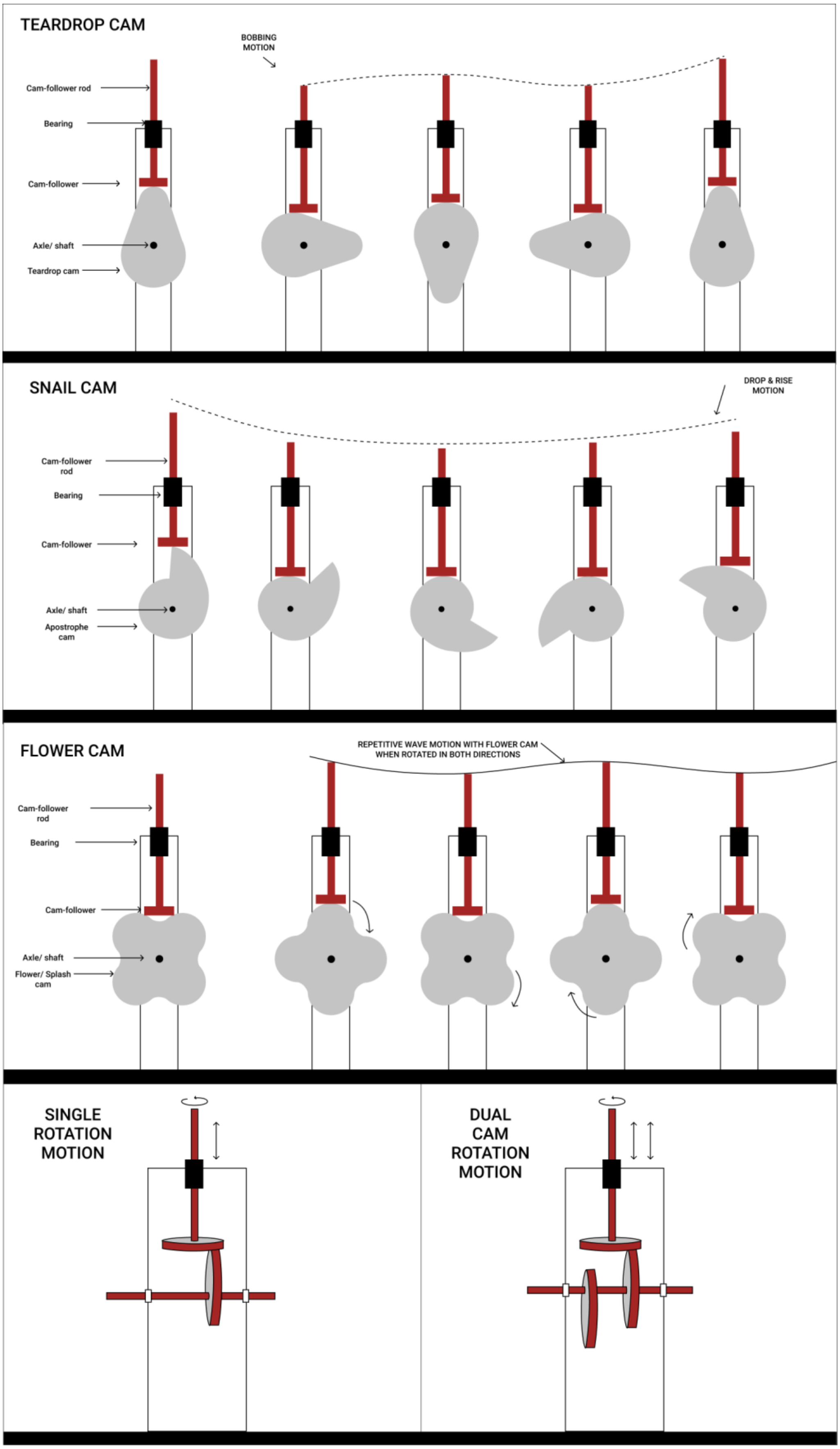

Figure 44: Illustrations visualising automata cams and cam-followers

6.8 Design of the automata atelier

While designing the play workshops, I drew inspiration from the Cranky Contraptions workshop at the LEGO Idea Conference. During the Cranky Contraptions workshop, to help the participants familiarise themselves with the workshop and stimulate inquisitiveness, the facilitators had designed individual material ateliers. In the ateliers, all the construction and art materials were arranged on tables in a visually pleasing manner. The workspace designed by the facilitators for the Cranky Contraptions workshop encouraged tinkering, iterative prototyping, and exploration of materials. In doing so, it also echoed Montessori's approach of providing a prepared environment, where play materials had been strategically arranged to facilitate inquisitiveness and learning.

For the RtD play workshops, I designed an *automata atelier* to facilitate play-sessions inspired by the prepared environment and material atelier of the Cranky Contraptions workshops. Automata ateliers for the RtD play workshops were segregated into several sections to ease access to all the materials and inspire inquisitiveness. The atelier was made up of geometric play materials along with supporting construction tools. The automata atelier was divided into the following sections:

6.8.1 Section 1 | Construction materials:

This section consisted of materials designed to build the automata mechanisms, such as supporting frame structures (refer to Figure 50 and 51), geometric shapes designed to function as cams, plastic straws (to design bearings to support the cam-followers and the axle), and bamboo skewers (to design the axle for the cam and the cam-followers).

In order to introduce children to distinctive geometrical shapes, test various movements associated with these shapes, and build automata structures with relative ease during these workshops, I shortlisted a few shapes inspired from the Montessori Geometric Cabinet (where their geometric form would translate well as cams). The following table lists geometrical shapes chosen as cams for the play workshops, based on a study of North's (2018) automata cams mechanisms and inspired by the Montessori Geometric Cabinet.

Table 7: Shortlisted cam shapes for the automata atelier.

Eccentric circular cam	Adopted from Montessori's Geometric Cabinet Drawer number 1.
Equilateral triangle cam	Adopted from Montessori's Geometric Cabinet Drawer number 3.
Hexagonal cam	Adopted from Montessori's Geometric Cabinet Drawer number 4.
Oval cam	Adopted from Montessori's Geometric Cabinet Drawer number 6.
A four-sided flower or splash cam	A rounded quatrefoil shape, which was adopted from Montessori's Geometric Cabinet Drawer number 6.
Snail or apostrophe cam	Unique and not adopted from Montessori's Geometric Cabinet.
Drop cam	A non-symmetrical oval shape, which was adopted from Montessori's Geometric Cabinet Drawer 6.

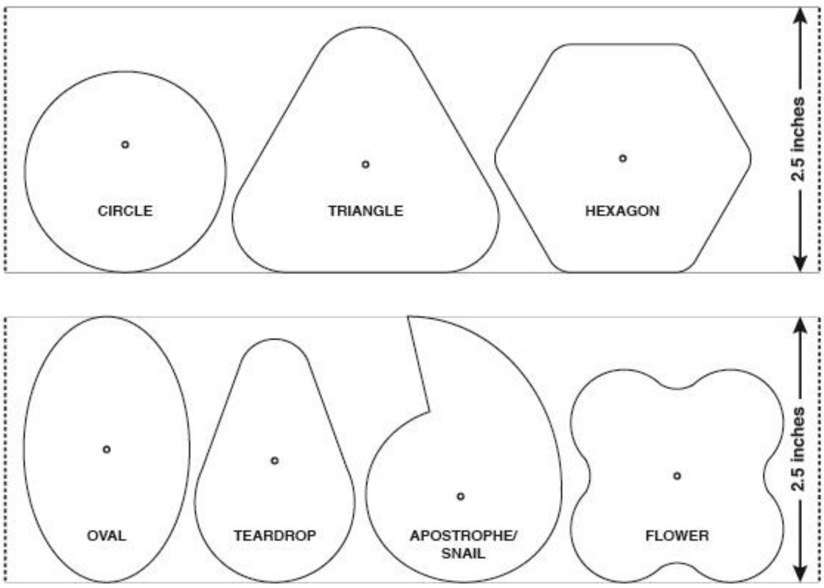

Figure 45: Cam shapes finalised for the play workshops

By selecting the aforementioned shapes as cams (see Figure 48), I hoped to provide a palette of multiple geometric shapes that could be used to construct automata, with different movements specific to certain shapes. This would also potentially expose the workshop participants to a taxonomy of various movements that they could associate to these shapes. I also hoped that constructing automata in these workshops would help the participants grasp the concept of dual representation (DeLoache, 2000), where they could comprehend geometrical shapes as a shape material (for example, the shape itself; a circle, a triangle, or a hexagon) as well as a cam (a component that makes the automata mechanism move).

6.8.1.a Design decisions: Geometric form of the cams

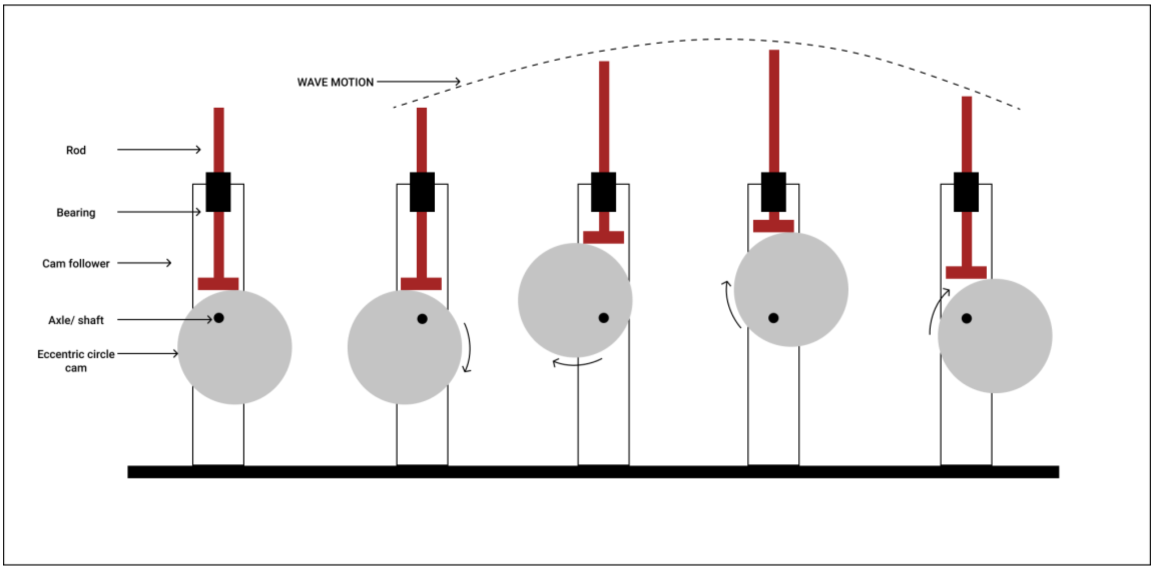

Figure 46: Wave motion created by an eccentric circular cam

All the cam shapes designed for the play workshops, had rounded contours, edges, and depressions[62] to allow the cam-follower to be propped over the cam and not get caught in its depressions, avoid wear and tear of the material (cardboard), and help the cam-follower move along the edges of a cam with relative ease (North, 2015).

The cam shapes were laser cut from 4 mm thick cardboard. A singular 0.2 mm pinhole was marked and cut inside the geometrical midpoint of each cam to allow an axle (bamboo skewers) to slide through the perforation while constructing the mechanism and eventually prop the cams inside the mechanism frame. As an exception, the circular cam had a 0.2 mm pinhole cut away from its midpoint and closer to one of its edges. This cam was called an *eccentric circular cam* (refer to Figure 46) as the offset pinhole (through which the axle would pass) in the cam would allow it to move more dynamically when arranged inside an automata mechanism.

Based on the safety protocols associated with building the mechanisms, as well as the structural limitations of a material like cardboard (where pricking it with force could have broken the cam, bent it out of shape, or hurt a participant), the pinholes were laser-cut before-hand.

62 Depressions in the geometrical form were specific to the snail and flower cam.

Figure 47: Frame designed to house the automaton mechanism

Apart from the cams, the frame within which automata mechanisms would be housed was also designed using cardboard. It was a rectangular frame constructed out of four alternating rectangles, two rectangles that measured 5 x 3 inches, and 2 rectangles that measured 4.5 x 3 inches (see Figure 50). The smaller rectangles were designed as the top and bottom sections of an automaton frame and the larger rectangles designed as the side panels of the frame. All the rectangular pieces had two pinholes; each laser cut along their central axis. The smaller rectangles had 2 pinholes (measuring 4 mm in diameter) along the central axis. These wider perforations were specifically measured as 4 mm to accommodate the bearing[63] without breaking the cardboard frame**.** The larger rectangles had 1.5 mm perforations for the axle rod (fashioned out of a bamboo skewer to hold the *cam*) to slide through the cams.

63 The bearing (also called the Guide) is a support structure that encases the rod attached to a cam follower. In this scenario, while designing the automata frame, the bearing was fashioned out of a piece of straw to support the rod attached to the cam follower.

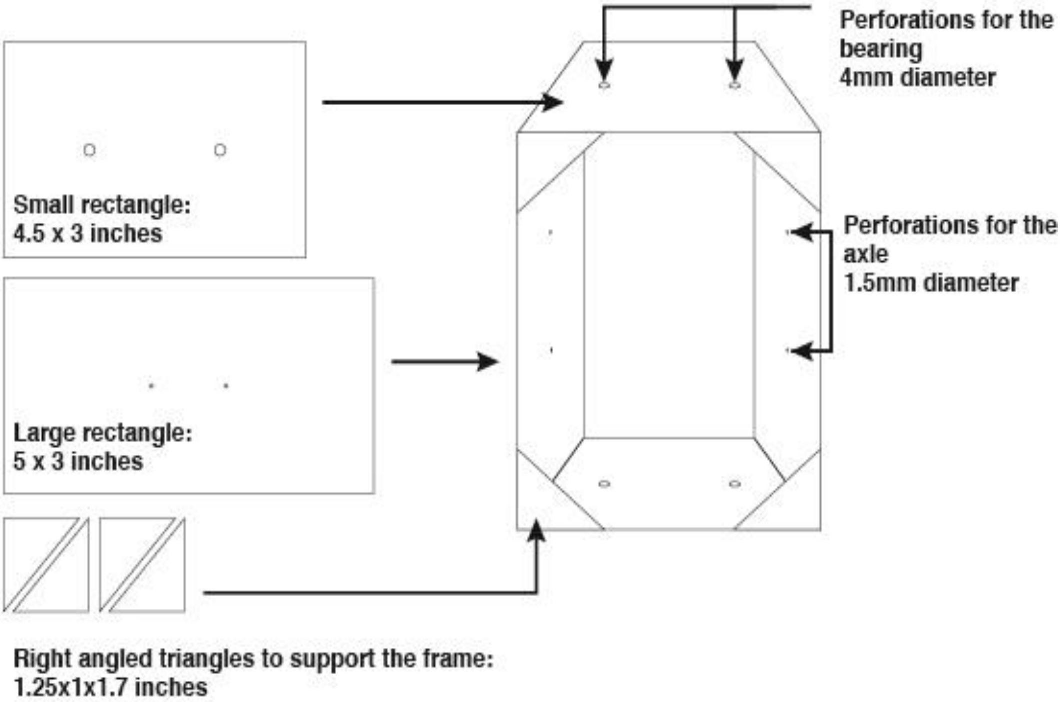

Figure 48: Measurements of the automaton frame to house the mechanism

6.8.2 Section 2 | Art materials:

This section of the automata atelier was designed to introduce playful, fun, and creative visual affordances such as themes, stories, narratives, doodles, and decoration. This section consisted of art and craft materials such as craft paper, pipe cleaners, bobbles, paper cups, craft foam, foam pellets (found in packaging parcels), cardboard cylinders, googly eyes stickers, sketch pens, markers, pencil colours, and crayons. These materials were offered to the participants to encourage them to conceptualise, imagine, and design narratives and stories to thematise their automata mechanisms.

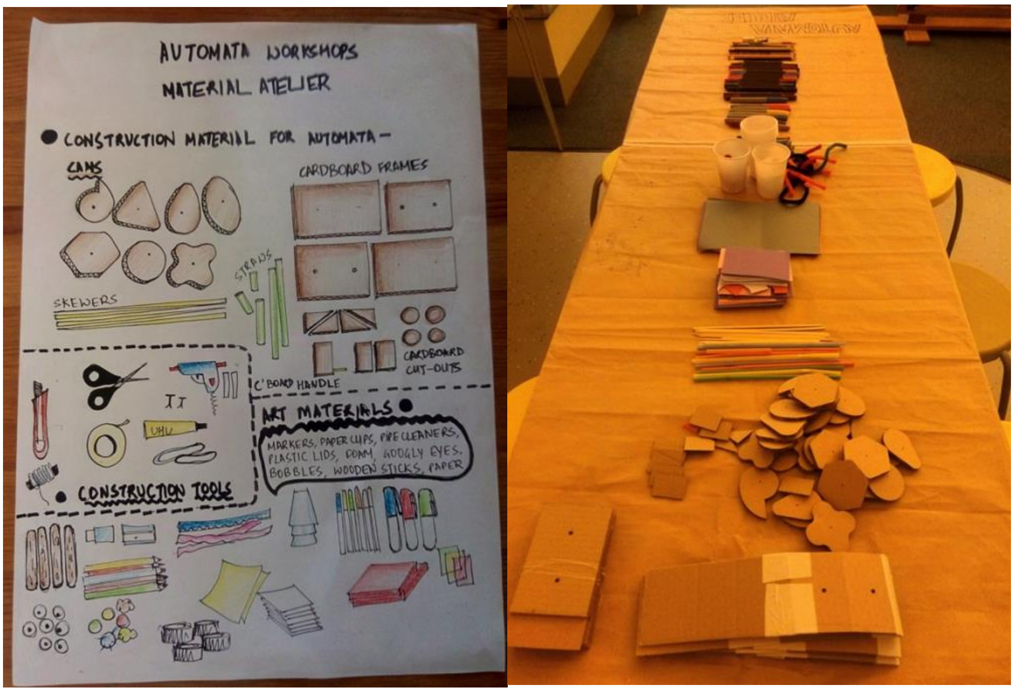

Figure 49: The complete automata atelier (conceptualised from sketch to actual arrangement based on allotted space at the Museum of Childhood)

6.8.3 Section 3 | Construction tools:

This section of the automata atelier consisted of construction tools to help build the automaton mechanism, such as glue guns, craft glue, paper fasteners, craft scissors, paper cutter, masking tape, cotton strings, and rubber bands. In order to ensure the safety of the participants, all the construction tools were safe-guarded and kept separately, except for masking tape, cotton strings, and rubber bands that the children were allowed to use on their own. As the workshop facilitator, I took ownership of the glue gun, paper cutters, and scissors to ensure that the participants didn't hurt themselves while constructing their automaton mechanisms.

6.8.4 Feedback booklets

While designing POP workshops, it was essential to obtain first-hand feedback about the workshops and learning outcomes from every participant. In order to encourage the participants to document their thoughts and feedback about the workshop experience, feedback booklets were designed as a part of the automata atelier.

These booklets were given to every participant after their play session ended. Participants were encouraged to be honest in their responses and had complete control over how they documented their feedback. In order to make the feedback process for the workshops more enjoyable and less boring for the children, the booklets were designed to resemble customisable scrapbooks, which allowed children to sketch, draw, and stick art materials in them.

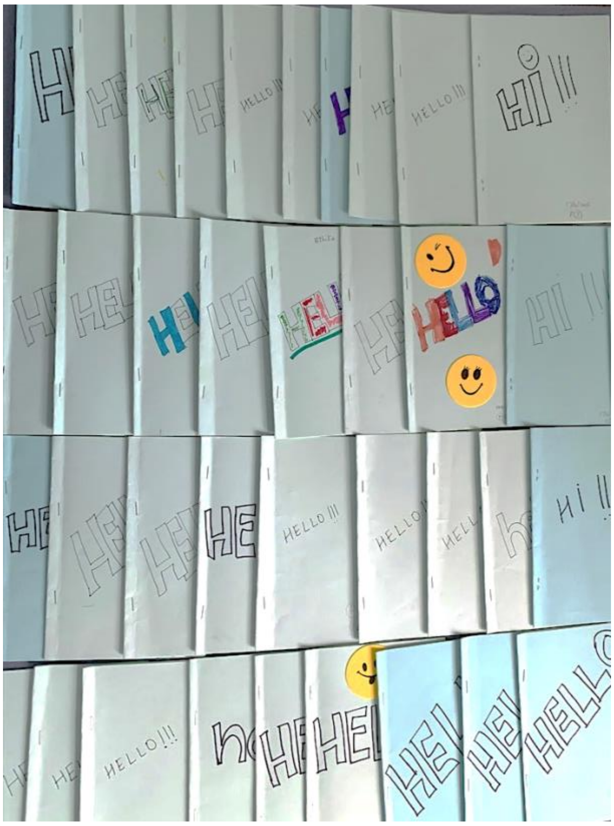

Figure 50: Feedback booklets filled by the participants

While being encouraged to sketch, draw, and stick art material in the booklets, the participants were also requested to respond to some key questions that the workshops hoped to address to help gather insights for RtD. As elaborated further in Chapter Eight, most of the participants completed their feedback booklets on their own and a few asked their parents help with spellings. Each booklet had four questions and extra space for the children to visualise their experience at the POP workshops. The questions were:

1. What did they make?

2. Which shapes did they use?

3. Did their toy move, bounce, spin, dance, wobble, jump?

4. Any other thought or feedback they would like to share.

These questions were added to the booklet in order to comprehend how the participants had engaged with the automata atelier during the workshops. These booklets were also designed to understand whether the participants had been able to associate the shapes they had interacted with and used in their automata constructions to the different kinds of movements their designed constructions eventually displayed. The booklets listed a few movements such as move, bounce, spin, dance, wobble, and jump beforehand. Apart from these, the participants were also encouraged to add additional words that they thought would make more sense to them and help them describe the movements of their designed automata constructions.

6.8.5 Prior planning and preparation

Similar to the DE research schedule, preparation had to be undertaken before commencing with the play workshops. These play workshops were branded as POP (Potentiality of Play) workshops. Similar to DE, before officially beginning RtD, it was mandatory to get signed permissions and approvals from Edinburgh Napier's Ethics Committee. A separate RtD ethics proposal[64] was drafted to explain the purpose of this method in this thesis. This proposal also described the design process and development of the POP workshops, along with listing all the components used to construct the automata atelier.

Health and safety protocols had to be taken into consideration (mandatory in the case of interacting with children) while designing the workshops and selecting materials. Extensive preparation had to be undertaken while selecting materials to design the automata atelier to ensure maximum safety for the participating children. Artefacts within the automata atelier were designed out of standard art materials such as medium density fibreboard (MDF), cardboard sheets (cut-out using laser cutters to ensure no rough edges), card paper, and craft materials such as craft foam, bobbles, felt pieces, markers, and glue. The ethics proposal specified that the automata atelier and the premise of the POP workshops were designed to be completely safe for the children. The proposal also

64 Refer to the appendix section at the end of this thesis.

specified that, as the facilitator, I would ensure that cutting tools such as scissors, paper cutters, and glue guns would only be handled by me during the workshop sessions.

Similar to DE, consent forms and information booklets about POP workshops were submitted along with the ethics proposal for approval. After a few revisions, the ethics proposal for RtD was formally accepted by the university and the process of contacting potential venues for the workshops could begin. The Museum of Childhood and Scottish Storytelling Center in Edinburgh were eventually finalised as CLEs for the POP workshops. These workshops were advertised across their social media channels to invite children and families for the play sessions.

A workshop information sheet was also drafted with a research summary and the workshop premise. Copies of this information sheet were given to the selected CLEs so that they could pass them on to potential visitors. The only restriction specified in the workshop was age; the workshops were designed for children in the preferred age group of eight to twelve years. These POP workshops were designed as drop-in and free play sessions for children and families. The time period of summer holidays in Edinburgh (between late June to early August 2018) was selected to organise these workshops, as children from various parts of the world would be expected to visit these CLEs in Edinburgh.

6.9 Chapter summary

Informal play-based learning environments such as CLEs afford experimental, iterative, and free-choice learning, which, in turn, responds to the limitations of formal environments. CLEs support play-based learning through the design of play premises that are iterative and flexible in nature. CLEs integrate play and learning as mutually influential as well as distinctive processes.

As discussed in Chapter One, Andre et al. (2017) argue that play-based activities that evoke curiosity, excitement, discussions, hands-on learning, and exploration, and are scaffolded by knowledgeable peers, adults, and/or family members, or supported by technology, are conducive to facilitating children's learning in CLEs.

This chapter has introduced RtD as an iterative and practice-based method that was adopted in this thesis to get substantive insights through the design and facilitation of POP workshops at CLEs. Here, POP workshops are *designed as a research method* that support affordances of design thinking such as flexibility, tinkering, iteration, and creative problem-solving. This chapter has discussed the influence of Montessori's geometry materials, prepared environments, presentation time, and the Cranky Contraptions workshop on the design of the play workshop premise and material atelier. Automata as a design idiom have been incorporated within the workshop premise to introduce STEAM concepts such as geometry and engineering by means of active and iterative object play.

Additionally, this chapter has also highlighted the change in the researcher's positionality; from essaying the role of a non-participating observer during DE, to designing and facilitating play workshops during RtD. This shift in positionality is particularly important to design research, as the researcher also embraces multiple roles while facilitating the workshops. Workshops as a research method allow the research to essay the role of an inside researcher, a research instrument, and an outside researcher (Ørngreen and Levinsen, 2017; Ahmed and Asraf, 2018).

This fluidity in the researcher's positionality during RtD allowed for the design of flexible scaffolding frameworks. Based on the interests and competencies of the participants as well as the premise of the POP workshops, by essaying these multiple roles, I could adapt and alter my facilitation style to best support them. This has been further discussed in Chapter Seven and Eight.

The next chapter aims to synthesise the dominant themes uncovered during the RtD fieldwork through the documentation of thirteen POP workshops across two CLEs in Edinburgh.

Chapter Seven:
Potentiality of Play workshops diaries (RtD)

Chapter Seven presents a chronological account and evolution of the RtD method through the design and facilitation of POP workshops. This chapter aims to address the first and third research questions of this thesis that focus on design thinking and design's contributions to play-based learning and its migration beyond formal classroom environments.

POP workshops were organised across two venues in Edinburgh over the course of two months between June to August 2018. Eleven workshops were organised at the Museum of Childhood in Edinburgh and two workshops were organised at the Scottish Storytelling Center in Edinburgh.

This chapter presents observations from the participant's interactions and experiences during the POP workshops through thirteen workshop diary narratives supported by images and observations. By way of organising, designing, and facilitating these play workshops, I hoped to identify design opportunities where Montessori's inherently static design language could be enriched and altered to accommodate dynamic affordances of iteration, prototyping, and tinkering as twenty-first century literacies.

These workshop diary narratives present examples of experimentation, problem-solving, and iterative learning undertaken during the workshops by participants tinkering and exploring the automata atelier. These diary narratives are categorised into sections that focus on participant reactions and responses, challenges faced by both the participants and me as the facilitator, evolution of the automata atelier, learning obstacles, and outcomes. Segregating these narratives into specific sections helps present a more holistic overview of designing workshops as a research method to conduct RtD.

In the next chapter, these narratives and excerpts from each workshop are further analysed and studied against the theoretical concepts of play-based learning discussed initially in Part One of this thesis. Evaluating these observations reveals the ways in which POP workshops harnessed the capacity of design thinking in informal play-based learning environments to acquire STEAM concepts (here, through the construction of automata).

In an effort to chronicle participant data gathered through the workshops, a code is introduced to identify participants and their workshop days. These codes have been allotted in order to maintain the participant's anonymity and protect their identity in compliance with the university's research guidelines for children. Numeric codes correspond to the chronological sequence of the workshop (for example, participant one from the first workshop is identified as P1_D1).

7.1 POP workshop diaries: Day One

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 17th June 2018

Total number of participants: 5

7.1.1 Initial preparations

On the first day, I arrived at the Museum of Childhood two hours before the workshop officially began. Since this was the first workshop session, I wanted to ensure that I had some spare time to accommodate any last-minute changes or logistical requirements by the museum. Once I arrived at the museum, I was informed that the museum staff were not aware of the POP workshops organised at their venue due to a communication lapse between their in-house team and the administrators with whose permission I had planned the workshops. This caused a slight delay in setting up the workshop atelier and getting things in order. Eventually, after clarifying with the museum staff, I was taken to a gallery room on the second floor, where I would be setting up the automata atelier and conducting these workshops. Between 10 am and 11 am, I prepared the play environment, and set up play materials and seating around the automata atelier.

The workshops had been advertised as free and drop-in sessions by the museum administration on their social media pages and website[65]. As a result of this, there was less clarity on the exact number of participants that would attend these workshops. A time slot between 11 am to 1 pm was chosen to conduct these POP workshops, as more visitors

65 Workshop advertisements posted by the museum of Childhood are shared in the appendix at the end of this thesis.

and families with school going children were expected to visit the museum between these hours.

I arranged the automata atelier to accommodate up to three participants and their accompanying parents/guardians in one session. The POP workshops were designed to facilitate play-based learning sessions for five to six participants per day. By accommodating fewer participants per session, this arrangement would give them easy access to the materials, allow me to dedicate sufficient time to each participant, make it easier to facilitate individual play sessions, and respond to queries regarding the workshops.

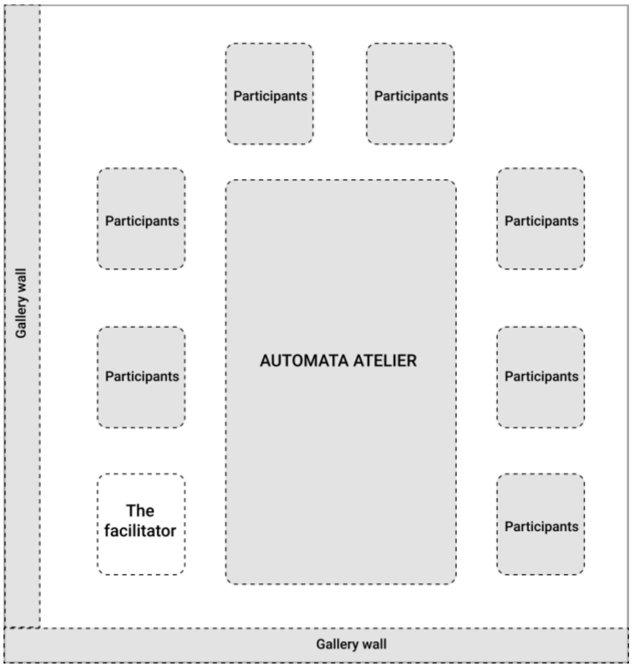

Figure 51: Layout of the POP workshop on Day One at the Museum of Childhood

The first half hour on the first day of the workshop was uneventful, since the museum had just opened for the day and there weren't many visitors. As I was located in a quiet corner in one of the museum galleries, the automata atelier was not noticeable to the visitors in the first instance. Eventually, by 11.20 am, visitors began to arrive at the museum and children began to approach the automata atelier with their parents.

When some children noticed the automata atelier with all the colourful play-materials and preconstructed automata samples arranged on tables covered with craft paper, it piqued their interest and curiosity about the workshop. Some parents walked up to me and asked me if their children could participate in the workshop. Some of these children were only four to five years old; they were much younger than the intended age group for whom these workshops were designed. I explained the age requirements and the premise of the automata play sessions to the parents. Some parents requested me to let their younger children sit with me in the atelier and sketch. As there were no participants in the workshop at that time, I politely obliged and let the younger children sit around the atelier and sketch for a few minutes.

At around 11.30 am, a potential participant (between the age range of ten to eleven years) came to me and inquired about the workshop. I explained the premise of the workshop to her as I hoped she might want to participate. I showed her some videos[66] of automata mechanisms I had previously constructed and arranged as samples on the atelier. This helped her visualise what the workshop entailed. This participant (P1_D1) was enthusiastic about the workshop premise and sat down to begin the play session.

After the first session, the workshop sessions got busy as more children joined in with their parents. By the end of my allotted two-hour slot at the museum, I had facilitated play sessions with five participants. All of them had successfully designed workable and diverse automata mechanisms, and taken their designed toys back home.

Some of these participants also took home extra cams to try and devise more automata mechanisms using cardboard pieces and other art material available in their homes. Most participants were excited to use *spare materials* such as amazon packaging boxes and packaging materials to design their own automata mechanisms. One of the participants mentioned that she would use the laser-cut cam shapes from the automata atelier as a stencil to try and devise her own cam shapes using cardboard available at her home.

7.1.2 Testing the workshop space and automata atelier

On the first day of the workshop, I was given a relatively small table to set up the automata atelier. Since it was the first day, I was able to test the arrangement of the atelier in the provided space. The first workshop also helped me identify limitations and opportunities of organising the automata atelier to be more functional and easier to access for the

66 Some videos of automata mechanisms can be accessed by links available in the Appendix section: Extra materials at the end of this thesis.

participants. After facilitating the first workshop, I was able to request for more tables and access to a better lit gallery space for the forthcoming sessions.

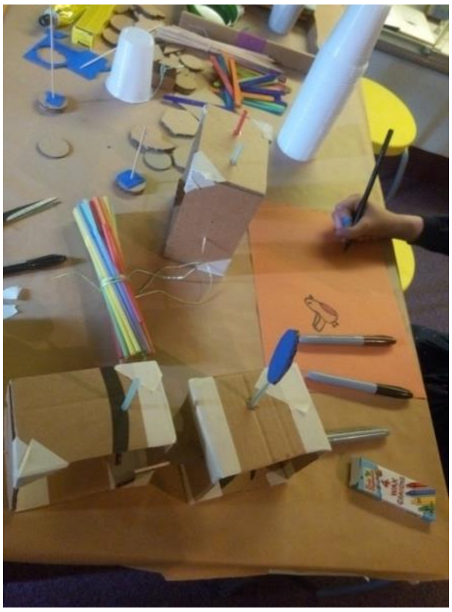

Figure 52: Arrangement of the automata atelier: Day One

7.1.3 Embracing the role of an inside researcher and research instrument

As discussed in Chapter Six, in order to embrace the role of a research instrument, the researcher should design the workshop environment to be a safe, accessible, and comfortable space for the participants, where they are incentivised to share their feedback, engage in discussions, critique the workshop format, and reflect on their learning outcomes with the researcher.

Safety measures for the POP workshops had already been considered, as discussed in Chapter Six. All the construction materials (Section one of the automata atelier) and art materials (Section two of the automata atelier) were placed in front of the participants. However, construction tools (Section three of the automata atelier) such as the glue gun, paper cutters, and scissors, were kept away from the participants. In case they needed to cut something using a paper cutter or use the glue gun, I would volunteer to cut and glue things for them. Keeping the construction materials closer to me and helping the participants use them ensured that no one hurt themselves.

In order to create an approachable, playful, and comfortable workshop atmosphere, I encouraged the participants to interact, compare, and play with the sample automata mechanisms that were a part of the automata atelier. This initiative was similar to what I had experienced as a participant as the Cranky Contraptions workshop at the LEGO Idea Conference in Billund. I explained the basic concepts of building an automaton to them, introduced them to the automata atelier materials, and provided assistance with constructing a working automaton prototype when they requested for my help. As an inside researcher, I observed that the participants actively engaged with the play materials. Once they understood the concept of building automata mechanisms, had familiarised themselves with the automata atelier, and tinkered with the basic automaton frame to get the mechanism to work (move), it was exciting for them to design *narratives* and add stories to their automaton. Each participant devised a new narrative and theme that supported their chosen cam shapes for the automaton.

As an example, the first participant (P1_D1) wanted to design a scarecrow out of wooden popsicle sticks and design a sketch of a robin bird out of card paper. The narrative of the automaton was that the robin would move (fly) away from the scarecrow, when the automaton worked. To support this narrative, P1_D1 chose two cams, a *triangular cam* and a *flower cam*. A common axle rod pierced through both the cam shapes when they were arranged inside an automaton frame (refer to Figure 56).

The cam-follower arranged over the triangular cam had the robin bird cut-out pasted on top of it. As a result, when P1_D1 rotated the axle on which the triangular cam was arranged, the cam-follower (that was arranged over the triangular cam) began to simultaneously move up and down and rotate. As a result, the robin cut-out pasted on top of the cam-follower began to move and mimic the movement of the cam-follower.

The scarecrow was glued to the second cam-follower that was arranged over the flower-shaped cam. On rotating the axle, the cut-out of the scarecrow only bobbed up and down. The scarecrow moved slower than the robin because the depressions of the flower cam were shallow and wider. As a result, the cam-follower arranged over the flower cam (with the scarecrow) moved at a slower and less intense speed, as compared to the cam-follower arranged over the triangular cam (with the robin cut-out). The scarecrow as a prop was also heavier than the robin, which further reduced the intensity of the cam-follower's movement. Consequently, the robin cut-out, due to its placement over the triangular cam, began to spin away from the scarecrow, which was the narrative conceptualised by P1_D1.

While building this automaton, P1_D1 demonstrated strong conceptual thinking, engineering, and narrative skills. Here, P1_D1 was able to understand the movements generated by different cam shapes (by interacting with the predesigned automata samples in the atelier), choose specific cam shapes, and construct a model that supported the narrative planned for the automaton.

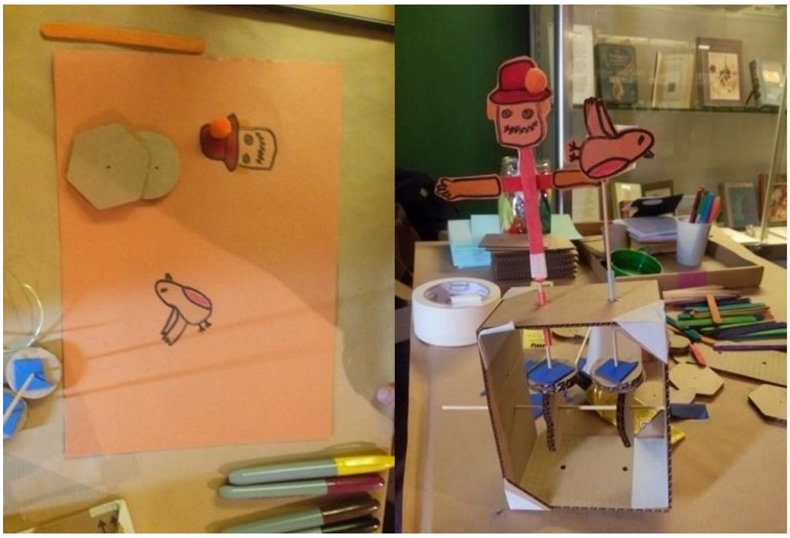

Figure 53: Automata: The scarecrow and the robin, as designed by P1_D1

7.1.4 Use of materials and design decisions

The last participant on Day One (P5_D1) wanted to cover the mechanism in their automaton model, while simultaneously designing a contraption that would allow the participant to repair or rearrange the mechanism if it stopped working. In order to achieve this dual purpose of hiding the automata mechanism and making its repair possible, the participant designed a *door* using a double folded flap of paper (see Figure 57). P5_D1 also designed a handle out of a wooden popsicle stick to keep the paper flaps (the door) in place. Problem-solving, inquiry-based learning, tinkering, and iterative design were undertaken by P5_D1 while constructing the automaton.

Figure 54: P5_D1's automaton with the secret door to hide the mechanism

7.2 POP workshop diaries: Day Two

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 1st July 2018

Total number of participants: 6

The second workshop took place two weeks after the first at the Museum of Childhood. The next set of workshops were planned a few days apart and spread over the month of July and the first week of August. The in-house team at the museum were now better informed and prepared for the workshops. They gave me access to larger tables and a bigger gallery space (as compared to day one) to set up the automata atelier. They also gave me additional tables to store extra materials and construction tools.

On the second day, I facilitated simultaneous workshops for the first two participants. Both the participants were enthusiastic about getting their automata constructions to work. The second participant (P2_D2) spoke extensively about their geometry classes and looked forward to STEAM play sessions at their school. P2_D2 chose an *eccentric circular cam* to design a rotating-flower themed automaton. A flower prop was glued to the cam-follower, which was arranged over the eccentric circular cam. Here, the movement generated by the cam-follower (as a result of continuous rotation of the eccentric circular cam mounted on an axle) led to continuous rotation of the flower prop. The participant also designed a flower wallpaper that corresponded to the floral theme of the automaton. This participant demonstrated strong narrative skills by designing an automaton with a common design language visible across its visual and mechanical aesthetics.

The next set of participants (P3_D2 and P4_D2) were younger than the intended age group. On their insistence, I let them participate in the play sessions and tried to guide them through the workshop. However, as the participants were relatively young (five and six years old), they did not engage with the materials in the way I had anticipated. They just wanted to sit and sketch. This session reaffirmed my decision to conduct the POP workshops for slightly older children between the ages of eight and twelve years.

7.2.1 Challenges with facilitation

With the last two participants on the second day (P5_D2 and P6_D2), facilitating the workshops was challenging for me as they couldn't converse in English. I tried to engage with them and explain the premise of the workshop while helping them build their automaton. Here, I asked their parents/guardians to translate the workshop activity for them.

Despite the translation support, I wasn't able to communicate with the participants about basic roadblocks and ways to overcome them while constructing the automata. For example, I wasn't able to explain to the participants that they should design a smaller prop that could be glued to the top of the cam-follower. A lighter prop doesn't weigh down the cam-follower, thereby making it easier to move the mechanism. As the participants attached heavy props to the top of their cam-followers in their mechanism, their designed automaton could not spin as steadily or regularly as they had hoped.

By constantly interacting with the supporting materials such as the preconstructed automata samples and videos, as well as by persistently tinkering with the prototype, the participants and I were eventually able to repair their constructed automaton, despite the language barrier. The participants engaged in problem-solving by iterative prototyping and tinkering with their models. The participants and I teamed up in a collaborative session to repair their constructions. Eventually, their constructed automata started to move steadily and they were satisfied with their model.

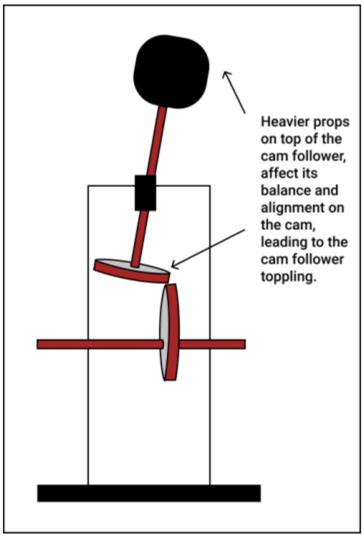

Figure 55: Imbalance in the automaton mechanism, caused by heavier props

7.3 POP workshop diaries: Day Three

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 5th July 2018

Total number of participants: 6

7.3.1 Challenges with facilitation

Six children participated in the workshop on the third day. The first participant (P1_D3) could not converse in English, so I asked the participant's parents to translate and help co-facilitate the workshop with me. Despite my apprehension of this session's play-tutoring format becoming over-prescriptive, I became more involved while facilitating the workshop and guiding P1_D3. However, instead of leading the play session, I encouraged P1_D3 to tinker with the play materials and sketch ideas to conceptualise a narrative for the mechanism.

This evolved into a collaborative session, where I encouraged P1_D3 to build the mechanism *with* me, while the parents translated our conversation simultaneously. Our collaborative effort was successful and we managed to design a movable automaton. Constant encouragement from the parents as well as our *co-design* session worked as positive scaffolding for P1_D3, despite the language barrier. Here, P1_D3 was also able to grasp the differences between different shapes that were used as cams in the automaton to create different movements.

Figure 56: Automata construction in process Day 3 at POP workshops

7.3.2 Accommodating others and adjusting the workshop premise

The next two participants were siblings. One sibling was much younger than the intended age group chosen for the workshop but insisted that he be allowed to participate in the workshop as well. Eventually, I had to accommodate both of them in the workshop as their parents *insisted* that I facilitate two play sessions and help both the children build automata.

The older participant (P2_D3) enjoyed watching and playing football, and hence wanted to build a football-themed automaton. I showed P2_D3 some videos of moving automata mechanisms, and encouraged him to interact and play with the preconstructed automaton samples displayed in the atelier. After playing with the automata samples, P2_D3 selected an *eccentric circular cam* to design his automaton (see Figure 60). Parallelly, the younger sibling (P3_D3) did not want to engage with the materials in the workshop and insisted that I construct a new automaton separately for him to play with.

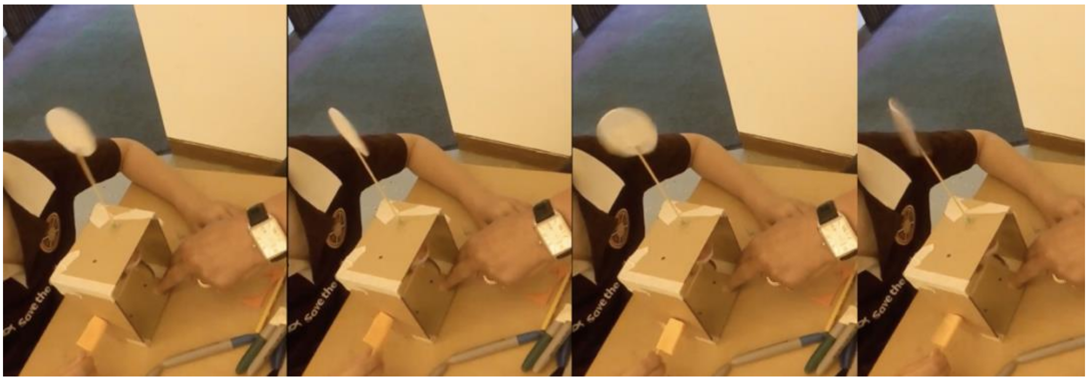

Figure 57: Football automaton (P2_D3) using an eccentric circular cam

7.3.3 Unique collaborations

The next two participants (P4_D3 and P5_D3) at the workshops were siblings as well. They wanted to collaborate and design a common automaton. Facilitating the play sessions with them was challenging since both of them wanted intricate contraptions with multiple mechanisms and props attached to a common automaton frame (see Figure 61).

Figure 58: A two cam automaton constructed by P4_D3 and P5_D3

Interestingly, due to their different preferences, both the participants decided to play with the preconstructed automata samples in the automata atelier in order to select a specific cam shape. Eventually, they selected two unique cam shapes (a *triangular cam* and a *hexagonal cam*) and designed an automaton frame. As they were designing a common frame with two cam shapes, they were able to test and differentiate between movements created by the triangular and hexagonal cams in the same frame.

The last participant (P6_D3) on the third day constructed a simple and functional automaton with an *eccentric circular cam*. This participant displayed strong critical and problem-solving skills by focused on designing a handle that could help interact with the mechanism more comfortably. This designed handle made it easier to interact and play with the mechanism (see Figure 62).

Figure 59: Automaton designed by P6_D3

7.4 POP workshop diaries: Day Four

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 8th July 2018

Total number of participants: 6

Six children participated in the fourth POP workshop. The first participant (P1_D4) began by sketching ideas on paper and brainstorming the design concept of an automaton. P1_D4's mother was excited by the prospect of designing an automaton from readily available objects found at home such as cardboard boxes and art materials. P1_D4 engaged in systematic iterative prototyping by taking time to understand the activity, finetune the movement of the constructed mechanism, and sketch ideas to finalise a theme, before building the final automaton. P1_D4’s mother discussed the outcomes of the workshop with me after the session, and we explored various possibilities of how automata mechanisms and similar STEAM themes could be incorporated within P1_D4’s future science projects at school.

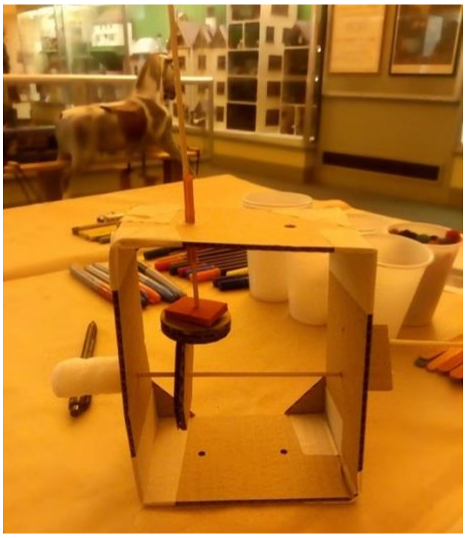

Figure 60: A test frame designed by P1_D4 to test the cam and cam follower

7.4.1 Challenges with facilitation

The second participant on day four (P2_D4) was much younger than the age group[67] that was pre-set for these workshops. This participant joined the workshop and insisted that we design an automaton together. Despite not engaging with the mechanical construction of the automata, the participant P2_D4 interacted with the automata atelier and played with the automata samples.

The third participant (P3_D4) actively engaged in the workshop and took time to construct and fine-tune the designed automaton. P3_D4 engaged in a step-by-step design process, from sketching ideas to building a working automaton mechanism after a few cycles of iterative prototyping (see Figure 64).

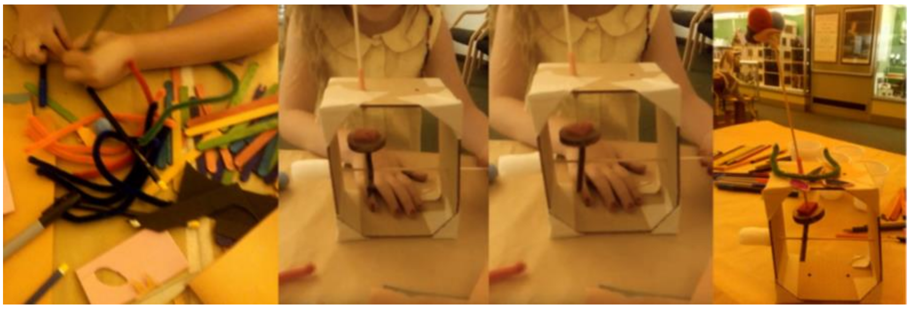

Figure 61: Design process undertaken by P3_D4; Sketching ideas, testing an automaton frame, and finalising the construction

67 POP workshops were designed for children between the ages of eight to twelve years.

7.4.2 Successful collaboration between participants

The next two participants (P4_D4 and P5_D4) were siblings and collaborated to design one automaton. This collaboration demonstrated successful scaffolded interactions between the siblings. Here, the younger participant P5_D4 was guided and helped by her older sibling P4_D4. They sketched and discussed concepts based on their chosen cam shape (*flower*) for the automaton. The older sibling P4_D4 discussed how this activity could be expanded further (by adding more cams, introducing LEGO motors to automate the movement, creating more models, as so on). The younger sibling P5_D4 designed a stick figure (a girl astronaut designed from smiley stickers and wooden popsicle sticks). The siblings also tried to define the movements of their automaton by writing "tiny bounce, big rotation" in their workshop feedback booklets at the end of the session. Both the participants took extra cam shapes, bamboo skewers, and straws with them to try and recreate this activity at home (see Figure 65).

Figure 62: The rocket and astronaut automaton design by P4_D4 and P5_D4

7.4.3 STEAM Learning Outcomes

The last participant on day four (P6_D4) was excited to construct an automaton that *visualised* a jumping dog. Since P6_D4 had already conceptualised a narrative, the participant and I discussed how different cam shapes generated different movements. We tried to assess all the cam shapes available in the automata atelier to select one that would best support the narrative of P6_D4's automaton. P6_D4 also interacted with the predesigned automata samples and eventually chose an *eccentric circular cam* to design an automaton.

P6_D4 actively engaged in the workshop session, and took time to carefully construct the mechanism and props for the cam-follower. P6_D4 designed and glued a cut-out of a dog with two different facial expressions on top of the cam-follower (gluing the two expressions back-to-back on the cam-follower; see Figure 66). As the cam-follower spun, the dog cut-out spun as well. As a result, the dog's different facial expressions were alternatively visible as the mechanism moved. P6_D4 displayed strong conceptual and narrative skills by selecting a specific cam shape (*eccentric circular cam*) and designing suitable props (a dog cut-out with two expressions) to support the story of a jumping dog automaton.

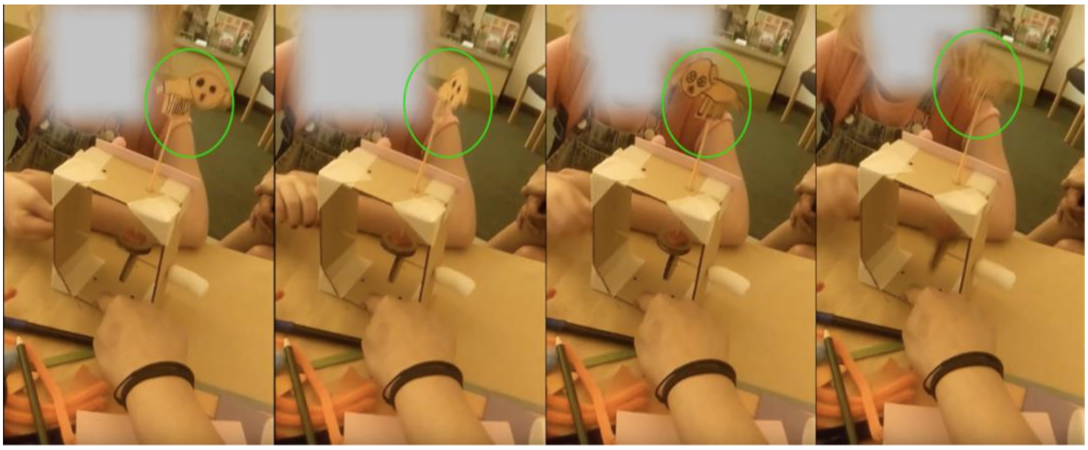

Figure 63: P6_D4 with the two-faced dog automaton

7.5 POP Workshop Diaries: Day Five

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 12th July 2018

Total number of participants: 2

7.5.1 Learning outcomes

The first participant (P1_D5) selected a *hexagonal cam* to design an automaton. The participant designed a monocle man with two different facial expressions as a prop to be glued on top of the cam-follower. The participant glued the two sketches of a monocle man back-to-back on top of the cam-follower. Consequently, as the cam-follower rotated, the visual prop of the monocle man spun as well. Participant P1_D5 had an interesting observation after hearing the mechanism move. P1_D5 exclaimed that "the mechanism sounded like a choo-choo train". This was the first instance of a participant associating specific auditory qualities to a designed mechanical automaton.

7.5.2 Challenges with facilitation and tinkering

It was challenging to facilitate the workshop for the second participant (P2_D5) due to language barriers. I asked P2_D5's parents to translate for us. Their involvement as translators helped the workshop premise as the participant began to interact with the automata atelier. P2_D5 prototyped a few mechanisms with different cams before finalising the *flower cam* as a cam shape. While building the mechanism, the participant faced a few issues. The artwork made by P2_D5 that was supposed to be glued on top of the cam-follower was heavy and intricate. This, in turn, negatively affected and disrupted the movement of the automaton. The participant and I also realised that the base of the cam-follower had to be a wider circle in order for it to work well with the flower cam and to avoid the cam-follower from falling to one side.

Consequently, this workshop session took longer as P2_D5 took more time and asked his parents for help, who discussed and translated the problems encountered by the participant. The participant engaged in iterative prototyping and tinkering with the prototype to ensure that it would work evenly. By changing the artwork glued on top of the cam-follower to a lighter one, and by designing a wider and heavier base for the cam-follower, the mechanism was eventually able to move steadily.

7.5.3 Introducing new play materials to the automata atelier

On-site DE fieldwork discussed in Chapters Four and Five revealed that the facilitation framework at Montessori schools did not encourage iteration and redesign of sensorial materials. However, theoretical accounts of both Fröbel and Montessori reveal that they themselves engaged in extensive design thinking through constant iteration and redesign of their play activities while developing their play materials**.** Similarly, Dewey as a design thinker and Nicholson's (1972/2009) theory of loose parts (as discussed in Chapter Two) endorse the design of adaptable and flexible play-based learning environments, where a child’s interests and needs must be taken into consideration when planning and designing learning materials, curricula, and the play environment.

While facilitating POP workshops and engaging with the participants as an *inside researcher*, specific pain points were identified during the automata construction process that were challenging and time-consuming for the participants. In order to further streamline the automata construction process and make it simpler, more enjoyable, engaging, and intuitive for the participants, the following play materials were redesigned and introduced to the automata atelier.

7.5.3.a Designing a test frame

Facilitation during the earlier workshops had revealed the need for an artefact that would allow the participants to initially test different cam shapes and cam-followers. Some of the participants were not convinced by simply playing with predesigned mechanism samples. When I observed P1_D4 construct a mechanism frame to try and fine-tune the movement generated by the selected cam shape, I realised that a test frame could have assisted the participant in this situation.

As a result, an *automaton test frame* was designed to help the participants test movements generated by different cams. The test frame had a removable axle. Here, the participants could slide the axle through the frame, attach different geometrical cam shapes to the axle, arrange it under a pre-attached cam-follower, and then rotate the axle to test how the cam-follower interacted with that specific cam shape. This test frame helped the participants select cam shapes and movements that they wanted to employ in their own automaton, before constructing their final mechanisms.

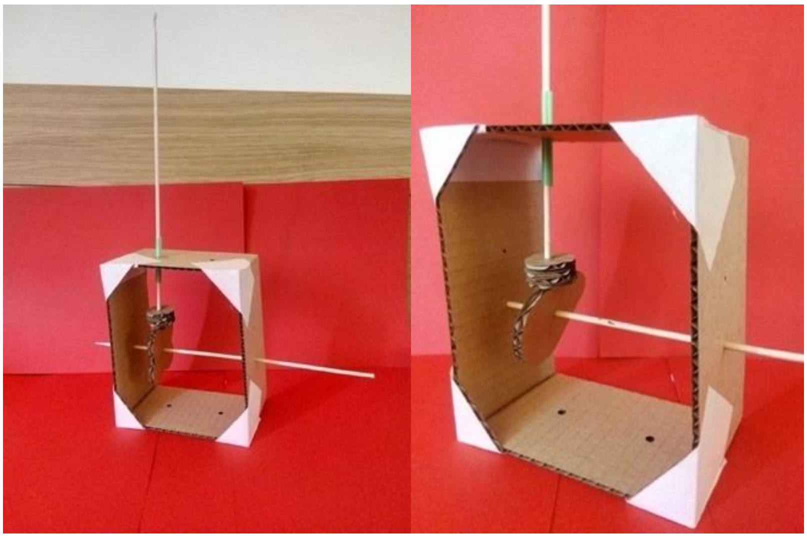

Figure 64: Test frame designed to try different cam shapes (here, with a flower and oval cam and a removable bamboo axle rod)

7.5.3.b Designing a heavier cam-follower

The base of the cam-follower was redesigned when participant P2_D5 and I realised that a bigger and heavier cam-follower helped the mechanisms in the automata move steadily and made the mechanism more stable. This was especially useful while using cams with unusual curves and depressions (such as the flower cam or snail cam). Based on North's (2018) research, a new standard cam-follower with a wider circular base was designed and added to the first section of the automata atelier. This cam-follower worked better with all the cam shapes chosen for this workshop and led to a smoother and more stable movement of the mechanism.

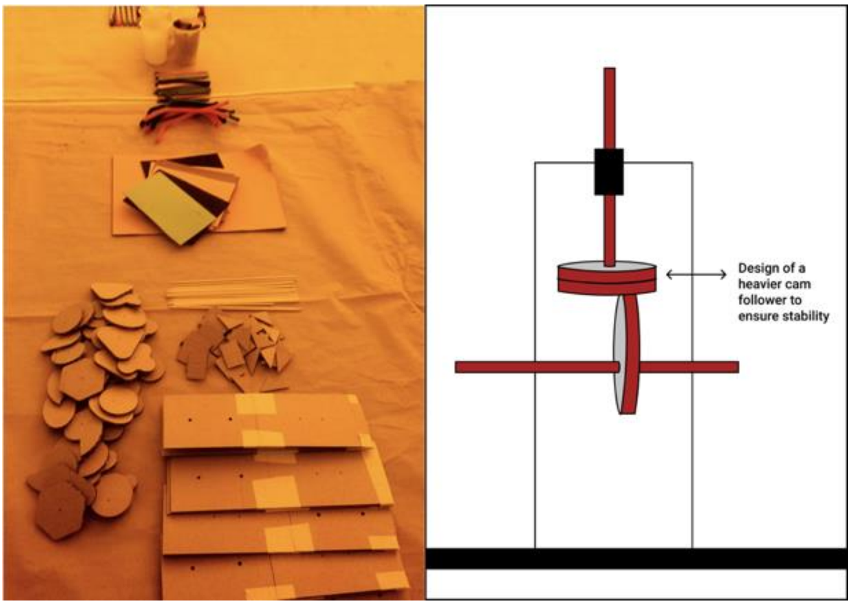

Figure 65: Evolution of the automata atelier – design of a heavier cam-follower

The circular cut-outs designed as the base for the cam-follower in the automata atelier (where they would come in contact with the cams) were increased to 5 cm in diameter. I also glued two cam-follower disks together. This made the cam-follower heavier in weight and further stabilised it. This additional weight also helped avoid the cam-follower slipping to one side in the mechanism when in motion.

7.6 POP workshop diaries: Day Six

Location: Museum of Childhood
Timeframe: 11 am to 1 pm
Date: 13th July 2018
Total number of participants: 2

7.6.1 Iterations and tinkering

The first participant (P1_D6) engaged in iterative prototyping by dedicating more time to exploring different cams and their movements. P1_D6 eventually decided to construct an automaton using a *triangular cam*. The participant designed a two-sided smiley face prop for the automaton, and spent time trying to ensure that the movement in the designed mechanism was stable and worked properly.

Figure 66: P2_D6 testing the mechanism using a redesigned handle

The second participant (P2_D6) designed a simple automaton with an *eccentric circular cam* and glued a paper cut-out of a cloud on top of the cam-follower. As a result of this, the cloud *jumped up and down,* and rapidly spun as the cam-follower moved. Later, P2_D6 designed a handle for the automata (see Figure 69). This participant was able to comprehend the activity of constructing automata using geometrical shapes and relate the designed mechanisms to real-life examples. The participant associated the movement of the automata handle to a manual window handle in a car. "Just like how we roll up a car window" is what P2_D6 exclaimed while testing the constructed mechanism by rotating the handle.

7.7 POP workshop diaries: Day Seven

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 15th July 2018

Total number of participants: 5

7.7.1 Successful collaboration

During the seventh workshop, the first set of participants were three siblings in the age range of eight to twelve years old (P1_D7, P2_D7, and P3_D7). They decided to collaborate and design a common automaton. It was a successful collaboration, where the three participants engaged in design thinking by discussing their ideas, sketching initial concepts on paper, and designing props to suit their concept. They even got their mother to participate and design props for their automaton.

While collaborating during the workshop, the participants collectively brainstormed and critiqued each other's ideas. Their mother's involvement in the activity added an additional dimension of playfulness to their collaborative play. Here, she was essaying the role of a team member, and not an adult or parent, which the participants seemed to approve of.

Figure 67: Rocket automaton designed by P1_D7, P2_D7, and P3_D7

The next set of participants on day seven were also siblings (P4_D7 and P5_D7). They decided to collaborate and construct a common automaton. It was challenging to facilitate their sessions, since they did not speak in English. Therefore, I asked their parents to help me translate the workshop premise for them. Once they began to follow the construction process and understand what the premise of the activity was (with the help of their parents translating the content), they were able to engage in a design process of experimenting and tinkering with the play materials to construct a successful movable automaton.

7.8 POP workshop diaries: Day Eight

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 19th July 2018

Total number of participants: 1

The eight workshop session saw one participant (P1_D8) attend the automata play sessions. Participant P1_D8 engaged in a slow and focused design process of trial-and-error and tinkering with the play materials while constructing an automaton. P1_D8 spent some time adjusting the placement of the cam-follower, cams, and axle to fine-tune the mechanism. P1_D8 designed an automaton with a *triangular cam* and covered one side of the automaton's frame with a sheet of paper to hide the mechanism. The automaton's visual theme was based on cats. Here, P1_D8 designed a cut-out of a cat and pasted it on top of the cam-follower. P1_D8 also drew another cat figure on a sheet of paper and glued it to the frame to cover the mechanism.

While reflecting on the design process of constructing the automaton, P1_D8 began to associate automata mechanisms to real life artefacts. Here, P1_D8 compared the rotating axle and cam of his automaton to the movement of using pulleys to draw open curtains at his home. As a result, after the play session, P1_D8 and I engaged in a discussion about pulleys and their applications in everyday objects at home such as curtains.

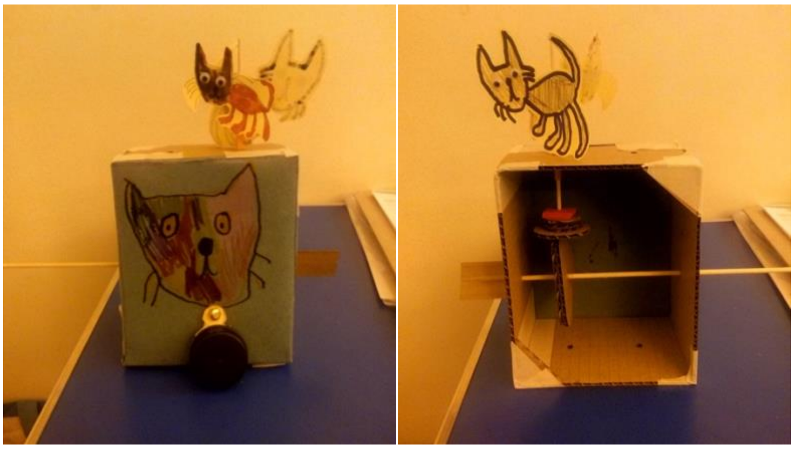

Figure 68: Cat themed automaton designed by P1_D8

7.9 POP workshop diaries: Day Nine

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 20th July 2018

Total number of participants: 2

Two participants attended the ninth POP workshop. They were siblings (P1_D9 and P2_D9) and they wanted to collaborate to design a common automaton. Both the participants brainstormed some initial concepts and eventually selected an *eccentric circular cam* for their automaton. They designed a two-sided prop for the automaton; a cut-out of a car designed by P1_D9 and a flower designed by P2_D9. They glued the artwork back-to-back on top of the cam-follower so that both the props would be visible as the cam-follower rotated.

The participants engaged in critical design thinking and problem-solving, where they designed doors on either side of the automaton frame to hide the mechanism. The participants also designed a hidden window behind one of the doors. This window was designed to allow them easy access to the mechanism, and repair it in case it stopped working or was misaligned (see Figure 72).

Figure 69: Automaton designed by P1_D9 and P2_D9, with the car and flower props and double doors to hide the mechanism

7.10 POP workshop diaries: Day Ten

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 22nd July 2018

Total number of participants: 2

On the tenth day, two participants attended the POP workshop. These two participants (P1_D10 and P2_D10) were siblings and collaborated to design one automaton. Initially, they spent some time tinkering with the predesigned automata test frame and tested different cams on it. Eventually, they decided to use the *snail cam* to design their mechanism. While associating the mechanism of an automaton to everyday objects, P2_D10 discussed how the handle designed in their automaton resembled the handle of a mechanical pencil sharpener. P2_D10 also helped P1_D10 think of new ways to construct the automaton and design decorative artwork for their mechanism.

It was a successful collaboration between the two participants. In this session, the younger participant P2_D10 took the lead while designing the automaton and tinkered with the materials to finetune the mechanism. P2_D10 also helped P1_D10 while constructing the mechanism and designing artwork for their model. Both the participants (P1_D10 and P2_D10) discussed how automata mechanisms are often a part of most machines observed in everyday life.

After the end of their play session, the participants discussed how the bearing of the automaton could be redesigned by using a paper cup instead of a plastic straw (as seen in the current model). They discussed that they would try to construct another automaton at home, using plastic cups as a bearing instead of straws.

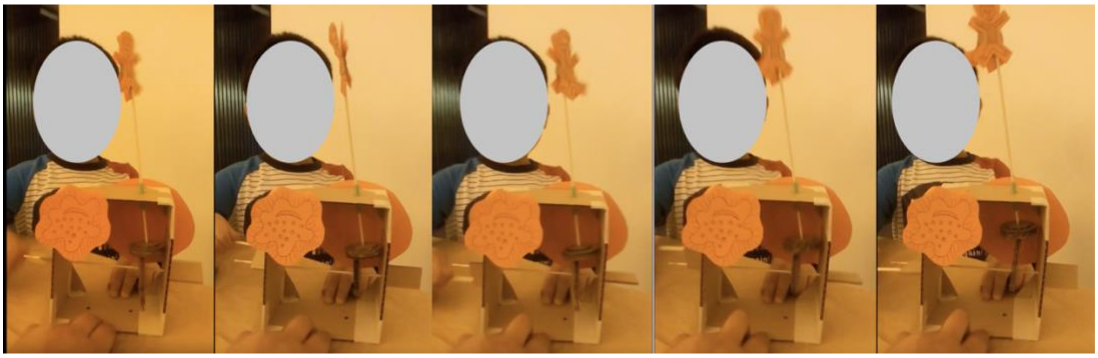

Figure 70: P1_D10 and P2_D10 testing their automaton's handle and mechanism

7.11 POP workshop diaries: Day Eleven

Location: Museum of Childhood

Timeframe: 11 am to 1 pm

Date: 29th July 2018

Total number of participants: 2

The two participants were siblings and decided to design two separate automata. The first participant P1_D11 tested some cams on the test frame and selected an *eccentric circular cam*. P1_D11 described the movement generated by the eccentric circular cam as “jumping up and down” while testing it on the test frame. The movement generated by an eccentric circular cam supported P1_D11’s narrative of designing a two-faced jumping owl. Based on this movement produced by the eccentric circular cam, P1_D11 named the automaton the “Bobbing Burrowing Owl”.

P1_D11 also designed props such as a sheet of grass (made out of green craft paper) to cover one side of the automaton’s frame and designed a worm out of pipe cleaners. P1_D11 narrated the story for the automaton, where the “owl was jumping up and down while trying to catch a worm, and the worm was hiding in the grass”.

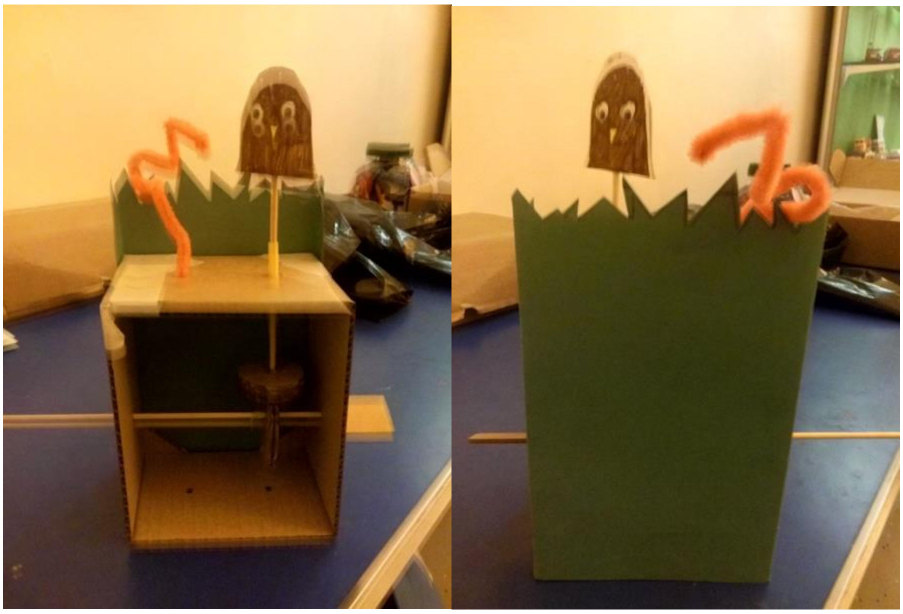

Figure 71: Automaton designed by P1_D11

7.11.1 Tinkering and iteration

The second participant (P2_D11) designed a two-cam automaton. P2_D11 wanted to design an automaton with two different cams, to compare two different movements. Hence, an *eccentric circular cam* and a *flower cam* were chosen.

P2_D11 engaged in design thinking by sketching, constructing, and tinkering with the play materials to design an automaton bot. Here, P2_D11 used play materials to elevate the height of the automaton, without disrupting the actual mechanism encased inside the automaton frame. P2_D11 designed the body of the automaton bot (the frame which housed the mechanism) and constructed legs for the automaton bot with the help of two paper cups that were glued to the base of the frame. The participant also used two cam shapes to design randomly moving googly eyes on the automaton bot. Here, each eye was glued to a separate cam-follower and moved at different speeds to simulate an obscure movement associated with the participant's understanding of googly eyes (see Figure 75).

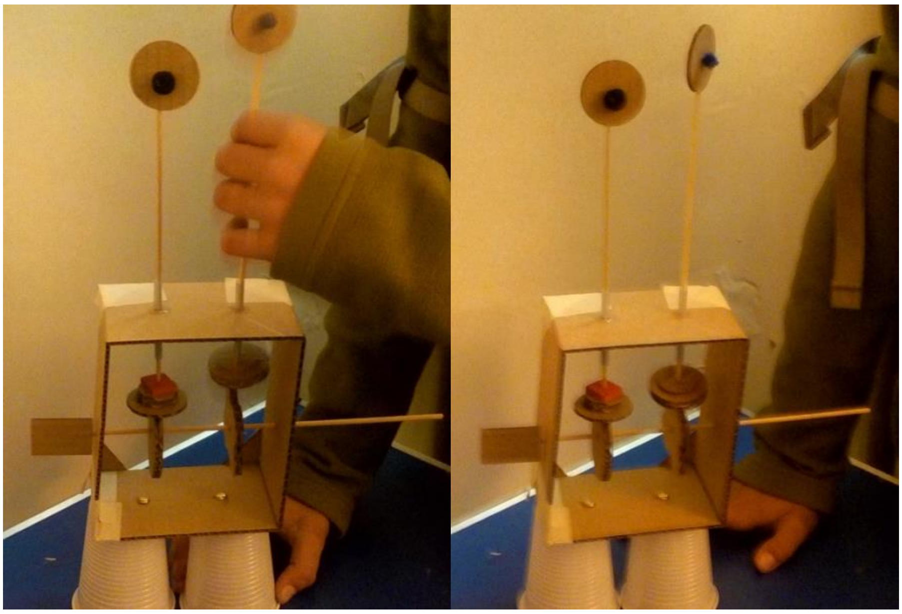

Figure 72: 2-cam automaton designed by P2_D11

7.12 POP workshop diaries: Day Twelve

Location: Scottish Storytelling Centre

Timeframe: 2 pm to 4 pm

Date: 29th July 2018

Total number of participants: 2

Unlike the Museum of Childhood, where the automata atelier was set up in one of the gallery spaces, the Scottish Storytelling Centre had a dedicated hall adjoining a café for workshops and interactive activities.

On the first day at the Scottish Storytelling Centre, two participants attended the POP workshop sessions. The first participant (P1_D12) did not initially engage in the workshop because of tiredness and disinterest in the workshop premise. However, P1_D12 eventually joined in and designed a space themed automaton. P1_D12 selected a *snail cam* and cut a rocket shaped prop out of paper that was glued on top of the cam-follower. P1_D12 selected the snail cam based on the unique movement it created. P1_D12 insisted that the "slow rise and sudden drop" movement generated by the snail cam was suitable to the space and rocket-themed automaton. P1_D12 insisted that the snail cam helped demonstrate how “the rocket was slowly launched into the air and then suddenly it fell”.

7.12.1 STEAM learning outcomes

The second participant (P2_D12) was very excited by the workshop premise. P2_D12 tinkered with the test frame and tested some cam shapes on it. The participant eventually selected a *triangular cam* based on the specific “hopping up and down” and “spin movement” it generated.

P2_D12’s automaton narrative was to visualise a cat (a representation of P2_D12’s actual pet cat) who was unable to catch a fish that jumped up and down and spun (the fish cut-out was glued to the cam-follower arranged over the triangular cam). P2_D12 displayed strong design thinking skills by conceptualising a narrative, engaging in inquiry-based object play by tinkering with the test frame, testing different movements generated by each cam, selecting a specific cam shape, and eventually designing an automaton to align the movement of a triangular cam with the conceptualised narrative.

P2_D12 designed a fish cut-out that was glued to the cam-follower rod. On rotating the axle, the cam-follower jumped up and down while rotating, due to which the fish prop jumped up and down and spun as well. P2_D12 also employed other shapes from the construction material section of the automata atelier to design the prop of a cat. P2_D12 then glued the cat cut-out on the automaton’s cardboard frame. P2_D12 wanted the fish to move, which is why the fish was glued to the cam-follower (the movable component of the automaton). Parallelly, in order to visualise a stationary cat, P2_D12 glued the cat to the automaton’s stationary frame.

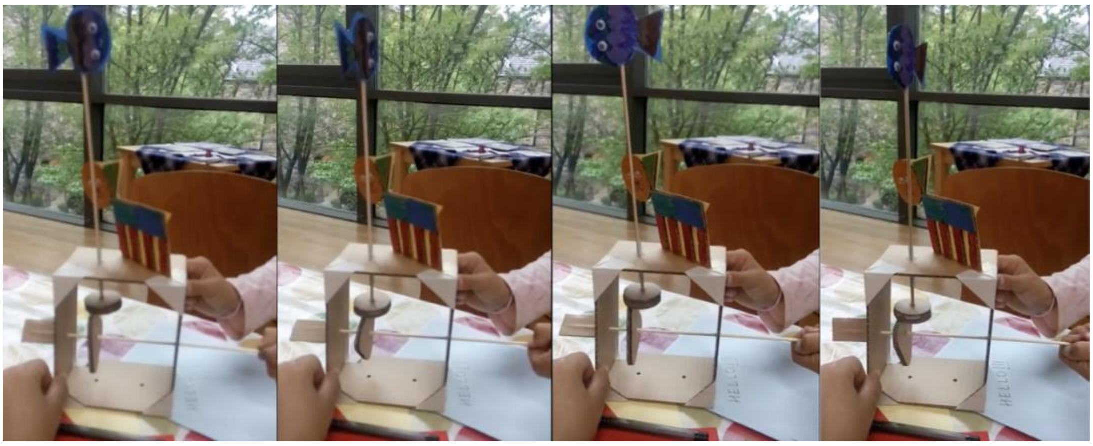

Figure 73: Fish themed automaton using a triangular cam – designed by P2_D12

7.13 POP workshop diaries: Day Thirteen

Location: Scottish Storytelling Centre

Timeframe: 11 am to 2.30 pm

Date: 1st August 2018

Total number of participants: 8

When I first arrived at the venue and set up the automata atelier, I was informed by the in-house staff at the venue that a family with two children were already waiting for me and wanted to participate in the workshop. Initially, when I interacted with the two participants (who were also siblings), they seemed disinterested in engaging with the workshop. However, once I set up the automata atelier, the older participant (P1_D13) came over with the younger sibling (P2_D13), and they decided to engage with the activity and design two separate automatons.

7.13.1 Successful collaboration

Participant P1_D13 was focused on the activity and also helped P2_D13 during the process of constructing the automata. P1_D13 decided to cover the automaton's mechanism with a sheet of paper. P1_D13 designed a cat prop that was attached to the cam-follower and kept bouncing as the axle was rotated. It was a simple and well-constructed automaton using a *snail cam*.

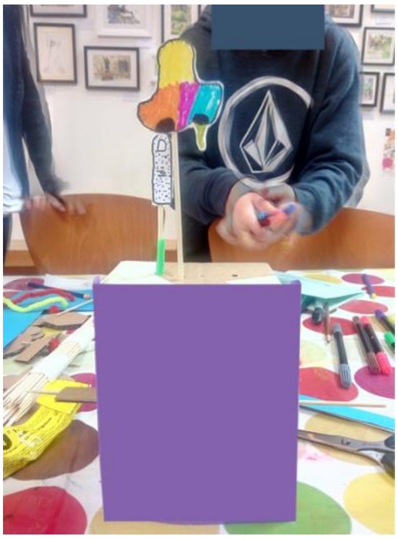

Figure 74: Nose digging automaton designed by P2_D13

P2_D13 demonstrated strong design and conceptual skills. Here, P2_D13 engaged in inquiry-based object play by tinkering with the test frame, testing different movements generated by different cams on the frame, selecting a specific (*snail)* cam shape, and then designing a narrative to suit the movement generated by the snail cam. P2_D13 decided to construct a “nose-digging machine” based on the “slow rise, sudden drop, and spin movement” associated with the snail cam. Choosing the snail cam, according to P2_D13, would add an element of comedy to the nose-digging narrative of the automaton. P2_D13 sketched a cut-out of a finger and glued it to the cam-follower as it *dug* into a stationary *nose,* which was a paper cut-out and glued to the frame of the automaton. The participant also preferred to cover the automaton’s mechanism using a piece of purple card paper.

7.13.2 Disinterest in the play premise

The next set of participants were siblings (P3_D13 was younger than the intended age group for the workshop and P4_D13 was the older sibling) who came to the workshop along with their parents. P3_D13 and P4_D13 were more interested in using the art material from the automata atelier to draw and colour, instead of constructing the automata. Since the participants did not speak English, it was difficult to explain the concept of the workshop to them. I showed the participants some videos of previously designed automata contraptions as well as the preconstructed samples in the atelier to encourage their interest in the workshop. However, instead of engaging in the activity of building automata, P3_D13 and P4_D13 sat down on the workshop bench and started to sketch. P3_D13 was annoyed by the entire premise of the workshop and kept talking to the family in a seemingly annoyed tone, requesting them to help her sketch a swan. Meanwhile, their parents kept intervening and insisting that I construct separate automata for both the siblings, which they could then colour.

Due to continuous insistence from their parents, I had to design two separate automata models for the participants, while they sketched and cut-out artwork to glue to the models. Eventually, I gave them the rest of their artwork sheets and more art material and requested that they continue their activity elsewhere at the venue. I had to politely request this family to eventually vacate the workshop space so that I could accommodate four other children who had just arrived at the venue and were waiting to participate in the workshop.

The next four participants were friends who arrived at the workshop together. Two of them (P5_D13 and P6_D13) collaborated to design a two-cam automaton. They engaged in a collaborative design process of testing different cam shapes, discussing ideas, brainstorming about the differences in the cam shapes and resultant movements, sketching concepts on paper, and designing a narrative for their automaton. They eventually selected a *snail cam* and an *eccentric circular cam* to design their automaton. They designed props such as clouds and two animal cut-outs (a pig and a cow), and glued them to the two cam-followers. In their automaton, they designed a narrative that complimented the two animal cut-outs and the different movements generated by the snail and circular cam. Both these participants took most of the cams and construction materials back home, as they wanted to design more automata machines.

Figure 75: 2-cam automaton designed by P5_D13 and P6_D13

The last two participants (P7_D13 and P8_D13) seemed disinterested in the workshop at the beginning. P7_D13 engaged with the workshop long enough to design a workable automaton. However, P7_D13 embraced the role of a helper and spent more time helping other younger participants build their mechanisms. P8_D13, despite the disinterest in the workshop premise, constructed an automaton using two *oval cams*. P8_D13 wanted to design a mechanism by using two cams in the same shape. However, the participant arranged both the cams at different angles on the axle to showcase the movement of "alternative rise and fall" in his prototype.

7.14 Chapter summary

The diary narratives discussed in this chapter help demonstrate that play workshops as a research method organised at CLEs support the rapid testing of ideas and flexible facilitation formats. It would not have been logistically possible to do this during my thesis in formal school-based environments. As observed through the diary narratives, POP workshops as a research method led to the evolution of the automata atelier as the participants and I engaged in more play sessions.

Interventions as a key component of designerly inquiry were introduced in the automata atelier, based on identified pain points and design opportunities during workshop facilitation. These workshops supported design interventions by provoking, changing, and redesigning artefacts, environments, and facilitation structures to engage in child-centered play-based learning (Dalsgaard, 2014). A new test frame was designed to test cam shapes, and the cam-follower was redesigned to be heavier and wider to support the construction of smoother automata mechanisms.

POP workshops as a research method integrated design thinking and scaffolding in multiple forms such as (1) providing automata as a design theme, which would challenge and stretch the abilities and competence of the participants, (2) presenting a material atelier supported by appropriate play artefacts, pivots, and props to construct automata, (3) encouraging participants to design supporting plots and narratives while constructing the automata, (4) integrating multiple themes, and (5) dedicating sufficient time, space, and play materials to interact and tinker with (Marsh et al., 2019).

Scaffolding was incorporated into the workshop format in multiple forms in order to design an authentic learning environment. In some scenarios when language comprehension was a limitation, natural mediator tools (Hall, 2007) in the form of parents and guardians essaying the roles of *translators* were introduced. This helped support the participant's play-based learning journey by designing a safe and comfortable communication network between the children (as participants), the parents (as translators), and me (as the facilitator). This measure underpinned Vygotsky's design perspectives on ZPD and Nicholson's (1972/2009) theory on loose parts, which support the design of an authentic and flexible learning environment, where natural mediator tools, play materials, play activities, and facilitation frameworks are designed to take the participant's competencies and abilities into consideration (Hall, 2007; Taber, 2018).

Scaffolding was also visible through collaborations between the participants in some play sessions. Participants discussed ideas, helped each other, engaged in critique and negotiations, tinkered with the materials, tested frames to select a cam shape, and argued about how the automaton should be designed. In most cases, one of the participants in a team was an older sibling, who would often guide and help the younger participant while constructing the automata.

CLEs such as museums and galleries are interesting spaces in which to design participative play-based activities for children. This is because their cultural function is to encourage exploratory and engaging educational experiences. In the context of CLEs, play is much more informal as compared to a classroom. Even if a designed play-activity is grounded in children learning new theoretical concepts, the difference in the designed space and momentum of a museum gallery leads to children embracing it as a more informal, play-centric, and social setting. The next chapter analyses and critically reviews all the workshops and the entire RtD method, along with its outcomes, and presents further insights.

Chapter Eight:

RtD - Analysis and Inferences

Following on from the introduction of the workshop diaries in Chapter Seven, Chapter Eight aims to address the first and third research questions of this thesis, which focus on design thinking and design's contributions to play-based learning, and its migration beyond formal classroom environments to CLEs.

As discussed in Chapter Seven, RtD was undertaken through thirteen play workshops that were designed for children between the ages of eight and twelve years in Edinburgh's museum and gallery sector. The Museum of Childhood and Scottish Storytelling Centre were selected as the two CLEs to conduct these play workshops. The workshops were designed to test an iterative and flexible format of play-based learning. Affordances of design thinking such as tinkering, experimentation, and iteration with play materials were designed within the workshop premise, which, in turn, supported RtD. Competencies of Montessori and STEAM were brought together through the construction of automata mechanisms. Here, automata became a design idiom that encouraged the participants to engage in conceptual, exploratory, and iterative play.

After readdressing the design rationale (**Section 8.1** – as explained further), this chapter segregates the empirical data from the POP workshops into the following design categories to present a holistic summary of the RtD method:

Section 8.2. Design of the automata atelier

This section analyses the tangible and improvisational qualities of the automata atelier that encouraged the participants to engage in inquiry-based learning and support design thinking.

Section 8.3. Design of the play-tutoring format

As discussed in Chapter Six, workshops foster engagement through collaborative discussions and constructive feedback between the participants and the workshop facilitator (Ørngreen and Levinsen, 2017; Ahmed and Asraf, 2018). This section analyses how the play-tutoring format, inspired from the concept of a smooth-striated workspace, was designed within these workshops to support multiple roles adopted by the researcher (me).

Section 8.4 Design of the workshop premise

Automata were identified as a design idiom to undertake play-based learning through the process of interaction and engagement with play materials in these workshops. This section analyses how scaffolding was incorporated within the workshop premise of building automata through dialogues, narratives, ZPD, and collaborative play to encourage tinkering and iteration during the workshop (Marsh et al., 2019).

Section 8.5 CLEs as workshop sites

This section analyses the design, aesthetics, spatial layout, and the overall ambiance of the CLEs, which affected the quality of facilitation undertaken during the play workshops

Section 8.6 Affordances of the workshop as a research method

This section analyses the intricacies, limitations, and affordances of conducting play-based learning sessions for children at CLEs.

8.1 Design rationale: POP workshops

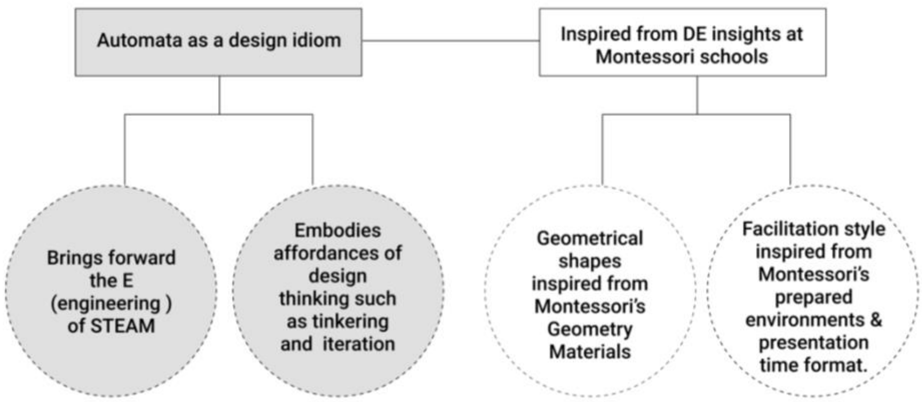

Figure 76: Design rationale of the POP workshops

Theoretical accounts of Montessori's work[68] demonstrate that her curriculum is designed to foster ceremonial play through prescriptive interactions with her sensorial materials.

68 Previously introduced in Chapters Two and Three.

Montessori's elaborate design language is a testament to sensorial training, where every play artefact in the method is compartmentalised to cater to a specific sense[69].

On-site DE fieldwork undertaken during this thesis (discussed in Chapter Four and Five) revealed that non-prescriptive and exploratory interactions with her sensorial materials were discouraged. Instead, Montessori facilitators prescribed *how to* play. This restriction led to lost opportunities for inquiry-based learning, design iterations, and curious exploration of the sensorial materials to construct new meanings.

In order to address the design gaps identified during the DE fieldwork at Montessori schools, POP workshops were designed to test a more exploratory and iterative play-tutoring format. Here, the construction of automata mechanisms as a STEAM theme was designed as the workshop premise to cross-pollinate affordances of design thinking (hands-on object interaction, construction of models and prototypes, tinkering, experimentation, and iteration of play materials) with Montessori's geometrical design language, prepared environments, and presentation time format.

Based on the concept of a smooth-striated workspace, the POP workshops were designed to oscillate between being purposeful and encouraging playful, exploratory, and iterative object play. In the workshops, the participants were given complete freedom to engage in the workshops individually, or team up with other participants and engage in collaborative play.

The play-tutoring format designed for the workshops focused on guiding the participants through a series of steps and interacting with the automata atelier. Here, the participants were encouraged to interact with shape materials (such as cams and cam-followers) in the automata atelier. The automata atelier also encompassed other play objects such as prototyped automata samples, test frames, and art materials. The workshop premise and automata atelier were designed to support flexible and iterative object play, where there were no prescriptive interactions designed to engage with the automata atelier. However, certain guidelines were formulated to introduce the participants to the automata atelier and guide them through the construction process.

Findings from these POP workshops have been categorised into the following sections (as outlined in the introduction) to help present a holistic overview of the RtD method,

69 Refer to Chapter Two.

and bring key design perspectives and contributions from the play workshops to the forefront of this thesis: Design of the automata atelier, design of the workshop play-tutoring format, design of the workshop premise, CLEs as workshop sites, and affordances of the workshop as a research method.

8.2 Design of the Automata Atelier

The visual display of the automata atelier for the POP workshops was inspired by the Cranky Contraptions workspace as well as Montessori's format of presentation time and prepared environments. The automata atelier for the POP workshops was segregated into three sections[70]: (1) construction materials, (2) supporting construction tools, and (3) art materials. The automata atelier was visually arranged to give the impression that this workshop would entail *making* and *construction* of some kind. There were a few samples of simple preconstructed automata samples that the participants were encouraged to interact with in order to test the mechanisms.

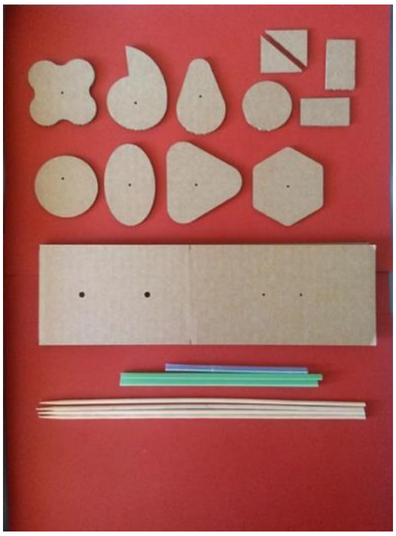

Figure 77: Construction section of the automata atelier

8.2.1 Affordances of tinkering with the automata atelier

During the POP workshops, participants readjusted, redesigned, and critiqued the play materials in the automata atelier. These workshops encouraged immersive and engaged tinkering with the atelier to support purposeful play and inquiry-based learning, as well

70 Refer to Chapter Six.

as experimental object play. This relationship to learning through active and iterative hands-on interactions with an assemblage of dynamic objects (objects in movement) underpins Dewey's (1897) perspectives on pragmatist play and Bevan et al.'s (2014) conceptualisation of tinkering (first discussed in Chapter One).

Mitch Resnick, the director of the Lifelong Kindergarten Group at MIT Media Labs (Massachusetts) and a LEGO Papert Professor of Learning Research, has extensively explored tinkering in play-based learning environments. In his book *Lifelong Kindergarten,* Resnick (2017) discusses tinkering as a foundational element to encourage creative thinking and inquiry in play-based learning environments. Interestingly, Resnick and Robinson (2017) place tinkering at the intersection of play and making. Certainly, tinkering fits neatly into the language and aims of twenty-first century play-based learning.

Tinkering is processual, and is therefore often meandering and winding. Despite being inefficient at times, tinkering allows for creativity, flexibility, and agility through a constant re-evaluation of goals and plans. Tinkering supports Nicholson's (1972/2009) theory of loose parts by encouraging fiddling and dabbling with heterogeneous concepts and materials. It affords exploration, testing, iteration, and problem-solving (Bevan et al., 2014), which are core design thinking skills.

According to Resnick and Robinson (2017), *planning,* unlike tinkering, is often assumed to be more valuable in play-based learning environments, as it is more organised, goal-oriented, direct, efficient, and top-down in terms of approach. Tinkering, as opposed to planning in play-based learning environments, takes a bottom-up approach, where a tinkerer initially begins with a simple concept, tries to bring it to life, and makes adjustments that continually refine the concept (ibid).

Tinkering allows for experimental, unpredictable, and proactive investigation of objects. As a twenty-first century literacy skill (Yakman, 2008, 2010; Resnick and Robinson 2017) that supports the adoption of a creative and innovative palette of tools, concepts, and phenomena, tinkering is integral to STEAM learning.

As discussed in Chapter Seven, constant tinkering and iteration to address the pain-points and roadblocks identified during the construction of automata led to the evolution of play materials in the automata atelier during the fifth POP workshop. Here, two new play materials were introduced in the automata atelier.

1. A test frame to try different cam shapes and test their movements.

2. A heavier cam-follower was designed to stabilise the mechanisms. Adding weight to the cam-follower supported the dynamic components of the mechanism, as the cam-follower stopped slipping to one side of the cams when in motion. This ensured continuous movement and smooth running of the automata.

Tinkering with the play materials led the participants to engage in design thinking. The automata atelier supported the design process of identifying an issue, iterating with play materials, and testing them until a satisfactory outcome was achieved. Tinkering in the play workshops was undertaken either individually or collaboratively with other play partners (other participants), as per their preferences. Tinkering in the POP workshops supported Deweyan design perspectives on pragmatist learning and Vygotsky's design perspectives on social play, where it was experientially pursued through hands-on interactions and, at times, collaboration with other play partners (Dalsgaard, 2014).

8.2.2 Material is immaterial

DE fieldwork at Montessori schools in India and Scotland revealed that children were fearful of *breaking* or *spoiling* sensorial materials. By observing Montessori environments in action, I was able to witness a visible, hierarchical approach to engaging with the materials. On many occasions, I saw facilitators take the materials away from children who were seen to be *misusing* them. The recurrence of perceived misuse and protection of the materials from wear and tear revealed the design of facilitator-led order of play, where children were dissuaded from independently interacting with the sensorial materials for the fear of *ruining expensive equipment*. While the Montessori method theoretically supports independent interactions and agency of the child, in practice, expensive sensorial materials and their high replacement costs led to instances of *helicopter facilitation* and *ceremonial guided play*, with the agency of children and intuitive interactions designed out of object play.

While endorsing tinkering, Resnick and Robinson (2017) argue that all kinds of materials (ranging from batteries and wires, to paper, cardboard, and modelling clay) can be employed in tinkering, making it an accessible and budget-friendly literacy skill and design affordance. Here, the fear of ruining materials is often not a concern while engaging with the materials, as the learning environment consciously encourages exploratory and experimental interactions with materials to support inquiry-based learning and problem solving.

To support this argument, the automata atelier for the POP workshops was designed using frugal and economical play materials to incentivise participants to interact and tinker with play materials without any restrictions or fear of damage. The POP automat atelier and play materials were designed to adapt to damage and alteration without restricting the play activity.

The construction section of the automata atelier was designed by laser cutting shapes and frames in cardboard[71]. As the facilitator, I ensured that there was a constant supply of play materials for the participants. In prioritising the child-centred aspect of play-based learning, the *material was immaterial*. By encouraging the participants to have agency and take ownership of the play materials, they were able to tinker with them without hesitation and be unafraid of making mistakes.

8.2.3 Design empowered position of choice-making

While the participants were given guidelines to construct the automata, and were aware that I was available to help and assist them at any point during the workshops, they were encouraged to take their time with the materials, question my facilitation, readjust and replace any of the materials from the atelier, and take ownership of their design process. Some participants chose to redesign the automata mechanisms and challenge the construction methods I recommended. Others critiqued the construction process and engaged in iterations, which eventually led to the design of a few unique automata prototypes (as discussed in Chapter Seven).

The play-tutoring format of the workshops supported a design empowered position of choice-making and iterative learning. POP workshops as a research method endorsed interventionist play, Vygotsky's design principles of imaginative play, and Dewey's design principles of pragmatist play as key components of design thinking. This made the workshops a more enriching and compelling play-based learning experience, in

71 Refer to Chapter Six.

comparison to the prescriptive interactions observed during on-site DE fieldwork at Montessori schools.

8.3 Design of the workshop play-tutoring format

Although the design of the POP workshops emulated components from Montessori's presentation time[72], the play-tutoring format also introduced elements of flexibility, adaptation, and a smooth-striated workspace.

The POP workshops were designed to encourage participants to move from concrete steps to abstract ideas (they were encouraged to think of narratives and storylines to contextualise and support the designed automata mechanisms). After being introduced to automata as a workshop premise, participants were given free rein to determine how to proceed. They could choose to collaborate with other participants or engage in individual play. They could choose to design a movable automaton and conceptualise a narrative on completion of the model, or choose a narrative initially that would inform their design and construction process eventually. The workshops were designed to support flexible learning (Nicholson, 1972/2009) and could be adapted to suit each participant's preference and competence. By filling out feedback booklets and responding to some questions at the end of every workshop session, participants were encouraged to examine their designed artefacts and the challenges faced by them during the workshops and, reflect on their learning outcomes.

The design of a smooth-striated workspace supported the interests and preferences of the participants. This further encouraged agency and incentivised participants to take ownership of their design processes and design decisions. In order to ensure a format of play-tutoring that supported a smooth-striated workspace, the POP workshops were segregated in four stages. These stages were designed to give the participants a few guidelines to help them navigate the workshop premise. The following section elaborates on and analyses these four stages.

72 Refer to Chapters Four and Five.

Stage 1: Workshop onboarding

1. Welcome every participant and their accompanying family/guardians to the POP workshop and introduce myself as the workshop facilitator.

2. Introduce the premise of the workshop and give a general summary of what these play sessions hope to achieve. Inform the parents that these workshops are designed for children between the ages of eight to twelve years.

3. Give the parents/guardians a workshop information sheet[73] and obtain their signatures on the consent forms. Confirm with the parents if they are comfortable with me documenting their children participating in the workshop through photos and video recording. Clarify that the photographs will be anonymised (while referring to the consent form).

4. Maintain a friendly, approachable, happy, and informal tone of voice throughout the workshop, and ensure that the participants and parents are comfortable.

Analyses of Stage 1: As a research instrument

The onboarding process was designed to welcome each participant and their accompanying family/guardians to the workshop. This stage was also essential since it informed the participants and parents about the intentions of organising these POP workshops, recorded their consent (by asking them to sign the consent forms), and confirmed their permission to document these sessions through photographs and video (while also informing them that the visual documentation would anonymise the participant's identities).

As discussed in Chapter Six, my research position underwent significant change vis-a-vis participants and the explicit control of the research environment, while designing the workshops as a research method. One such role that I embraced while facilitating these workshops, was of a *research instrument*. As a means of designing a workshop premise where the participants felt safe and comfortable, on-boarding the participants in an earnest and enthusiastic manner was crucial. Based on the argument presented by Ahmed and

73 Refer to appendix at the end of this document.

Asraf (2018) in Chapter Six, this stage was adopted while designing workshops as a research method in the hope that the participants would feel more valued and willing to engage in the play premise and provide feedback.

Unlike Montessori and other schools environments where parents are not a part of day-to-day learning and presentation time at schools, at CLEs such as the Museum of Childhood and the Scottish Storytelling Centre, parents/guardians accompanied the children to play workshops and could choose to participate with them or sit with them as silent observers. During the POP workshops, I hoped that the parents/guardians would give the children complete control to decide whether they needed any help and not automatically insert themselves as co-participants within the workshops.

Stage 2: Introduction of workshop premise: Design of automata and movable mechanisms

1. Begin the workshop by engaging the participants in a conversation about their school life, holidays, and subjects they study at school. Enquire whether their schools organise STEAM and play activities.

2. Introduce the participants to the automata atelier arranged in front of them. Question them about what they see and observe if they can identify any of the materials displayed in the atelier. Give them some time to observe and interact with the automata atelier. Encourage them to pick up materials and play with them.

3. Direct the participant's attention towards the geometrical shape materials placed in the atelier. Question whether the participants can identify any of the shapes from the atelier.

4. Based on their answers, direct their attention towards the seven specific shapes[74] from the automata atelier and encourage them to pick the shapes up, touch and feel the physical form and material of the shape with their hands, and play with the shapes. Count each side of every shape with them, and ask them to feel the differences between straight edges and curves of each shape.

74 Refer to Chapter Six on shapes selected as cams for the automata atelier.

5. While they interact with the shapes, slowly introduce the concept of automata to them. Ask them, "How would you like to use these shapes and design a movable toy/machine that you can take home and show your friends?".

6. Immediately support this question by showing them videos and samples of predesigned automata and introduce the workshop premise of building automata.

7. Ask the participants if they have any doubts and questions about the workshop theme and automata, and if they would like to proceed?

Analysis of Stage 2: As a research instrument and inside researcher

During stage two, I continued to essay the role of a research instrument by enthusiastically interacting with the participants and reflectively working towards establishing a friendly rapport. Most of the participants responded positively to discussions about school, friends, and summer holiday plans. I focused on keeping the conversations casual and light-hearted to make the participants feel at ease.

I briefly introduced the concept of STEAM to every participant, and enquired about whether their schools organised any play or design activities for them. Some participants were aware of STEAM activities, and gave me examples of STEAM and play sessions they had attended at school, which covered activities such as play with sensory clay, making slime, designing science experiments, outdoors trips, playing with natural materials, and so on.

While engaging in conversations about STEAM learning and play sessions organised at their schools, I was also participating in the workshops as an *inside researcher*. I shared my views on STEAM learning with these participants, and confessed my fascination for LEGO toys and magnetic clay. During the DE fieldwork, I had been unable to interact and converse with the school children; this had led to awkward ethnographic encounters (Koning and Ooi 2013). However, during the POP workshops, I was able to establish direct communication with the participants. This helped me curate my facilitation style to suit their play preferences. It also made these workshops, as research sites, less awkward and more *natural* for me to be a part of.

By engaging in these casual conversations and discussions during the first two stages, I hoped to establish a friendly and interactive relationship with the participants and their accompanying families. I hoped that this would help them feel comfortable and valued as participants in this workshop. Instead of establishing my status as a facilitator who controls and leads these play workshops, I hoped that the participants would perceive me as an MKO[75], or a capable peer, guide, and co-participant.

During on-site DE fieldwork, the order of play that emerged in various levels across various activities was usually adult-led, adult-initiated, or adult-focused through ceremonial guided play and helicopter facilitation. In contrast, by essaying the roles of an insider researcher and research instrument during RtD, I hoped to become an extended arm of the participant community, and design a participant-led and participant-focused play-based learning environment.

Stage 3: Construct and build automata

1. If the participants agree to continue with the workshop, encourage them to pick up a few sheets of paper and some pencils and some cut-out cam shapes, and ensure that the predesigned automata samples are placed in front of them.

2. Give each participant plenty of time to brainstorm, doodle, and sketch ideas. Guide them (if they ask for help or appear to be confused) and brainstorm with them if they need any help with developing a narrative (if they choose to initially think of a storyline to support their construction). Encourage them to play with the predesigned automata mechanisms to help them get acquainted with the look and feel of the mechanisms.

3. Ask the participants to choose a cam shape, and consider if they want to design an automaton with one or two cams. Reiterate to the participants that they have control over what they want to design, which shapes they want to use and how they want to proceed.

75 MKO or more knowledgeable other. This concept has been discussed in Vygotsky's theory of ZPD in Chapter Two.

4. Once the participants have chosen their cam shapes, help them construct the basic frame of the mechanism (if they request for help). Guide them to get their mechanism to work steadily and help them if they face any design challenges and roadblocks (when they ask for it). Give the glued mechanism frames enough time to dry.

5. As the automata mechanisms are being constructed by the participants, encourage them to spend some time designing, drawing, and colouring props, and think of narratives and storylines to support their designed automata.

6. Finally, assemble the working and decorated automata. Help the participants with assembling the final automaton model (if they ask for help).

Analysis of Stage 3: As a research instrument and inside researcher

As discussed in Chapter Seven, some participants wanted to construct the mechanism first and then think of a narrative to add to the construction. Others preferred to think of a story, visualise props, and then select cam shapes based on how the movement generated by their chosen cam shape/shapes would support their designed narrative. Participants could choose to proceed in any manner they wished.

Here, the play-tutoring format underpinned Nicholson's (1972/2009) theory of loose parts, where creative learning environments must be designed to be supportive, adaptable, flexible, and receptive to children's new ideas. This includes encouraging children to lead the design process.

When the participants began to work on their automata concepts, I assumed that some would require more guidance than others with constructing their mechanisms. I anticipated that the construction of a working mechanism, which requires both conceptual planning and an understanding of arranging a mechanical rig, would present challenges. This was indeed the case. Most participants requested for help and guidance while constructing their basic frame and mechanism of the automata. Some participants needed an extra set of hands to help them hold the cardboard pieces in place, as they glued the mechanism together. Others wanted me to co-design the automaton prototypes *with* them.

Brereton and Buur (2008) argue that adapting participatory design methods to engage in iterative prototyping and continuous research can lead to new types of participatory relationships, which bring the researcher closer to members of the particpant community. Within the framework of participatory design, Binder and Brandt (2008) conceptualise co-design as mutual learning, where they visualise participatory design projects *not* as site-specific, but instead as modes of inquiry that focus on maintaining transparency during the design process.

By co-designing with some participants, I was able to engage in close quarters with them with the hope of becoming an extension of their community (Brereton and Buur, 2008). Participatory co-design also helped maintain a transparent process of engaging with the materials, as well as working and struggling with the construction of the automata mechanisms as a team. By co-designing automata mechanisms with some participants, characteristics of participation and prototyping converged. Here, both the participants and I, as co-designers, were collaboratively involved in idea generation and iteration by constructing prototypes (van Waart et al., 2015).

In some other instances where two or more participants had teamed up to design an automaton, they preferred to take control of constructing their mechanism without my help. After building and constructing their automata models, most participants were excited to discuss their final designs, ideas, and narratives. Some participants wanted to continue playing with their automata models and add more artwork.

Stage 4: Reflect on the design process: Feedback booklets:

1. Ask the participants to showcase their final automaton and talk about their concept.

2. Give them some time to play and interact with their designed automaton.

3. Ask the participants and their parents if their constructions can be photographed.

4. Request the participants to complete the feedback booklet.

Analysis of Stage 4: As a research instrument and outside researcher

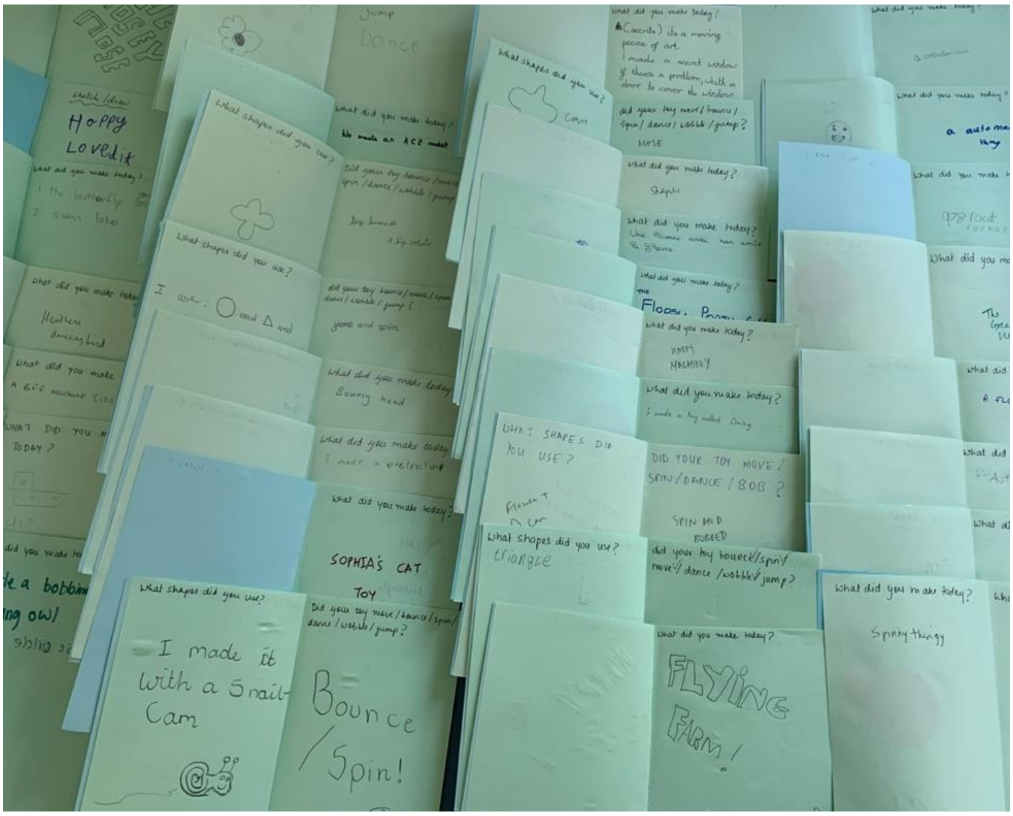

Figure 78: Some of the feedback booklets from the POP workshops

As discussed in Chapter Six, as a means of encouraging participants to reflect on their learning outcomes, simple and colourful feedback booklets were designed and given to each participant at the end of every play session. Here, participants were encouraged to sketch, draw, stick art material, and at the same time, answer some key questions that would help me gather their feedback and insights on the play workshops.

In each feedback booklet, participants were asked to:

1. Assign a name to their designed automaton.

2. Write down the shape/shapes they had employed as *cams* to design their automaton.

3. Describe the movement generated by their automaton and allot terms (taxonomy) to define and recall that movement.

4. Describe their workshop experience in the feedback booklet, in any format preferred by them (by writing, drawing or gluing stickers in the booklet, and so on).

Binder et al. (2008) argue that where designing is an inherently future-oriented practice, reflection on its own is a meaningful design intention that must be deliberately cultivated from the beginning of a design process. The lack of reflection in play activities had been identified as a design gap while undertaking DE at Montessori schools. Consequently, within the POP workshops, reflecting on the workshop premise and object interactions was consciously designed into the play-tutoring format.

In order to reflect on the workshop premise and learning outcomes, feedback booklets were designed to serve a dual purpose. These booklets supported my role as a research instrument. Here, these booklets incentivised the participants to share their honest feedback and perspectives with me, and reflect on the workshop outcomes (Ørngreen and Levinsen, 2017; Ahmed and Asraf, 2018). These booklets also supported my role as an outside researcher as I could keep them with me at the end of every workshop, as documented evidence of participant insights in their own words (Ørngreen and Levinsen, 2017; Ahmed and Asraf, 2018).

8.3.1 Overall analysis of the play-tutoring format

8.3.1.a Taxonomy of movements and reflections as design intentions

Ibes and Ng (2011) describe how certain play activities provide children with a working terminology to classify movements (for example: linear, rotary, oscillation, and so on). This taxonomy of movements was introduced to the participants during the workshops. While the participants were introduced to the automata atelier, and encouraged to interact with the predesigned automata samples, test cam shapes, and design narratives for their mechanisms, they were often asked how they would want their mechanism to move.

While facilitating the play sessions, I would use words such as “bounce, jump, dance, move…” to describe how some of the automata constructions moved. Often, while reflecting on their designed automata, and narrating their concept to their parents/guardians and me, the participants would sometimes remember these words and repeat them to describe the way their mechanisms moved. Vygotsky (1978) argues that, when imaginative play is designed within a play-based learning environment, it helps children become more competent in their language use, which, in turn, helps them regulate their thought process. Vygotsky (ibid) argues that, by engaging with play objects through imaginative play, children begin to explore an object's physical properties, and learn to symbolically represent them by designing narratives and rules of interaction.

During the POP workshops, children would sometimes develop their own terminology by employing descriptive words such as "shake, wobble, bob..." to explore the capacity of their mechanisms. Language development in participants was supported during the workshops while discovering the affordances of shapes, while using the shapes as cams, exploring the cams on test frames, building and fine-tuning the mechanisms, discovering and verbalising the roadblocks and pain-points encountered during the building process, and tinkering with the materials. Later, language development in participants was further supported when they presented their narratives and stories, reflected on their workshop experience, and documented their feedback in the booklets (Scharer, 2017).

In the POP workshops, this symbolic use of language through words to describe the automata movement, helped the participants connect the visual and tangible form of their selected cam shapes to the non-tangible and dynamic movements generated by their automata models.

The following terms were pre-written in the booklets to classify potential movements of the automata mechanisms: bounce, wobble, up and down, dance, spin, and jump. Although these words were introduced in the booklets, participants could add additional words based on their description of the movements generated by their automata. The following table presents a list of titles that participants gave to their automata, along with the shapes they used as cams and the movements their automata generated.

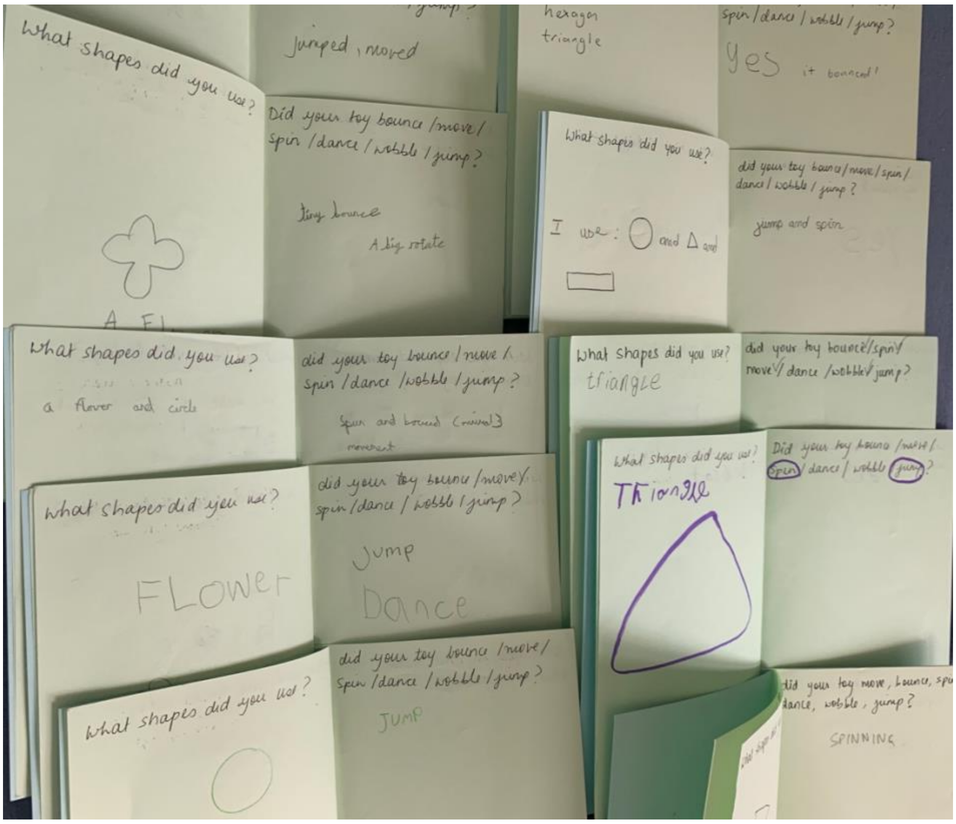

Figure 79: Participants responses documented in the feedback booklets

Table 8: Documented responses from the feedback booklets

Workshop day and date	**Participants**	**Name of the automaton**	**Shapes used as cams**	**Words used to describe the automaton's movement**
Day 1: 17th June 2018	P1_D1	Scarecrow and the scared birdie (Robin)	Flower cam + Triangle cam	Spin and bob
	P2_D1	"A BFF machine (its magical)"	Flower cam + Hexagon cam	Spin and dance
	P3_D1	A ship	Eccentric circular cam + Flower cam	Turn and Spin
	P4_D1	Dancing Bird	Hexagon cam	Spin and wobble
	P5_D1	Secrets ("Secrits") a moving piece of art.	Eccentric circular cam	Jump and move
Day 2: 1st July 2018	P1_D2	"Spinny Thingy"	Flower cam	Up and down
	P2_D2	"I made a toy called daisy".	Eccentric circular cam	Spin and move

	P3_D2 and P4_D2 (Siblings)	Shapes	Triangle cam	Spin
	P5_D2 and P6_D2 (Siblings)	Dragon and Butterfly	Flower cam	Move
Day 3: 5^{th} July 2018	P1_D3	The great heart	Flower cam	Spin and dance
	P2_D3 And P3_D3 (siblings)	Automaton football	Eccentric circular cam	Spin
	P4_D3 and P5_D3	A flower	Triangular cam + Hexagonal cam	Spin and wobble
	P6_D3	Smash the happy lolly	Eccentric circular cam	Dance and bounce
Day 4: 8^{th} July 2018	P1_D4	"I made a construction."	Hexagon	Shake and rotate
	P2_D4	Stickman	Eccentric circular cam	Jump and move
	P3_D4	Eva's flower automaton	Flower cam	Jump and dance
	P4_D4 and P5_D4	P4_D5: "I made a rocket with an astronaut in space". P5_D5: "we made an astronaut and a spaceship. It was really cool".	Flower cam + Eccentric circular cam	P4_D5: "tiny bounce, big rotate". P5_D5: "Spin and bounce (minimal) movement".
	P6_D4	Angel machine	Eccentric circular cam	Jump
Day 5: 12^{th} July 2018	P1_D5	Bouncy Head	Hexagon cam + Triangle cam	Bounce
	P2_D5	Schicki and Miki	Flower cam	Jump and spin
Day 6: 13^{th} July 2019	P1_D6	Happy Machiny	Triangle cam	Spin
	P2_D6	Cloudy	Eccentric circular cam	Spin and jump
Day 7: 15^{th} July 2019	P1_D7 P2_D7 and P3_D7	ACE Rocket (ACE is an acronym of their three names)	Eccentric circular cam	Spin
	P4_D7 and P5_D7	"une licorne avec son amie fleure" - (a unicorn with her flora friend)	Triangle cam	Spin and jump
Day 8: 19^{th} July 2019	P1_D8	Rainbow cat	Triangle cam	Spin and jump

Day 9: 20th July 2019	P1_D9 and P2_D9	Jump Box	Eccentric circular cam	Spin and jump
	P3_D9	Secret Minecraft object	Triangle cam	Bounce, spin, move and wobble
Day 10: 22nd July 2019	P1_D10 and P2_D10	Flopsy-popsy 611	Apostrophe (snail) cam	Move and spin
Day 11: 29th July 2019 (11am to 2 pm)	P1_D11	Bobbing Burrowing Owl	Eccentric circular cam	Bob
	P2_D11	A googly-eyed automaton	Flower cam + Eccentric circular cam	Bounce
Day 12: 29th July 2019 (2pm to 4pm)	P1_D12	978 'rockit' (rocket)	Apostrophe (snail) cam	Move, spin and jump
	P2_D12	Sophia's cat toy	Triangle cam	Move, jump and spin
Day 13: 1st August 2019	P1_D13	"I made a cat with a toy"	Apostrophe cam (snail cam)	Bounce and spin
	P2_D13	The Nosey Nose	Apostrophe cam (snail cam)	Bounce and spin
	P3_D13 and P4_D13	Butterfly garden and swan lake	Triangle cam + Hexagon cam	Move, jump, spin and bounce
	P5_D13 and P6_D13	The Flying Farm	Apostrophe (snail) cam + Eccentric circular cam	Jump and bounce
	P7_D13	A construction name	Apostrophe (snail) cam	Jump
	P8_D13	An Automan thing	Two Oval cams	Jump and spin

By documenting their findings, the participants gave new meanings to their designed models. By choosing movement-depicting words to describe their constructions, the participants were able to articulate how their chosen cam shapes and automata moved. For example, an eccentric circular cam rotated, while simultaneously moving up–and-down, whereas an apostrophe cam afforded a rise and sudden fall movement (slow ascent and sudden drop) when used in an automaton.

In addition to language development, describing and documenting the way their automata moved, and the specific cam shapes they used, helped the participants grasp the concept of *dual representation* (DeLoache, 2000). Here, they were able to comprehend geometrical forms as a shape (a circle, a triangle, a hexagon) as well as give the shape a newly imagined and constructed meaning (the cam shape as a component that generates movement in their constructed mechanism). To summarise, they were able to identify shapes based on its physical characteristics and eventually associate these shapes to objects (cams in an automata) that created different kinds of movement.

8.3.1.b Active participation and involvement

As introduced in Chapter Seven, parental involvement led to positive participation during some workshop sessions. Here, some parents assisted the participants by helping them design movable mechanisms, sketch, brainstorm, create props, design cut-outs to decorate and thematise the automata, and have fun while engaging in the workshops. One such incidence was observed with the first participant on the fourth workshop day. P1_D4's mother was enthusiastic about the workshop premise and automata. She discussed the potential of automata as an engaging platform to learn simple engineering concepts. While P1_D4 took some time to test and finetune the movement of the automaton before proceeding with the workshop, his mother helped him only when he requested her assistance and continuously encouraged him. Both the participant and his mother also discussed the possibility of using this workshop activity towards designing a project for the participant's school science project.

During this session, my role as a research instrument was further bolstered when the parents and P1_D4 shared their feedback about the learning implications and future adaptations of this workshop activity. In this scenario, engaging in a dialogue and reflecting on the play workshops helped P1_D4 think of future possibilities of exploring automata within the context of a formal learning environment like his school.

8.3.1.c Employing natural mediator tools

As illustrated in Chapter Seven, some workshop participants did not speak in English, which made it challenging for me to communicate with them. In order to ensure that the absence of a common language did not exclude these participants from engaging in these workshops, improvisational measures were adopted within the facilitation framework. In such situations, I requested the accompanying parents or guardians to participate in the workshop and translate its content for the participants.

Fortunately, all the parents and guardians who attended the workshops could converse in English. This helped me address the language limitations encountered during the workshops. The presence of family members provided the workshops with natural mediator tools (Hall, 2007) to help the participants engage in the premise of building automata. This supported the design of the workshop as an authentic learning environment, where the competence and interests of the participants were taken into consideration, while engaging in play activities with the children. This affordance of a flexible and adaptable facilitation format, which encouraged parental involvement by the means of translating the workshop premise, worked positively for the play premise. Here, the participants felt supported when their parents and guardians translated the contents of the workshop. This, in turn, incentivised them to not abandon the play workshop and instead purposefully engage with the play activity of designing automata.

By inviting parents and guardians into the workshops as mediator tools (translators), I had to trust them, and hope that they did not engage in helicopter facilitation or unknowingly assert control over the workshop premise and learning process adopted by the participants. Interestingly, in this situation, I had to take on an additional role; that of a *supervisor*, who had to audit how the parents and guardians translated the play workshops for the participants. Here, I had to keep insisting that the participant should take the lead in designing the mechanisms and engaging with the automata atelier, where both the parents as mediator tools and myself as the facilitator were there to only guide and support them in the workshops.

8.3.1.d Negotiating power and order in the workshops

Some parents also had children younger than the intended age group for the workshop with them, who were interested in joining their older siblings as workshop participants. There were instances when the younger siblings requested that I construct an automaton for them and their parents were often insistent that I should allow the younger children to participate in the play sessions, regardless of the age restrictions. In such situations, while maintaining my role as a research instrument, I politely obliged and, in addition to facilitating automata sessions for the older siblings, I constructed small movable mechanisms for the younger siblings as well. Though certain complications appeared while trying to coordinate play sessions with families, they were dealt with and overcome without undue impact on the core work.

8.4. Design of the workshop premise

As discussed earlier in this chapter, the premise of the play workshops integrated Montessori and STEAM competencies through the design idiom of automata. This workshop premise embodied scaffolding through a dialogic exchange of ideas and criticisms, design of narratives, collaborative play, and adaptation of natural mediator tools (discussed in the previous section) that encouraged tinkering and iteration with play materials to construct automata.

These attributes of scaffolding, when viewed through Fröbel's design lens of exploratory play, Vygotsky's design lens of imaginative play and multimodal communicative practices, and Dewey's design lens of pragmatism and interventionist play, contribute to collective meaning-making and encourage creativity in play-based learning environments (Marsh et al., 2019). The following section elaborates on the above-mentioned attributes of the scaffolding framework of the POP workshops, and analyses how these attributes implicated design and design thinking in the play-based learning experience of the workshop participants.

8.4.1 Dialogic exchange of ideas and critique

As observed on-site during DE at Montessori schools, presentation time with Montessori's sensorial materials did not accommodate a dialogue between the facilitators and children. The children were not given an opportunity to critique or question the sensorial materials or play activities, develop individual narratives and iterations, or redesign the sensorial materials. Montessori pupils were not encouraged to think of alternative ways of engaging with the materials or reflect upon their activities at the end of a play session.

In comparison, during the POP workshops, participants were encouraged to discuss their design process, describe the challenges of the workshop premise, come up with suggestions on how to improve the play materials, and reflect on their constructed automata. This gave them a platform to organise their thoughts and share their ideas. It opened up a dialogue as to how they could extend their designs, add more props, experiment with other shapes as cams, and design other automata mechanisms using readily available materials at home.

To illustrate, I refer to the second participant from the eleventh workshop[76] - P2_D11 designed an automaton *bot* by re-purposing two plastic water cups as *legs* of the automaton and elevating the overall height of his final prototype. These design decisions were supported by the workshop premise, where P2_D11 was encouraged to discuss ideas and engage in tinkering and iterations with the materials from the automata atelier, and come up with a practical solution to *elevate* the designed prototype. While reflecting on the final automaton, P2_D11 was excited to share the learning experience with his friends at school and was already thinking of new ways to further develop the automaton.

In comparison, the seventh participant on the thirteenth workshop[77] (P7_D13) was more interested in essaying the role of workshop helper and spent more time helping other younger participants build their mechanisms. While P7_D13 engaged in the workshop long enough to design a simple automaton, his interactions and help provided to other participants were equally valuable as a learning experience. Here, P7_D13 engaged in collaborative play by interacting with the automata atelier and participants, along with scaffolding the construction process for other participants by offering to help them. As observed, the workshop premise was flexible and considered the needs and interests of both the participants. The workshop premise did not constraint their interaction with the automata atelier or with other participants.

As discussed in Chapter Two, while re-reading Dewey as a design thinker, his perspectives on pragmatism prompt us to think of children (here: participants) as useful actors, who, similar to designers, draw on interactive artefacts and systems to make sense of their world (Dalsgaad, 2014). Based on Deweyan perspectives, giving the participants an opportunity to make sense of the workshop premise and to voice their doubts, and encouraging reflection during the POP workshops, aided their knowledge acquisition.

76 Refer to Chapter Seven.
77 Refer to Chapter Seven.

Interestingly, Kenny and Barblett (2010)[78] also argue that this kind of dialogic exchange of ideas between children and adults is central to learning and teaching through play.

8.4.2 Design of narratives

In their discussion of narratives and emergent literacy, Nicolopoulou et al. (2006) argue that it is important to capitalise on the significance and developmental value of imaginative and symbolic play while designing child-centred activities. The authors (ibid) argue that narratives afford symbolic play, while simultaneously extracting and mobilizing imagination, emotion, and cognition (Nicolopoulou, 1993; Nicolopoulou et al., 2006).

By approaching the construction of automata through narratives, participants began to engage in symbolic play and, by extension, imaginative play. As observed, sustaining the narrative component in the movement, form, and identity of their mechanisms helped to maintain the participants' interest in the workshops (Kenny and Barblett, 2010).

As an example, the first participant from the eleventh workshop (P1_D11) engaged in imaginative and symbolic play while constructing his automaton, which was conceptualised around an owl trying to catch a worm and called the "Bobbling burrowing owl". P1_D11 chose an eccentric circular cam since the movement this cam generated resonated with the narrative P1_D11 was trying to create. Here, P1_D11 used the term "bobbing" to imagine a narrative and design symbolic prop. This supported his decision of selecting a specific cam shape and the movement it generated to design his automaton.

As discussed in Chapter Two, Bodrova and Leong (2007) argue that Vygotsky's understanding of imaginative play focuses on play activities that create an imaginary situation and endorse enactment of roles. As a design thinker, Vygotsky argues that imaginative play supports language acquisition and cognitive development in children. Imaginative play affords the design of narratives, exploratory play with objects and spaces, and reflective communication with play partners through kinaesthetic gestures and words, all of which support creative pedagogic practices and design thinking.

The POP workshop premise was designed to afford imaginative play where participants could develop roles and narratives to extend diverse possibilities afforded by the automata

78 Refer to Chapter One.

atelier. Fostering children's initiatives in this way is central to play-based learning methods (Nicolopoulou et al., 2006). During the POP workshops, the practice of composing playful narratives (Paley, 1986, 1991, 2004) led the participants to take ownership of their designed automata and gave them an opportunity to engage in playful story-telling.

As a facilitator, I did not intervene, or question the participants' plots and narrative structure. In the case of those unable to converse in English, they preferred to communicate and discuss their narratives with their parents. In such scenarios, the parents would summarise the participant's narrative to me, while we reflected on the design of their automata.

8.4.3 ZPD, scaffolding, and collaborative play

Re-reading Vygotsky as a design thinker in Chapter Two allowed us to understand how transitory learning stages can be designed in the learning environment with the help of scaffolding and internalisation of knowledge. Vygotsky conceptualised various transition stages in ZPD, within which learning takes place. During these stages[79], activities are designed to help the learner transition from guided learning through scaffolding (assistance provided by MKOs or capable peers) to internalised learning.

POP workshops were designed to support stage one of ZPD. The main focus of this stage was to introduce the participants to the automata atelier, and guide them towards eventually taking control of their design and construction process. As discussed in the earlier sections of this chapter, the play-tutoring format was designed to move through four stages:

(1) Workshop on-boarding → (2) Introduction of the workshop theme (automata) → (3) Construction of the automata through engagement with the automata atelier → (4) Reflecting on the design process.

These stages were designed to deconstruct the facilitation process into manageable sections, which would make it easier for me as the facilitator to provide more assistance to the participants initially, and eventually support and encourage them to design an

79 Stages of ZPD are elaborated upon in Chapter Two of this thesis.

automaton on their own. Diary narratives from Chapter Seven demonstrate that, during the workshops, some participants chose to work on their individual automata while others chose to collaborate to construct a single automaton. Both individual and collaborative play choices were adopted into the flexible workshop premise, and led to interesting outcomes.

Here, I refer to participants three and four from the third POP workshop. Despite both having very specific aesthetic expectations from their automaton model, P3_D4 and P4_D4 (siblings) insisted on collaborating. Interestingly, their different preferences encouraged them to spend more time interacting with the preconstructed automata samples in the atelier. This indirectly incentivised them to select two unique cam shapes (triangular and hexagonal cams) and design a common automaton to compare their different movements.

Scaffolding, in this scenario, came into play when their conflicting views indirectly led to deeper engagement with the automata atelier by designing movable mechanisms with two unique cam shapes and simultaneously comparing them. The POP workshop, as a flexible learning environment, hence supported their decision to collaborate, while the automata atelier and the workshop premise supported their individual choices to tinker and iterate with specific play materials.

8.5 CLEs as workshop sites

As discussed previously, Edinburgh Museum of Childhood and Scottish Storytelling Centre were chosen as the two play sites to conduct the POP workshops. These CLEs were an ideal platform to undertake informal, iterative, and improvisational practice-based research. Within the two sites, the affordances of the physical space at the Museum of Childhood were considerably different from the Edinburgh Scottish Storytelling Centre. While more workshops were organised at the Museum of Childhood (eleven) compared to the Scottish Storytelling Centre (two), the allocated spaces of both sites affected the facilitation of the workshops.

Jahreie et al. (2011) argue that play-based learning in museums is fundamental to developing children's understanding of new concepts. Moreover, the authors contend that CLEs foster playfulness and active engagement that enables children to manipulate, test, and explore ideas in a learning environment that aligns itself with the goals of museum education.

Similarly, Mayfield (2005) argues that play is the raw material of knowledge at CLEs such as museums. Current museum education relies on play-based learning to encourage children to observe, wonder, interact with, and question exhibits. This inquiry-based learning is integrated into the design and content of museum play activities (Wolf and Wood, 2012), and makes museum learning both hands-on and dialogical (Henderson and Atencio, 2007; Andre et al., 2017). Inquiry-based learning is designed to be undertaken within the limited time frame of a museum visit, and is also limited to interpretive tools designed around the artefacts and exhibits.

At the Museum of Childhood, an empty corner of a toy gallery on the second floor was dedicated to the POP workshops. The allocated workshop space was limited in size. The gallery itself was dimly lit with no natural light filtering in (windows with light blocking curtains). The gallery housed vintage dolls and mechanical toys behind glass shelves, making the space appear dull, formal, and unapproachable. The primary focus of the POP workshops was to invite playful and active exploration of designed play materials. However, the dull atmosphere of the gallery room was paradoxical to the perception of an inviting and playful space.

Another disadvantage of the gallery space at the Museum of Childhood was that there was no privacy or segregation of space to conduct the workshops. As a result of this, on busy days with lots of visitors at the museum, it was difficult to maintain an independent workshop environment and avoid intrusion by passing visitors. Visitors, especially with small children, would want to come and sit in the workshop space and let their children use the automata materials. Sometimes, I had to facilitate the play workshops with participants, while simultaneously document my observations and speak to passing visitors to explain the premise of the workshop.

The lack of privacy made it difficult to concentrate on facilitating the play sessions when it became noisy in the gallery. This constant interruption often distracted the participants and disturbed the workshop premise. At times, museum visitors assumed that I was an employee of the museum and would walk to the workshop space, ask for directions, and interrupt my play sessions with general queries about the museum, which I was not equipped to answer. Some also assumed that the play materials displayed on the automata atelier were free to pick up and use and would take away art materials without checking with me, which further disrupted the workshops.

In comparison, a separate gallery space was assigned for the POP workshops at the Scottish Storytelling Centre. It was a bright, well-lit, and colourful space, with a wall-sized window overlooking a back garden. Since this space was often used to conduct theatre, play and art workshops, it was bright, playful, inviting, and informal, which worked in favour of generating an active, engaging, and pleasant workshop environment. It was spacious and consisted of foldable tables, chairs, and a display shelf with various toys, which was fitting to the premise of the POP workshops. Here, I could curate the space as per my needs and requirements for the workshops. The reception staff at the Scottish Storytelling Centre had previously informed visitors about the scheduled dates and time of the POP workshops. This helped avoid intrusion from random gallery visitors and did not interrupt my facilitation during the play-sessions. This further ensured that the workshops participants were given privacy and not disturbed.

It can be inferred that spatial design and arrangement of the learning environment along with components such as light, sound, access to privacy, ability to rearrange the furniture, and the lack of interruptions affected the quality of my facilitation. I was less stressed and more focused while facilitating the POP workshops at the Scottish Storytelling Centre as compared to the Museum of Childhood. It was easier to control the play space at the Scottish Storytelling Centre and ensure that the participants were not interrupted or disturbed while engaging in the workshops.

8.6 Affordances of the workshop as a research method at CLEs

Undertaking RtD through these workshops revealed the intricacies, limitations, and affordances of conducting play-based learning sessions for children at CLEs. As a practice-based method, RtD is oriented to capturing data in the *present* and, like the POP workshops, it values collaborative processes that allow for iteration, refinement, and moderation (Ørngreen and Levinsen 2017). RtD and the participatory workshop format share processual and reflective values.

In the case of the POP workshops, the synergy of RtD and the participatory workshop format provided dedicated time and space to explore play-based learning within informal environments. Unlike DE, RtD undertaken through workshops allowed me to curate the play-setting within which the automata atelier was tested.

As discussed earlier in the thesis, participatory design strives to strike a balance between reflexivity and pursuing predefined goals (Brereton and Buur, 2008). In the POP workshops, adapting participatory design as a potential measure to engage in iterative prototyping and co-designing with participants helped me (the researcher) get closer to members of the community (participants and sometimes their parents/guardians). Participatory co-design led to the creation of a transparent process while engaging with the automata atelier and struggling with the construction of the automata mechanisms as co-participants.

8.6.1 Limited participants per session

The workshops were spatially arranged to accommodate a maximum of three participants per session. This helped me curate play sessions for individual participants, guide them, and give them plenty of time, space, and additional materials to engage in iterative learning. Although this might appear different to where and how Montessori systems are used, it can be compared to small independent learning groups in Montessori schools[80].

However, in comparison to conducting play sessions for school environments, which often reside within overarching curriculum guidelines and timeslots, designing play activities at CLEs afforded the luxury of time, space, and freedom to creatively explore the construction of mechanisms. This also did not negatively impact the learning outcomes of any pre-stated school curriculum.

8.6.2 Challenging and stretching the learner’s competencies

While conceptualising the play activity and designing the automata atelier, the construction process of the automata mechanisms was designed to be challenging. However, it was also deconstructed into smaller steps. Most components of the automata mechanisms were predesigned, glued (automata frames and cam followers), and

80 Small, independent learning groups were observed at the school sites during the design ethnography research phase at M.S.2.0.

simplified to ensure that participants would enjoy the process of exploring shapes and constructing the mechanism, and not solely focus on the final outcome.

POP workshops accommodated different kinds of learners with different agendas, without compromising on the quality of object play and facilitation. When faced with a challenge during the construction process, a few participants requested that I build the entire mechanism for them, instead of working through the activity themselves, which necessarily affected their learning outcomes. This could have been because they were excited by the prospect of taking a working automata model home instead of exploring and tinkering with the materials.

In other instances, some participants took it upon themselves to work through the challenging aspects of the construction process and only asked for advice. These participants were focused on comprehending the steps of building an automaton on their own, so that they could explore this activity further at home. Observing participants interact with the automata atelier helped me evaluate the play materials and the construction process. This allowed me to evaluate how the workshops could be improved and designed to be more intuitive and playful.

8.7 Chapter summary

This chapter has analysed POP workshops, which were designed to explore play-based learning through RtD. Throughout the chapter, the aim has been to identify and address the first and third research questions, which focus on design thinking and design's contributions to play-based learning and its migration beyond formal classroom environments to CLEs.

As this chapter has shown, analysing the workshop premise helped examine the ways in which scaffolding frameworks were designed to support the activity of automata construction. Affordances such as a dialogic exchange of ideas and criticisms, exploration, co-design, adaptation of natural mediator tools (Hall, 2007), narratives, and experimentation supported inquiry-based learning through tinkering, iteration, and the evolution of the automata atelier.

This chapter has further demonstrated that CLEs such as museums and gallery spaces support play-based learning through the design of flexible and iterative play premises that integrate play and learning as mutually influential as well as distinctive processes. This, in turn, supports designer thinking, designerly inquiries, and creative pedagogical practices.

As a workshop facilitator, I embodied the role of an inside researcher, while collaborating with some of the participants to co-design automata. As a research instrument, I designed the workshop environment to be a safe, accessible, and comfortable space for the participants, which encouraged them to engage in social play, discuss their findings, and reflect on their learning outcomes. In order to further bolster this reflection process, colourful feedback booklets were designed to encourage participants to document their learning outcomes. These booklets were also designed to support my role as an outside researcher, as they helped document rich participant insights.

The design of the play-tutoring format and its segregation into multiple stages supported a design empowered position of choice-making and exploratory learning. The workshop premise, designed as a flexible and adaptable learning environment, supported participant-centred facilitation by allowing me to transition between multiple research roles. As a result, the participants felt valued and more willing to engage in a dialogic exchange of ideas and provide feedback. By adapting the role of a research instrument as well as occasionally engaging in co-design sessions with the participants, I was able to establish trust with the parents and participants. This further supported the design of a participant-led (child-led) and participant-focused (child-focused) play-based learning environment.

This thesis now moves to Part Four, which summarises findings from both primary and secondary research undertaken during this thesis.

Part Four

Part Four concludes the thesis with Chapters Nine and Ten, which consolidate the primary and secondary research data from the first three parts of the thesis.

Chapter Nine is the discussion chapter, which summarises the contributions of design and design thinking in play-based learning environments. It aims to bring the interconnectedness of design, design thinking, and play-based learning to the forefront of this thesis. This is then followed by Chapter Ten, which is the conclusion chapter.

Chapter Ten responds to the research questions posed at the beginning of this thesis, and contextualises the findings within the prevailing STEM and STEAM landscapes, where design thinking and design could be developed within a play-based learning approach. The chapter further evaluates the multimethod approach adopted during this thesis and reflects on the research methods of DE and RtD. It presents an overview of this thesis's contributions to knowledge, and proposes suggestions and recommendations to further help develop an understanding of play-based learning and its relation to design thinking and design.

Chapter Nine: Discussion

This chapter aims to synthesise and summarise all the findings from the primary and secondary research undertaken during this PhD. In so doing, it further aims to argue that design thinking, design, and play are historically intertwined in the pedagogic theories and materials of key theorists.

This chapter summarises the contributions of design thinking and design in play-based learning environments, following the structure presented in the first three parts of the thesis. It begins by revisiting the development of design in current and historical play-based learning environments first discussed in Part One and reveals its pervasiveness within both formal and informal learning spaces. It then revisits the re-reading of play pedagogues as design thinkers, arguing that their historical contributions towards an emergent language of play-based learning bear its roots in design thinking and design practice.

Next, this chapter revisits the research method of cross-cultural DE introduced in Part Two, which was embarked upon to uncover design localisms, design gaps, and design opportunities within the Montessori method. This chapter then revisits Part Three and the practice-based research method of RtD, which was initiated to engage in iterative and exploratory research through the design of play workshops. Finally, the chapter summarises findings from the primary and secondary research to bring the interconnectedness of design, design thinking, and play-based learning to the forefront of this thesis. This further helps respond to the research questions and contributions to knowledge, which are then presented in Chapter Ten.

9.1 Part One

Part One (Chapters One and Two) explored the evolution and potentiality of design thinking and design in the conceptualisation of historical and current play-based learning environments. As discussed in Chapter One, design thinking (Brown and Kātz, 2009) is a process of invention, intervention, and development of ideas through playful and heterogeneous modes and materials. Play-based learning, in itself, endorses the design of artefacts, parameters, structures, and restrictions to help create joyous interactions and avenues for learning. In this way, design thinking, design, and play-based learning share a common intention of incepting materials, spaces, resources, and structures to support the pedagogic needs of a child through playful and joyous interactions.

In Chapter Two, key pedagogues were re-read as design-thinkers in order to argue that design thinking and design have historically been central to both play and learning environments. Re-reading their historical approaches revealed design's centrality to the evolution of play-based pedagogy and practices, which has bolstered, directed, and influenced the design of current play-based learning environments.

9.1.1 Fröbel's design perspectives

As discussed in Chapter Two, Fröbel's Gifts and Occupations are designed as modular, colourful, and elemental play materials that afford physical (tactile) and conceptual exploration, ideation, and multiple configurations. These materials are designed to encourage inquiry and problem-solving through two-dimensional and three-dimensional constructions, which eventually supports the acquisition of abstract concepts such as counting, arithmetic, and geometry (Zuckermann, 2010). By means of abstract representation, Fröbel's pedagogic materials encourage an iterative exploration of relationships and affordances, through both form and materiality.

As a design thinker, Fröbel provides physical variables (Gifts and Occupations) and an exploratory approach to play that is in line with Nicholson's (1972/2009) theory of loose parts. Through modular aesthetics, multiple interactions, and abstraction, Fröbel's materials develop designerly perspectives of reflective self-activity (Brosterman and Togashi, 1997). In Fröbel's kindergarten, the teacher or facilitator occupies the role of a guide instead of an instructor. As a design thinker, Fröbel extends a world of play that privileges adaptable and flexible learning environments, which, in turn, sustain design thinking and creative pedagogical practices.

9.1.2 Vygotsky's design perspectives

As argued in Chapter Two, Vygotsky as a design thinker endorses the design of adaptable learning environments, which promote imaginative play and transitory learning stages, and embody scaffolding to help learners achieve their learning goals based on their competence.

Imaginative play supports children's engagement with narratives through (1) conceptualising an imaginary situation, (2) adopting roles, (3) engaging in exploratory object and symbolic play, and (4) reflectively communicating thought processes and ideas to play partners using words and gestures. Imaginative play introduces children to objects, play spaces, facilitation frameworks, and play structures that are designed to support symbolic representation of objects and self-regulation. Vygotsky as a design thinker argues that these characteristics make imaginative play a suitable activity to instigate language and cognitive development in children.

As a design thinker, Vygotsky (1978) supports play-based learning environments designed to adopt transitory learning stages (ZPD). According to Vygotsky, scaffolding structures that are designed based on observation and knowledge of children's competencies help them develop agency and independent interactions. This, in turn, supports internalisation of knowledge.

It can be argued that Vygotskian design perspectives on imaginative play, transitory learning stages, symbolic play, exploratory object play, and informed scaffolding structures support the design of materials, interactions, and facilitation frameworks that are flexible, child-centred, and adaptable. These, in turn, support design thinking through creative pedagogical practices.

9.1.3 Dewey's design perspectives

As discussed in Chapter Two, Dewey as a design thinker endorses inquiry-based and iterative learning environments that dissuade structuralist and predetermined approaches to play-based learning. Dewey implicates design thinking as a pragmatist platform that integrates experiential, hands-on learning that is backed by trusting the teacher's knowledge to nurture inquiry. Dewey as a design thinker endorses pragmatist education, where experiential learning takes precedence over theory, and knowledge is acquired through active interaction with objects and spaces (Dalsgaard, 2014).

While focusing on education curricula designed to be child-centred, Dewey as a design thinker further endorses experimentation as an essential affordance of play-based learning environments. Here, Dewey argues that play-based learning environments should incorporate experimentation and exploratory play as they help evaluate potential situations and act as catalysts for knowledge acquisition. However, unlike Fröbel, who endorses open-ended play, Dewey as a design thinker justifies purposeful play and experimentation as educational, where play artefacts, activities, and curricula are based on children's insights, and grow out of their existing knowledge and experiences.

Hence, it can be argued that Deweyan design perspectives on purposeful play, active object play, experimentation, and exploratory play underpin the design of child-centred and pragmatic play-based learning environments.

Fröbel, Vygotsky, and Dewey's design contributions on play can be read alongside Nicholson's theory of (1972/2009) loose parts since all of them insist on providing children with tangible and intangible variables in their play environment, which support inventiveness, agency, creativity, and discovery. These, in turn, endorse design thinking and creative pedagogy through affordances such as iteration, tinkering, and experimenting with play materials and interactions.

9.2 Part Two

In Part Two of this thesis (Chapters Three to Five), cross-cultural DE was introduced as an observation-based research method, which focused on examining Montessori's designed materials, spaces, and systems in-situ. Cross-cultural DE was undertaken at Montessori schools in Scotland and India to support the study of the method's localised practices and culturally influenced interactions. This helped to comprehend the contributions of design thinking and design in the Montessori curriculum. Chapter Four presented DE through on-site vignettes and notes. This was followed by Chapter Five, which presented an analysis of the DE fieldwork.

The following section expands on DE findings from language acquisition sessions as observed on-site during DE, which pinpoint play activities designed to encourage creative pedagogical practices and design thinking in the Montessori method.

9.2.1 Design thinking: Language acquisition in the Montessori method

DE fieldwork revealed that Montessori's language materials are interacted with in a multi-sensory capacity. Activities designed for language materials such as Sandpaper Alphabet Tiles, Large Movable Alphabets, and Semolina and Sand Trays afforded the engagement of children's visual, tactile, stereognostic[81], and auditory senses. Although Montessori's sensorial materials are designed to focus on only one sense at a time (based on her theoretical framework[82]), during DE, I observed that most of Montessori's language materials afforded training multiple senses simultaneously, where children would interact with language materials physically (tactile and haptic feedback through physical contact), listen to the pronunciations, engage with the visual form and shape of the language materials through hands-on object play, and simultaneously memorise the visual form of the alphabets.

Observing language activities at M.S.2.0 and M.S.3.0 demonstrated that language materials for multiple Indian languages were designed using the same design principles and aesthetics as the materials for English.

A multi-sensorial atelier of materials and activities was designed to support language acquisition. Affordances of haptic and tactile interactions were designed by collectively employing textured materials (use of sandpaper, use of semolina and sand in trays, wooden and plastic alphabet cut-outs) to help a child remember and recollect the visual form of an alphabet. Sensorial play was designed through playful interactions with different materials by integrating kinaesthetic gestures and object play (for example, running fingertips on Sandpaper Alphabet Tiles, and replaying the same hand movement on sand or semolina trays to continuously train a child's muscle memory).

While DE findings from the observations of her language activities showcased the design of multi-sensorial activities, exploratory object play, gestural learning, and social play, Chapters Four and Five also revealed vignettes of constrained, ceremonial, instructional, and didactic activities that did not support child-led and iterative learning processes. DE fieldwork from Chapters Four and Five demonstrated that, often, children purposely *hacked* or reinterpreted Montessori's *ceremonial guided play* format, characterised by *shepherding* and *helicopter facilitation* by teachers, to engage in intuitive, iterative, and

81 Haptic
82 Refer to the section on the Montessori method in Chapter Two.

exploratory interaction with her sensorial materials. Here, it could be argued that, while her method dissuades non-prescriptive play and intuitive interactions, children themselves appropriated (Flint, 2016) affordances of exploration, iteration, and hacking regarding some of Montessori's sensorial materials and activities.

As discussed in Chapter Five, analysing on-site DE data illustrates that Montessori's rich, yet restrictive, design language can be broadened to accommodate twenty-first century literacy skills (Yakman, 2008, 2010). As the Montessori method inherently focuses on developing mathematical, art, and science skills (which are key to STEAM learning), it is plausible for Montessori and STEAM environments to share a design language grounded in active and iterative play-based learning.

9.2.2 Reading the Montessori method alongside Fröbel, Dewey, and Vygotsky's design perspectives

Fröbel and Montessori designed to respond to the needs of the children rather than the educational system of that time, keeping their users (children) central to their iterative process. Through constant iteration and redesign of play resources (design of sensorial materials, play artefacts, and play spaces), play facilitation (design of facilitation techniques based on analysis of observed behaviour), and play processes (prescribed activities, frameworks), both of them engaged in extensive design thinking.

Both Fröbel and Montessori designed play-based approaches to learning that not only focused on the educational outcome, but also privileged the learning process. I argue that it was their close attention to the processes of learning and the material affordances of multi-sensorial interactions that gave Fröbel and Montessori their sensitivity to educational objects and the social and inter-subjective capacity of play. However, while Fröbel designed for open-ended and exploratory play (which were also encapsulated as affordances in the design of the play activities for Gifts and Occupations), the Montessori method endorses a prescriptive and predefined format of object play.

The Montessori method argues that precise interaction with her sensorial materials encourages a child to direct his/her attention towards a specific object, and learn by continuous and unmediated repetition of an activity, and eventual reflection of how that activity was conducted (Zuckerman, 2010). However, when observed through the lens of design thinking, Montessori's prescriptive interactions, as documented during my DE, showcased that these mimetic and helicopter facilitated interactions were counterproductive to experimental and exploratory play with her sensorial materials.

While the Montessori method supports Deweyan design principles of hands-on learning and object play, it does not support iterative play, interventions, experimentation, and exploratory play. Both Montessorian and Deweyan design principles provide children with variables in their play environment (in line with Nicholson's (1972/2009) theory of loose parts). However, the Montessori method has designed a prescriptive frame of constrained interactions and object play around her sensorial materials through ceremonial guided play, shepherding, and helicopter facilitation, which inhibit inventiveness, creativity, and discovery.

When compared to Vygotskian design principles, the Montessori method has a specifically designed scaffolding framework to guide facilitation of play activities in the curriculum. However, while Vygotskian design principles support design thinking and creative pedagogical practices through imaginative play, symbolic play, exploratory object play, and flexible and adaptable scaffolding structures that consider a child's competencies and interests, the Montessori method leans on prescriptive and instructional *play-adjacent (rather than playful)* activities, which are not iterative, flexible, and experimental.

9.3 Part Three

In order to further explore possibilities of integrating certain affordances of the Montessori method with twenty-first century literacies of STEAM learning, Part Three (Chapters Six to Eight) of this thesis introduced the practice-based research method of RtD, which was chosen to engage in iterative and exploratory research through the design of play workshops. Chapter Seven presented on-site accounts of POP workshops designed to undertake RtD through diary narratives. These workshops were designed to integrate affordances such as tinkering, dynamic play, interventions, and iterations in a flexible and exploratory format of play-based learning, which, in turn, supports RtD and design thinking

According to Ibes and Ng (2011), when engineering is integrated with a Montessori activity, it *springs to life.* By this, the authors (ibid) propose the potential of the Montessori method to open its prescriptive frameworks and animate engineering education. Conversely, this could also refer to engineering and its relative design language's capacity to animate Montessori activities and materials. The authors (ibid) argue that this cross-pollination of both the learning frameworks paves the way for more critical engagement, inquiry, and influx of new content, as well as activities to explore that content. In this thesis, as a means of integrating Montessori with STEAM themes, *automata* and movable mechanisms were identified as suitable design idioms to support the design of a workshop premise and automata atelier.

Play-tutoring for POP workshops was inspired by Montessori's prepared environments and presentation time format, where play materials were displayed in a manner that afforded independent choice and selection by the workshop participants. However, instead of engaging in instructional and ceremonial presentation of play materials as observed during DE, the play workshops were designed to encourage flexible and exploratory material interactions.

Unlike the Montessori learning environment, play materials for these play workshops were cheap, readily available, and designed to be replaced, hacked, and altered. These design measures supported Nicholson's (1972/2009) theory of loose parts since the workshops presented a wide selection of tangible variables (such as geometric shapes, art materials, mechanical prototypes to play with) and intangible variables (such as automata as a design idiom, story-telling, and narratives), all of which incentivised children to engage in experimentation, iteration, and discovery while having fun.

9.3.1 Iteration and tinkering to support design thinking

As seen in Chapter Seven, diary narratives from the POP workshops demonstrated the ways in which children engaged in tinkering and iterations while building automata mechanisms. Participants were encouraged to engage in symbolic and imaginative play by designing narratives and stories to support their designed mechanisms. The workshops endorsed Vygotskian design principles, where imaginative play encouraged the participants to symbolically represent their design artefacts (here, automata) through supporting plots and narratives. These, in turn, contributed to collective meaning-making and encouraged creativity (Marsh et al., 2019).

Workshops were *designed as a research method* to support both collaborative and individual play, where the choice rested with the participants. Participants were encouraged to ask questions, engage in a dialogue, and challenge the workshop premise. Unlike the Montessori method's prescriptive learning process, where divergence was discouraged, these workshops revealed that finding new ways of designing an automaton, and engaging in trial and error, produced purposeful play materials. These redesigned play materials addressed the pain-points identified by the participants and optimised the automata construction process by making it easier, quicker, and more playful.

These instances of purposeful play through trial and error, active object play, experimentation, and redesign of materials supported Deweyan design perspectives of pragmatist play-based learning. The replaceability and low cost of the automata atelier further supported tinkering and iterative play, where there was no constraint of *careful use of materials* that would inhibit exploration through rearrangement, trial and error, and even destruction of prototypes.

As discussed in Chapter One, while elaborating on the concept of valued objects in play, Pellegrini and Jones (1994) argue that children exhibit high levels of competence and complex play when they interact with valued toys and with peers/adults as they are motivated to maintain play. As observed during the POP workshops, participants displayed high levels of engagement and motivation while constructing automata, which leads to the proposition that the play-tutoring format designed for the POP workshops also afforded high value and sustained play. Since the reward at the end of the workshop was a dynamic and playful prototype that was constructed by the participants and could be taken back home by them, there was a sense of responsibility and ownership, which further motivated them to engage in the play workshops.

9.3.2 Participatory co-design and reflection

Brereton and Buur (2008) argue in favour of re-reading participatory design tools in order to contribute to the grey innovative area between design and use. While the authors (ibid) refer to developing digital prototypes and engaging in cause-effect feedback through participatory design, the same principle could be applied to the design of participatory play workshops. The POP workshops were designed to support Brereton and Buur's (2008) endorsement of participatory and exploratory formats of engagement with participants. The play workshops further supported Brereton and Buur's (2008) argument of providing the design researcher the agility and freedom to encourage iterative and experimental design explorations with the automata construction to gain better comprehension of individual interactions within the context of a specific workshop premise. This also maintained transparency between the participants and the researcher, as we collectively participated in identifying challenges and pain-points while building the automata and interacting with the automata atelier.

Table 9: Visualising design affordances in the Montessori method and the POP workshops

The Montessori method	**Montessori -Design affordances**	**POP workshops**	**CLEs - Design affordances**
Classification of objects focuses on pre-defined sensory attributes.	One object is designed for one sense. Design of restrictive affordances. For example: The Pink Tower is designed to train the visual sense.	Classification of objects focuses on meaning and purpose.	Objects can be interchanged, replaced, and redesigned based on context.
Objects are designed for self-correction.	Design of constrained affordances, which sometimes disallow open-ended exploration. For example: Knobbed Cylinders are not designed to be stacked. They are only designed to be picked up and placed in their correct boxes.	Objects are not designed for self-correction. Activities rely on exploring objects to identify their *appropriate* affordances.	Encourages experimental play and exploration of materials and interactions.
Facilitators discourage 'non-Montessorian' exploration of sensorial materials.	Unidirectional and prescriptive design. Facilitators engage in helicopter facilitation to dissuade exploration.	Facilitators do not discourage wrong answers.	The format encourages multi-directional learning through exploratory and interventionist play.
Emphasis on individual work	Facilitation frameworks are designed to afford	Emphasis on cooperative and	Scaffolding frameworks are

and focus on the importance of personal choice.	individual interactions with sensorial materials.	collaborative learning.	designed to afford both individual and social play.
Materials and activities are designed for repetitive interactions.	Mimetic activities of play. Encourages shepherding.	Materials and play activities afford questioning and challenges.	Encourages contingency and thinking of multiple scenarios to solve a problem.
Rich repository of singular designed affordances in the objects and tools.	Restrictive and repetitive frameworks of play.	Interchangeable and appropriated affordances based on use of preferred tools and objects.	Encourages subjective use of materials. Nothing is fundamentally pre-set.
Outcome oriented play-inspired learning.	Pre-formulated outcomes. Not designed to be challenged.	Process-oriented, playful, and experimental learning.	Encourages multiple ways of engaging and interacting with play materials.
Materials hold higher ground in terms of power, and need to be protected from wear and tear. "Materials or play-objects are precious and need to be interacted with carefully."	Designed for "careful play".	Even the risk of destruction of the materials or play objects is encouraged during the learning process.	Materials are immaterial and can be replaced. The learning process holds higher ground.
Children are encouraged to engage in step-by-step, sequential, and prescriptive interactions with predesigned sensorial tools to acquire knowledge.	Knowledge acquisition by imitation and prescriptive learning.	Children are encouraged to build their own cognitive tools and processes to acquire knowledge.	Encourages knowledge acquisition by construction and tinkering with various tools.

9.4 Chapter summary

Based on the findings and discussions presented in this chapter, it can be argued that, while the setting of the play-based learning environments and the educational structures within which they reside (either formal or informal) is crucial, *play materials and interactions themselves are proponents of play, thanks to their affordances*. Observing the POP workshop environment through the lens of design demonstrates that these informal play-settings support the rapid testing of ideas and tools, which would normally not be possible in school-based environments.

Setting formal, play-based learning environments within CLEs or similar educational spaces (such as museums, galleries, science centres, and so on), where the primary environments of display are likely to influence each other, may need greater exploration. A similar concept occurs when dedicated artists and designers occupy a status of residence at museums and galleries, and spend time engaging with audiences through creative practice. An example of an environment that has taken this approach is at Tel Aviv University, which recently set up a student design lab in the museum. A similar setup is being explored by the International school of Billund and the LEGO Foundation, where the LEGO House has designed lessons for school classes from grades 1 to 6. The LEGO House is a learning space in Billund that has been architecturally designed to embody a playful learning approach. The LEGO House is divided into four colour-coded zones, where each zone has adopted a playful learning approach inspired from Danish learning objectives. Here, all the lessons are based on LEGO's Learning through Play philosophy.

The LEGO House and the LEGO Foundation are working towards developing multi-disciplinary research partnerships with academic and industry experts, parents, caregivers, school systems, institutions, and governments to explore the benefits of play. Their work focuses on engaging in collaborative design thinking by identifying, testing, and developing play artefacts, play spaces, play structures, and play programmes, and sharing their findings and research across various media and academic platforms. The foundation's current focus extends to the future of play, play and objects, the potential social capital of children, and global dialogues on learning. These focus areas again bring to attention the affiliation and inseparability of design and play

This chapter has summarised findings from the primary and secondary research undertaken during this thesis. Summarising the design principles of Fröbel, Montessori, Dewey, and Vygotsky, and reading them alongside the research findings from DE and RtD, illuminates the ways in which design has been integral to the actions, identities, symbols, and spaces of play, both historically and within contemporary learning environments of Montessori schools and current CLEs.

The next and final chapter aims to draw conclusions to the thesis by revisiting the research questions presented at the beginning of this thesis.

Chapter Ten: Conclusion

In order to identify the significance and implications of the research findings, the aim of this final chapter is to return to the founding research questions, and to consider the findings of both primary and secondary research:

1. What are the contributions of design thinking and design to play-based learning environments?
2. In what ways has the design language of play evolved, from its emergence in historical learning environments to the current landscape of twenty-first century education?
3. How can design thinking and design support play-based learning's migration beyond the scope of formal classroom environments, in the twenty-first century?

This chapter begins by considering the benefits and implications of re-reading historical play pedagogues as designers and design thinkers. In so doing, it aims to reveal how these theorists have shaped the evolution of play-based learning through the design of tangible artefacts, spaces, and structures, and intangible facilitation frameworks and play formats. The argument that follows is that *design-thinking has historically been at the heart of play-based learning*.

By reflecting on the findings of DE, RtD, and, in particular, the restrictive pedagogy of the Montessori method, this chapter outlines how Montessori's now global, play-based curriculum is counterproductive to learning through intuitive processes of exploration and iteration. The chapter considers the counter to this restrictive approach to play-based learning as that which lies in the affordances of tinkering and iteration. As this chapter will argue, the research will be of interest to not only designers, but also a wide range of actors such as pedagogues, museum curators, and policy makers, each of whom contribute to where, what, and how children are taught.

Before making its final concluding points, the chapter considers the benefits of adopting a multimethod research approach (Morse, 2003) through DE and RtD. It also reflects on the shortcomings and limitations of these methods. This chapter concludes by presenting recommendations and future possibilities to develop research on the intersection of design and play, which aims to enrich the current landscape of play-based learning.

1. What are the contributions of design thinking and design to play-based learning environments?

Design research adopts human-centred traits that allow it to sit across many boundaries. Design thinking and design endorse invention, intervention, creativity, exploration, experimentation, and development of ideas through playful and expansive means. Play, as an intrinsically motivated activity (Huizinga, 1955), also requires tools, devices, parameters, and restrictions and an imagination to overcome them, in order to support development of new skills, and design joyous interactions and vehicles for learning for children. Hence, a coupling of design and play is inevitable in the creation of adaptable and flexible play-based learning environments that support the pedagogic needs of a child.

Design and design thinking as exploratory and adaptive models have contributed to play-based learning environments through the conceptualisation of physical, symbolic, and discursive artefacts such as (1) constructing models and prototypes, (2) reciprocity between criteria and constraints for design challenges, (3) communicating through verbal, written, and symbolic discussions, (4) providing diverse opportunities to facilitate learning, and (5) encouraging different perspectives to problem-solving and meaning-making, all of which help foster the creation, allocation, and assessment of knowledge (Kelly and Cunningham, 2017; Li et al., 2019; Marsh et al., 2019).

2. In what ways has the design language of play evolved, from its emergence in historical learning environments to the current landscape of twenty-first century education?

The historical design language of play focused on interactions with pre-designed pedagogic play materials that were elementary, modular, and definitive. Historical play materials afforded training of specific senses, and were presented in distinct play environments and educational structures. As demonstrated through the fieldwork undertaken during this thesis, the design language of play has shifted from predesigned and predefined play materials and environments of the twentieth century, to experimental platforms and formats of the twenty-first century, which embody design thinking through affordances such as tinkering, dynamic play, hacking, iteration, and exploration (Litts, 2015; Cochrane and Antonczak, 2015; Resnick, 2017; Li et al., 2019; Marsh et al., 2019). The twenty-first century educational landscape of play-based learning identifies STEM and STEAM as interdisciplinary silos that support thematic and panoramic learning. These offer opportunities for inquiry-based and learner-driven knowledge comprehension by adopting both traditional tools and new technology to support twenty-first century literacies (Yakman, 2008, 2010) such as tinkering, prototyping, inquiry-based learning, iteration, and experimentation. In this way, design-enriched play has become a twenty-first-century language of literacy.

3. How can design thinking and design support play-based learning's migration beyond the scope of formal classroom environments, in the twenty-first century?

Twenty-first century literacies (Yakman, 2008, 2010) such as tinkering, prototyping, inquiry-based learning, iteration, and experimentation propose the design of flexible and adaptable play-based learning environments. These design-enriched twenty-first century play environments can provide a multitude of intangible and tangible variables to support inventiveness, creativity, and discovery in children which, in turn, support design thinking and creative pedagogical practices.

As explored through the fieldwork undertaken during this thesis, in order to explore new and innovative learning formats that support the design and testing of experimental play materials and facilitation frameworks, the learning environment must embody exploratory investigations of the material and social world (Nicholson, 1972/2009; Martin and Dixon, 2013; Martinez and Stager, 2013; Bevan et al., 2014). Litts (2015) refers to the maker movement as a good example of an exploratory, play-based learning environment that is fundamentally altering the way educators and educational researchers envision teaching and learning by moving beyond the scope of formal-learning school environments.

Unlike learning undertaken in formal school environments, which functions within a specific pedagogic framework and curriculum usually defined by the state, play-based learning at CLEs such as museums, maker spaces, public galleries, and tinker studios exceeds simple acquisition of facts and knowledge. Instead, it navigates towards play-based interactions with objects in different settings that embed knowledge acquisition through participation in hands-on, iterative, and experiential learning (Wöhrer and Harrasser, 2011; Andre et al., 2017).

Design thinking and design as exploratory and adaptive models support the migration of play-based learning beyond the scope of formal classrooms, by incepting experimental learning platforms. These platforms offer opportunities to identify issues, ideate concepts, design possible variables (ranging from play materials, play spaces, and activities, to facilitation frameworks), and rapidly test them. Here, variables are designed to adopt affordances of design thinking such as tinkering, dynamic play, hacking, iteration, and exploration. In such setups, tangible variables such as play materials, which are deployed to engage in play-based learning, are typically low-cost, thrifty, replicable, easily sourced, and support these affordances of design thinking. Other intangible variables, such as play activities and facilitation frameworks, are designed to be flexible, adaptable, and cater to the needs of the child to incentivise them to engage in play-based learning.

10.1 Contributions to knowledge: Key pedagogues as design thinkers

This thesis has re-read key play pedagogues as design thinkers and identified their perspectives that recognise play materials and facilitation, or interaction frameworks, as proponents of play, based on their designed affordances and educational structures (formal or informal). This thesis has then perused these design perspectives whilst parallelly undertaking primary research during DE and RtD to identify their contributions to an emergent language of play-based learning that supports design thinking.

Fröbelian design perspectives guide play-based learning in the twenty-first century by embedding design and design thinking through:

- Play materials designed for *self-activity*, which have modular aesthetics and afford multiple interactions, abstraction, and child-led object play.
- Facilitation and interaction frameworks designed to afford reflexive practices, flexibility, child-directed play activities, open-ended play, and exploratory play.

Montessorian design perspectives guide play-based learning in the twenty-first century by embedding design thinking and design through:

- Play materials and environments designed to afford prescriptive and step-by-step interactions, mimetic play, sensorial learning, and training of motor skills using a progressive logic of exploring muscle movement and gestural learning.
- Facilitation and interaction frameworks designed to afford guided play, multi-sensorial object interactions, and kinaesthetic learning.

However, in the context of this thesis, Montessorian design perspectives such as prescriptive interactions and mimetic play, as well as newly formulated affordances of her design language (based on on-site DE research) such as ceremonialism, shepherding, and helicopter facilitation are viewed as counter-intuitive, structuralist, and limiting to play-based learning in the twenty-first century since they design intuition, exploration, discovery, iteration, and inquiry-based learning out of play-based learning experience.

Vygotskian design perspectives guide play-based learning in the twenty-first century by embedding design thinking and design through:

- Play materials designed to afford symbolic, imaginative, and exploratory object play.
- Facilitation and interaction frameworks designed to afford transitory learning through staggered stages of interaction that support flexible, social, and adaptable scaffolding structures.

Deweyan design perspectives guide play-based learning in the twenty-first century by embedding design thinking and design through:

- Play materials designed to afford active object interactions, experimentation, and iteration through tinkering and hacking.
- Facilitation frameworks designed to afford purposeful play and pragmatist learning through child-centred play and hands-on learning.

Identifying these design perspectives and analysing them across the findings uncovered from DE and RtD helped document precedence, occasions, and structures in play-based learning environments where design and design thinking were covertly present and highlighting them. Re-reading Fröbel, Montessori, Dewey, and Vygotsky's historical play pedagogies through the lens of design thinking and design through the study of their play artefacts, structures, materiality, and interactions helped bring design to the forefront in their work.

In the current and future landscape of play-based learning, especially with regards to informal CLEs, it will not only be professional educators that are designing for education. Designers are increasingly getting involved in examining, intervening, disrupting, reframing, and enriching play-based learning environments.

Identifying Fröbel, Montessori, Dewey, and Vygotsky as design thinkers has been undertaken to make them and their theories more visible to the design community by consolidating their explicit design perspectives. These perspectives have been presented as contributions to knowledge through this thesis in the hopes of providing guidelines and valuable mindsets to designers, as they examine the cause-effect relationship of design and play, and consider approaches and interventions while designing for future educational landscapes.

10.2 Reflecting on the fieldwork: Design at the heart of play-based learning

On-site DE fieldwork from Part Two of this thesis demonstrated that, despite being portrayed as a progressive design system of play-based learning when incepted in the early twentieth century, the Montessori method in the current landscape of twenty-first century education appears rigid and dated. It is designed to warrant that activities are undertaken in a non-critical capacity. On-site DE observations suggest that the Montessori method is rooted in an approach that is designed to control actions and behaviours, and is devoid of free-thought, and hence experimentation, iteration, and discovery. Merely engaging in predefined object interaction designs intuitive learning and creativity out of the curriculum.

Analysis of on-site DE data presents the argument that Montessori's emphasis on the design of multi-sensorial learning tools reveals her process as well as her materials to be a rich repository of experiential design in learning environments. With attention to the multi-sensorial aspects of design and learning outcomes, her method highlights the effects and preferences of using certain materials while designing specific tools. Her holistic approach to design for learning follows a progressive logic of exploring muscle movement in writing and creating props that mimic real objects (for example, button and cloth frames designed to mimic the act of unfastening a button). The discussion about her language materials and her designed measures demonstrates that Montessori's design language constitutes an amalgamation of distinct design affordances, which can be extracted, redesigned, integrated, and iterated to conceptualise rich, holistic, and experiential artefacts and systems that support design thinking and creative play-based pedagogical practices.

Theoretically, the Montessori method argues that children learn most effectively when their surrounding environment aids their natural desire to learn. However, the method itself needs to evolve and expand to accommodate twenty-first century literacies (Yakman, 2008, 2010) such as tinkering, prototyping, inquiry-based learning, iteration, and experimentation. A modernised version of the Montessori method, which is designed to be more flexible, dynamic, evolutionary, and exploratory, is a promising play-based learning environment. It can cater to the educational needs of the twenty-first century child, as well as support design thinking and creative play-based pedagogical practices.

Part Three of this thesis presented RtD as a practice-based research method, which allowed the testing of play materials in-situ at CLEs. RtD through play workshops was undertaken to counter the restrictive approach to play-based learning (as observed during DE at Montessori schools) through the designed affordances of tinkering and iteration.

Designing affordances of iteration and tinkering in the interactions with the workshop materials led to the participants engaging in intuitive play and focused problem-solving. These affordances also supported the redesign and evolution of play materials and techniques through participatory research and experimenting with an exploratory automata atelier. The facilitation framework designed for the POP workshops embraced multiple learning styles. It encouraged the participants to challenge the learning framework (designed by me) and explore other possibilities of constructing automata.

Resnick and Robinson (2017) argue that children differ from one another in the ways they learn and play; therefore, in order to aid knowledge acquisition in children, we need to design learning environments that support all types of play and learning styles. As observed during the POP workshops, the design affordances of tinkering, iteration, and exploratory play, along with a flexible facilitation framework, gave the children an opportunity to curate their learning trajectory.

Children must be given opportunities to engage in play-based learning in an integrated setup that affords literacies such as tinkering, prototyping, inquiry-based learning, iteration, and experimentation through a design thinking model (Brown and Kātz, 2009). This, in turn, supports a child-centred, insightful, flexible, and exploratory landscape of play-based learning to foster creative pedagogies and design thinking (Resnick and Robinson, 2017).

Resnick and Robinson (ibid) acknowledge that, over the past century, unlike the fields of agriculture, medicine, and manufacturing, which have undergone fundamental transformations by new technologies, unfortunately, the core structures and strategies of educational systems have remain largely unchanged, being stuck in a mindset aligned to the needs and process of an industrial society.

I concur with Resnick and Robinson (ibid) when they deliberate that there is hope as more CLEs such as museums, exploratory play spaces (The LEGO House) community centres, libraries, and policy makers (such as Inspiring Scotland[83]), along with formal play environments (such as the International School of Billund), are working together to provide children with opportunities to make, create, experiment, and explore new concepts. These evolutionary formats of play-based learning are forgoing traditional approaches of didactic learning and incorporating better strategies to equip children as creative thinkers to help survive in an ~~n~~ever evolving world.

10.3 Multimethod Design Thinking (MDT) research model:

This thesis has also developed a Multimethod Design Thinking (MDT) research model to support a multimethod research approach (Morse, 2003) in a design thinking (Brown and Kātz, 2009) framework (see Figure 83). By adopting two qualitative research methods of DE and RtD, the MDT research model was developed to transition from inductive to deductive research. Here, both DE and RtD supported observation and participative research practices to engage in a comprehensive study, which helped identify and determine design's role and contributions in play-based learning environments.

83 Inspiring Scotland has advocated for Nicholson's (1972) theory of loose parts in the following document, Play Strategy for Scotland: Our Vision. Inspiring Scotland has introduced it within a wider approach to develop free play at homes, schools, and in the community. Inspiring Scotland argues that the theory of loose parts is effective within a collaborative, inclusive, and rights-based approach that considers the needs of children and young people at every step. More information about this initiative can be accessed herehttps://www.inspiringscotland.org.uk/who-we-are/history/

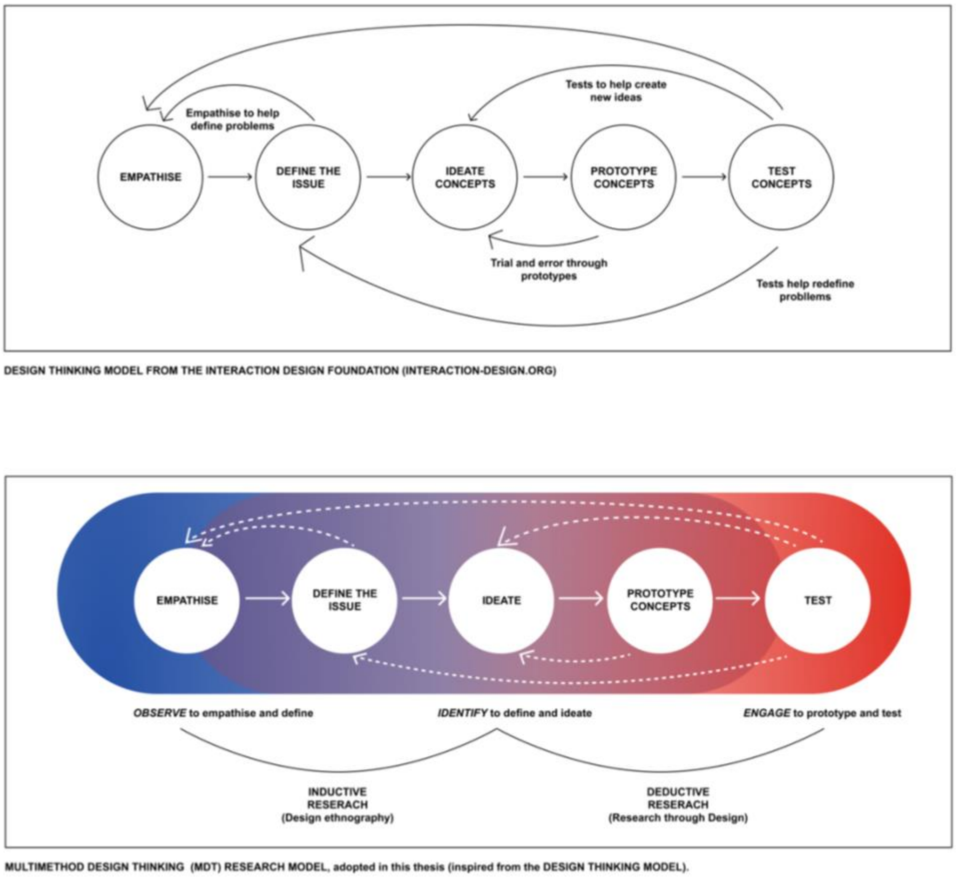

Figure 80: MDT research model developed during this thesis (inspired from the design thinking model (interaction-design.org)

As seen in Figure 84, inductive research undertaken through cross-cultural DE (design ethnography) supported observing Montessori schools in two countries and *discovering* local adaptations of Montessori's universalised curriculum. On-site DE fieldwork demonstrated how design thinking through affordances such as tinkering, dynamic play, hacking, iteration, and exploration (which, in turn, support agency and child-centred play activities) were designed out of the curriculum.

Here, design opportunities were *identified* to integrate affordances of the Montessori method with STEAM literacies such as tinkering, prototyping, and contextual inquiry to support design thinking. These opportunities were then translated and designed into participative play workshops to undertake RtD. RtD at informal CLEs, in turn, allowed me as the researcher to actively *engage* and participate in prototyping and testing the designed play materials in-situ with a predefined user group (children between the ages of eight to twelve years), and capture their rich insights through interactions and engagement with the play workshops.

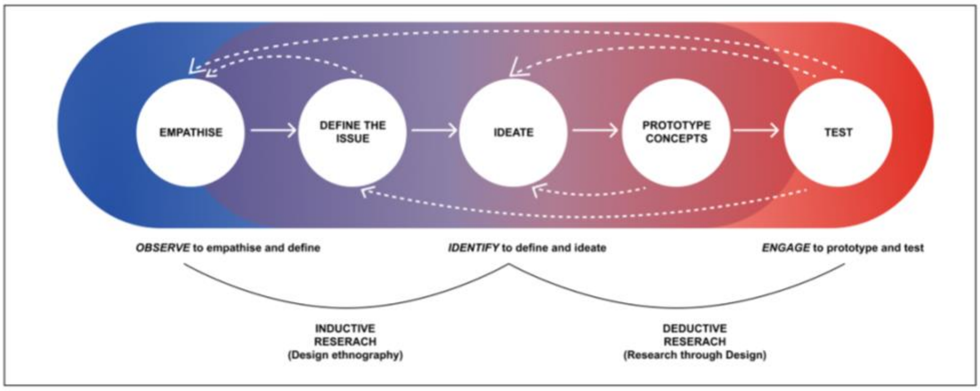

Figure 81: MDT research model

The MDT research model also allowed me to adopt multiple research positionalities, while engaging with the research methods as a designer. While engaging in cross-cultural DE, I was a non-intrusive design observer who could move from an assumed-inside researcher to assumed-outside researcher's position. Transitioning from DE to RtD led to an overhaul in my research positionality as I adopted the role of an active designer, who was also the facilitator, participant, inside researcher, outside researcher, and research instrument, while engaging in the play workshops.

10.3.1 Reflecting on the MDT research model and research methods

Any conclusions and recommendations derived from adopting the MDT research model through cross-cultural design ethnography (DE) and research through design (RtD), case studies, can only be generalised with caution due to the specificities of the research environments, limitations, and research framework. These findings and recommendations have emerged from access to limited sites within a specific time frame, and therefore have to be considered while acknowledging the limitations and obstacles encountered during this thesis.

While the MDT research model allowed me to undertake comprehensive research by assuming different positionalities as a designer within the constraints of this thesis, I only engaged in the first level of an iterative and exploratory design process. As seen in Figure 84, the dotted arrows in the MDT model visualise the back and forth between empathising, identification, ideation, prototyping, and testing of concepts. The design thinking model (Brown and Kātz, 2009) focuses on constant interaction between these stages, where, after testing a concept, a designer goes back to the drawing-board to iterate and modify ideas based on findings from on-site research.

This iterative and evolutionary model is based on the assumption that the designer has constant access to the research space and participant group in order to constantly test and modify their concepts. However, in the case of the MDT research model adopted in this thesis, I did not have continuous access to the research sites during DE and RtD. I was only able to engage in the first round of observation and identification of design opportunities at Montessori schools during DE, and design and test play materials inspired from on-site DE findings through play workshops during RtD. Due to limitations with the allotted time, resources, and access to the research sites, I wasn't able to engage in a constant iteration and testing of play materials. I couldn't organise play workshop sessions for a longer time frame, and then go back to the Montessori schools to discuss and critique my findings. Individual and logistical limitations of both the research methods constrained the research undertaken during this thesis.

10.3.1.a Design Ethnography (DE): Revisiting the method

As discussed in this thesis, cross-cultural DE was adopted to undertake an observation-based study of the Montessori method in-situ; specifically, the ways in which learning through play relates to artefacts, spaces, and systems. Here, on-site fieldwork hinged on observing children at certified Montessori school sites across the two countries.

At M.S.1.0 in Scotland and M.S.3.0 in India, I was given a very small window of 2-3 hours in the morning to conduct on-site fieldwork. As discussed in Chapter Four, I was allowed to be on-site at M.S.1.0 and M.S.3.0 for a limited timeframe. Both these sites insisted that allowing an outsider within the classrooms for an extended time frame might disturb the learning process.

Unfortunately, adhering to the restrictions imposed by both these sites affected the empirical data gathered during DE. Since I was never allowed to observe continuous engagement and interactions with the sensorial materials at these schools, and how children transitioned from one activity to another during the course of the school days, my comprehension and analysis of children's onsite behaviour was based on observations conducted within a limited time frame.

In comparison to the other two sites, fieldwork at M.S.2.0 in Bangalore was less restrictive as I was allowed to stay on-site for the entire school day. This was pertinent to observing the design and facilitation of all the activities the children engaged in regularly. By being on-site every day, I was able to systematically observe how often some activities were facilitated over the course of a week. Regular on-site fieldwork led to more nuanced and chronological observations, where I was also able to analyse how curricula were designed to canvas a range of themes; from mathematics, science, and language acquisition, to P.E., sensorial learning, and free play. It was also crucial to observe how children's interaction with the sensorial materials evolved as they transitioned from discovering a new material or concept at the beginning of a week to getting more acquainted with it by the end of a week.

DE was limited in terms of sample size, where I was only able to study three different Montessori Schools in two countries. Conducting DE research across more Montessori schools, both in Scotland and internationally, was outside the scope of this research project, given the limited time and resources available. Groundwork for this research method was also time-consuming, as various entities were involved and contacted for approval before commencing with the fieldwork.

It has to be considered that on-site data from this sample size only illustrates general characteristics of Montessori schools. It is crucial to recognise that, given the number of Montessori schools present across the globe, the findings from this sample size cannot be used to attest for the workings of all Montessori schools. Empirical data gathered from this sample size of three schools presents an introductory understanding of the Montessori method through the lens of design. By undertaking on-site DE at three Montessori schools, this thesis has identified the fundamental design language of the Montessori paradigm, along with its archetypical affordances, to help single out distinct opportunities within the curriculum to integrate twenty-first century literacies. If it would be possible to observe more Montessori schools across the globe, one can consider that these research findings could be further expanded, altered, and critiqued.

10.3.1.b RtD: Revisiting the method

As discussed in the previous chapters, CLEs were chosen as sites to conduct POP workshops. CLEs were an ideal informal learning environment to undertake iterative and improvisational practice-based research since there was no risk of interrupting children's state-mandated learning curriculum, as compared to schools. POP workshops were designed with playful, inquiry-based, iterative, and tinker-friendly activities which were voluntary and open to children from all over the world. The only limitations in terms of participants were that these workshops were designed for children between the ages of eight and twelve years and were facilitated in English.

As discussed earlier in this chapter, the MDT research model adopted during this thesis was limited to engaging in the first level of design thinking, where I was unable to engage in more rounds of iteration, testing of play-materials, and revisiting the play sites.

In the case of play workshops, since these were designed as short play sessions, I was unable to follow up on how the workshop participants might have continued with the play activities later. Due to the limited time and the drop-in feature of the play sessions, it was not possible to follow up on any eventual inquiries, findings, or challenges that the workshop participants might encounter if they chose to design their own automata in the future. There was also no way of gauging any impact and ramifications that these play sessions might have had on the overall geometrical and STEAM comprehension in children once they left the workshop.

Unlike regular play-based learning sessions at Montessori schools, where facilitators can document every activity and learning outcome of a child to examine their development, the POP workshops were designed to observe the learning outcomes observed only during the actual play sessions, through the use of feedback booklets.

It can therefore be argued that these POP workshops embodied the role of time-bound *taster play sessions*. The workshops were designed to encourage play-based learning through the affordances of design thinking such as tinkering and iteration, in an environment that encouraged scaffolding through exploratory, flexible, and participative learning.

RtD in this thesis, allowed for constant iteration and tinkering with the workshop premise to design a more intuitive and engaging format of play-based learning. Based on the findings and analysis of the method as discussed in Chapter Eight, it can be argued that undertaking these POP workshops for a longer timeframe, across other CLEs, might have led to further design iterations and evolution of the automata atelier and workshop premise. The current set of thirteen workshops was designed to only introduce a foundational concept of building automata mechanisms. These workshops, due to limited availability of time, resources, funding, and access to space, could not be designed to explore, for example, the evolution of building automata mechanisms, where children, after comprehending the basic mechanism, could proceed to build more complex or varied structures, and engage in further explorations with the automata atelier.

If given the opportunity to redesign the POP workshops, I would try to get access to a select sample size of participants and engage in a set of ongoing automata play sessions with them, where I would be able to observe their learning trajectory, and how familiarity and continuous interactions with the automata atelier might influence their engagement with the activity.

10.4 Recommendations

This research study is contextualised by shifting educational paradigms and the globalisation of educational platforms. While focusing on the triad of play, pedagogy, and design, an additional educational landscape of cultural learning environments (CLEs) comes into view. CLEs such as museums and public galleries extend the scope of play-based learning beyond formalised spaces of schools and bring into relief the predominance of design while incepting platforms, ateliers, and activities to initiate learning through play.

This thesis presents guidelines, mindsets, and perspectives on design and play-based learning that have been drawn up by undertaking a design thinking-led model of research in-situ. By observing, identifying, designing, and testing possibilities to enrich twenty-first century play-based learning environments, this thesis has consolidated and developed key design perspectives that support twenty-first century literacies.

Based on the summary of research findings uncovered from the MDT research model adopted in this thesis, along with the contributions to knowledge, the following recommendations have been identified, which are of value to designers, along with current pedagogues, educationists, and policy makers. Some of these recommendations are especially useful to designers, who are hoping to engage and contribute to twenty-first century play-based learning environments by designing interventions and approaches to facilitate play pursuits.

10.4.1 Embody tinkering, iteration, and hacking within the design of play-based learning frameworks

Resnick and Robinson (2017) argue that, in formal learning environments ranging from elementary school through university, courses in mathematics and science are traditionally designed to favour planners over tinkerers, which leads to a lot of children losing interest in these subjects eventually. Resnick (ibid) further argues that the issue lies with how these subjects are presented and taught, which leads to tinkerers being led to believe that these subjects aren't necessarily for them.

While discussing the design of play-based learning environments to support multiple learning styles, Resnick and Robinson (ibid) cite Turkle (1984) and Papert (1980), who formulated the term *epistemological pluralism* to highlight the importance of accepting, valuing, and supporting many different ways of knowing.

The POP workshops were designed to endorse Turkle's (1984) and Papert's (1980) conceptualisation of epistemological pluralism, where they encouraged multiple ways of engaging with the automata atelier and the workshop premise. It can also be argued that Turkle's (1984) and Papert's (1980) epistemological pluralism supports Nicholson's (1972/2009) loose parts, since it accounts for flexibility and adaptability of learning environments, to consider all kinds of learners.

Hence, within the current landscape of play-based learning, play-based activities and courses designed to afford accommodation of multiple learning styles of children from all backgrounds (Resnick and Robinson, 2017) are key to engaging and supporting different types of learners.

10.4.2 Design to embody agency of the learner

As observed collectively during DE and RtD, prepared environments and presentation time formats, when designed to afford agency and independence, often led to deep engagement and focused interactions by the learners.

To illustrate, the POP workshops were designed with a specific premise of constructing automata mechanisms with the help of an automata atelier. During the workshops, children were also taken through the entire automata atelier and presented with methods of constructing automata mechanisms. However, as they were given complete freedom to explore different ways of constructing automata, designing narratives, props, choosing movements, and taking complete control of their construction process, no two automata looked or functioned the same. Here, each participant explored the premise of automata constructions, and designed something unique based on their interests and preferences.

Another factor that afforded agency of the learner was that they owned their automata constructions, and could take them home and work on them later, which allowed them to think of future possibilities and other ways of designing new mechanisms based on the knowledge acquired during the POP workshops.

From a design perspective, it would be easier to design an activity with a concrete end goal, instead of providing opportunities for open-ended exploration and iteration, since that would require factoring in unforeseen outcomes and possibilities of not achieving a predefined outcome. However, play activities that are designed for prescriptive, instructional, and mimetic interactions, and that have a predefined outcome in sight, can lead to lost opportunities of children developing their own ideas and intuition.

This does not mean that play activities should be designed with no constraints, themes, or time frames. Instead, within the framework of engaging with specific materials or learning a new concept, activities should be designed to afford freedom, exploration, and a diversity of outcomes.

10.4.3 Design a thrifty and modestly prepared environment

As Montessori engaged in observation and iteration-based design research while designing her curriculum, her designed sensorial materials subscribe to a very meticulous design aesthetic. Consequently, Montessori's sensorial materials are expensive and only available with certified Montessori material manufacturers across the globe. Their high price value is embodied within their prescribed activities, as one of the cornerstones of the Montessori paradigm is protecting the sensorial materials from rough use, damage, and wear and tear.

STEAM learning at play-based environments such as the Tinkering Studio, on the other hand, focus on the using a variety of materials, ranging from thrifty, replicable, and easily sourced play materials such as paper, clay, wires, pipe cleaners, cardboard, and other bric-a-bracs to prototyping kits such as Makey-Makey and Arduino. Play materials that are designed to be less expensive, accessible, and replaceable afford more opportunities for exploratory and iterative play. Here, less value is given to the outcome, since the process of learning through tinkering, iteration, and exploration holds more significance and promotes agency in children.

I coined the phrase *material is immaterial* in play-based learning while facilitating the POP workshops, by which I advocate for the use of easily available and low-cost play materials to enrich play-based learning environments. This phrase has been coined in comparison to expensive sensorial materials as documented in the Montessori curriculum, which are designed to be exclusionary and restrictive, thereby making it more challenging to freely interact with them. This recommendation of low-cost and easily available play materials further supports Nicholson's (1972/2009) loose parts theory, since it recommends offering multiple physical and intangible variables to support flexible and iterative learning.

The Montessori method, due to its meticulous design language and design blueprint, presents opportunities for designers, playmakers, and pedagogues, who can study and refer to her vast repository of designed sensorial materials, and incept play materials that are thrifty, iterative, and low-cost, while keeping their sensorial affordances intact.

10.4.4 Design for dialogic exchange of ideas, feedback, and reflection

Designing for exploratory and iterative play is a metaphysical process because, as designers, we are in-charge of designing learning experiences for learners. A crucial characteristic of designing for iterative learning is receiving feedback and criticism. Contrary to the on-site fieldwork across Montessori schools, where material interactions were ceremonial, prescriptive, and monologist, the POP workshops were designed to encourage feedback, criticism, and a dialogic exchange of ideas.

As observed during the facilitation of POP workshops, feedback received from the participants was both objective and subjective, which gave the participants an opportunity to voice their concerns, confusions, and ideas. Objective feedback consisted of participants discussing concrete findings and problems encountered during the construction process such as "The cam follower is sliding away from the cams" or "This mechanism is not moving properly". As the objective feedback was focused on a specific issue that they wanted to address while building their automata, the participants would brainstorm and engage in focused tinkering to resolve these issues.

Subjective feedback, on the other hand, usually consisted of aesthetic observations and personal perceptions of the workshop premise such as "I want to use green craft paper to design leaves for my automata" or "I want to design props out of foam for my automata". Both these types of feedback afforded a dialogic exchange of ideas, reflection on the design process, receiving concrete comments or answers to address issues, and guidance while tinkering with the workshop materials. Getting live feedback from the participants also helped me as a facilitator. Here, I was constantly adjusting the automata atelier and engaging in design iterations with the play materials to make the process of automata construction less complex, and more intuitive and playful, for the participants.

As discussed earlier in Chapter Two, Vygotsky's theory of ZPD is useful to conceptualising play artefacts, spaces, and environments, where the play-based learning environment can be flexibly designed to afford social mediation or individual learning. In the case of POP workshops, both the participants and I were essaying the roles of an MKO or a capable peer, based on specific situations. In the case of the POP workshops, as I was designing play activities for participants, iteration and refinement of the automata atelier hinged on their critical feedback, and was crucial to incepting an engaging, enjoyable, and creative play-based learning experience.

Reflecting on the workshop premise was also crucial as it allowed participants to relate their learning experience to their understanding of the world. Some participants, as discussed in Chapter Eight, were able to associate automata to machines and mechanisms they encountered in their daily lives. This process of reflection helped them recognise the relationships between the play objects and their lived experience, thereby leading to new insights and ideas.

10.5 Future possibilities and routes for this research

By undertaking an MDT research approach to design experimental formats of play-based learning, this thesis has explored possibilities of engaging children in iterative and creative ways of knowledge acquisition. Through the discovery and examination of various contributions, implications, and affordances of design in play-based learning, this thesis has shared several design perspectives to help designers, pedagogues, play workers, and policy makers incept, design, and maintain playful learning experiences.

Learning and play are deeply complex. Rogers (2011), while reviewing play perspectives from the eighteenth century to the twenty-first century landscapes of early childhood research and practice, argues that play ideologies have outlasted the circumstances that incepted them, where multiple belief systems now co-exist with other paradoxical perspectives of play. Rogers (2011), while quoting Cannella and Viruru's (1997, p.124) articulation of "early childhood educators defending play as a sacred right of childhood to support children's wellbeing", argues that this type of sacred play has been institutionalised by early educators such as Fröbel and Montessori in the design of their sensorial materials and environments. Rogers (2011) further argues that some of these designed environments provided for children's play have remained unchanged in many aspects, when compared to the dramatic changes that have reshaped most societies.

Resnick and Robinson (2017) argue that, with our society transitioning from an industrial society to an information society, knowledge extracted from information is being viewed as a resource that is driving the economy. The authors (ibid) further suggest that, in order to meet the needs of a creative society, structural barriers around disciplines within the education system need to be broken down.

The authors (ibid) endorse the formation of a creative society, where, with people having to adapt to constant change, there are opportunities to develop young people as creative thinkers. They (ibid) argue that, in order to appropriate these opportunities, parents, teachers, designers, and policy makers need to come together and collaborate to help children develop their voices, explore ideas, and reflect on their learning.

As I write this chapter, the world is slowly emerging from a global pandemic and lockdown, which has drastically altered the educational landscape and brought to light the disparities and obstacles of current educational frameworks. With the rapid onset of COVID-19, closure of schools and public learning spaces has led to home-schooling and online learning tools becoming the new normal for the foreseeable future.

In a newspaper article with the Guardian, Paul Ramchandani, the LEGO professor of play at the University of Cambridge, has spoken in support of incorporating play-based learning within home-schooling and future educational landscapes that await a post-pandemic world (Ferguson, 2020). According to Ramchandani, didactic learning is not offering any long-term benefits. Instead, Ramchandani endorses play-based learning ~~through play~~ categories such as rough and tumble play, imaginative play, and unstructured play, all of which in their various capacities, promote design thinking, creativity, agency, and additionally support the physical, emotional, and developmental needs of the child (Ferguson, 2020).

The current notion of developing didactic approaches to support pedagogy appears to be at odds with the expectations of the connected and knowledge-intensive world as it exists today. Huq and Gilbert (2015) argue that now, more than ever, there is an increasing demand from parents, students, employers, and societies to cultivate capabilities that help deal with uncertainty, ambiguity, and volatility, which didactic learning cannot fulfil. As discussed earlier in this thesis, there has been a surge of interest in both the academic and socio-economic landscape to extrapolate design thinking's relationship to play, and the design of objects, spaces, and structures to transform learning environments. Government bodies, industries, and educational and research institutes are investing time and capital to better comprehend how play-based learning can enrich the current educational landscape and permeate both formal and informal learning spaces.

By endorsing a design-thinking mindset supported by flexible and adaptable facilitation frameworks, play-based learning must now be designed to aid the social and emotional development of children by equipping them with tools to engage in creative problem-solving and navigating uncharted territories. Now, more than ever, there is a need to *re-invent* the education wheel by focusing on the needs of the children, and ensuring that play-based learning doesn't become an anxious and grimly regimented process in a post-pandemic world.

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Appendix 1: List of toys and play zones at the Smart Play toy library

The toy library was segregated in multiple play *zones*. The following table documents the observations and inferences from the short DE pilot study at the toy library:

Zones of Play	Observation	Play materials
Messy play	This consisted of consisted of two short tables, where children could sit on floor mats laid out on either sides of these tables, and use those tables to paint, sketch and work on art/craft projects. Volunteers, play workers and adults accompanying the children, usually sat down with the kids to paint	Cut-outs of animals, geometrical shapes, pieces of paper, paint jars (with an anti-spill cover) and glitter were laid out on this table.
Sensory play	This section consisted of short tables with mats and small chairs placed on either of the sides arranged on the tables. Since the paint used to tint the modelling clay was not edible, volunteers at the toy library had to constantly watch children to ensure that they didn't accidentally ingest it. During my volunteer work with the library, I observed that there were days when this corner of the library was entirely ignored by the children, and other times, it was a place of constant activity. The sensory play corner often also became an area for messy play when the library was busy. Typically, if two or more children started to interact and play with the modelling clay, others would often others join in. If the children were extremely vocal and squealing with delight while playing with the modelling clay, other children would respond to this excitement and move to this section.	Modelling clay (made in-house using scented baby oil, white flour, water and non-toxic paint), rolling pins, cookie-cutters and other tools
Fantasy Play	Another section of the room was dedicated to *fantasy play*, where two model kitchen sets were arranged. One was a traditionally designed wooden kitchen set from IKEA and the other was a plastic kitchen set. The play plus volunteer staff switched the kitchen sets randomly, so that every week, children got to play with a different set. Often, children stood near the kitchen sets, and mimicked their mothers, by pretending to 'cook' food or make 'tea' for them. This space was always active as a play area and was never ignored by the children.	Kitchen sets
Auditory play	There was one family in particular, who always spent maximum time near the musical instruments. They had 2 children, ages four and	Musical instruments such as a toy piano, guitar,

	one. Their older child loved playing with the toy piano and guitar. Having observed him for a couple of sessions, even their younger child, who was just learning to stand and walk, started to interact more with rattles and bells rather than other toys, was more responsive to musical toys and the piano, and was always crawling near the older sibling, to play with rattles while he was on the piano.	drums and other musical toys in the library.
Block Play	During my time volunteering at the library, I observed that parents often encouraged children to play with *LEGO* and some of them would regularly join their children and build structures and abstract shapes out of these blocks.	*LEGO* and *mega blocks*
Ball Pit	Children preferred playing inside the ball pit and it was a very popular activity. They would often start throwing balls at each other across the room and jump between the ball pit and the tire seat. They found it amusing to throw balls at other people and would often do it more specially when told not to by their mothers.	Ball Pit
Train set and racetrack	These play spaces were extremely popular with the boys at the library. Most kids would start racing with their cars across the library, often causing some noise and disturbing the younger children with the chaos of racing cars. This behaviour was constantly discouraged in the library and parents would be asked to intervene to dissuade the children from racing in the room.	Train set and a racetrack for cars.

Appendix 2: Design ethnography paperwork

The following documents were submitted to the Research Ethics Committee at Edinburgh Napier University, to get permission to undertake ethnographic research.

- Consent form – Parents
- Consent form – Montessori teachers and Facilitators
- Consent form – Children and young people
- DE Ethics form

Consent form – Parents

Edinburgh Napier University Research Consent Form – Parents

RESEARCH TOPIC: POTENTIALITY OF PLAY

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. In this project, the consent of parents/ guardians of children participating in the research is mandatory before starting onsite observation research. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to allow my child to be a participant in the research project based on studying the potential of play-based learning curriculums at Montessori Schools, through observation research. Pankhuri Sanjay Jain, a PhD. student at the School of Arts and Creative Industries at Edinburgh Napier University, will conduct this research.
2. The broad goal of this research study is to explore ways in which design of spaces, toys and learning tools is implicated in playful learning processes. Specifically, I have been asked to allow the researcher to observe my child and his/her colleagues study while their normal classes are conducted during regular school hours; where the researcher will sit in the classroom, silently observing and writing notes. This should take no longer than a month to complete, with the researcher coming into the classroom once or twice a week. Consent of the school administrative in-charge, parents of other students, teachers as well as the students themselves will be taken beforehand, prior to conducting any sessions on-site. A copy of all the signed parental consent forms will also be handed to the school administrative in-charge.
3. I have been informed that my child's identity and responses will be completely anonymised. My child's name will not be linked with the research materials, and my child will not be identified or identifiable in any report subsequently produced by the researcher.
4. I also understand that if at any time during the session, my child wishes to discontinue, he/she is free to leave/ stop the session. That is, my child's participation in this study is completely voluntary, and he/she may withdraw from it without negative consequences. However, after data has been anonymised or after publication of results, it will not be possible for the data to be removed as it would be untraceable at this point.

SPECIAL PERMISSION REQUIRED (please tick one of the 2 options)	YES	NO
I consent to allow the researcher to photograph my child, during her onsite research process. In this situation, any photographs taken will be completely anonymised and my child's identity and facial features will be blurred/obscured during the final documentation of this project, following the research integrity protocol at Edinburgh Napier University, where the researcher is based. This is to ensure complete protection of the child's identity.		

5. I have read and understand the above and consent to my child's participation in this study. My signature is not a waiver of any legal rights.

Name of the Participant:

Name of the Participant's Parent / Guardian:

Parent's / Guardian's Signature Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature Date

Consent form – Montessori teachers and facilitators

Edinburgh Napier University Research Consent Form –

Montessori teachers and Facilitators

POTENTIALITY OF PLAY

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in the research project on studying the potential of play-based learning curriculums at Montessori Schools. Pankhuri Sanjay Jain, a PhD. student at the School of Arts and Creative Industries at Edinburgh Napier University, will conduct this research.
2. The broad goal of this research study is to explore ways in which design is implicated in playful learning processes. Specifically, I have been asked to conduct my normal classes during regular school hours, where the researcher will sit in the classroom, silently observing and writing notes. This should take no longer than a month to complete, with the researcher coming into the classroom once or twice a week. Consent of the school administrative in-charge, parents of the students as well as the students themselves will be taken beforehand, prior to conducting any sessions on-site. The school administrative in charge will also have a copy of all the signed parental consent forms.
3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researcher.
4. I also understand that if at any time during the session, I feel unable or unwilling to continue, I am free to leave/ stop the session. That is, my participation in this study is completely voluntary, and I may withdraw from it without negative consequences. However, after data has been anonymised or after publication of results it will not be possible for my data to be removed as it would be untraceable at this point.
5. In addition, should I not wish to answer any particular question or questions, I am free to decline.
6. I have been given the opportunity to ask questions regarding the procedure and my questions have been answered to my satisfaction.
7. I have read and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of the informed consent form for my records.

Participant's Signature ______________________ Date ______________

Consent form – children and young people

Edinburgh Napier University Research Consent Form
for Children and Young People*
To be completed by the participant

	√	X
I have been given enough information about this project.		
It has been explained to me how the information I give will be used.		
I agree to take part in the research on studying the potential of play-based learning curriculums at Montessori Schools.		
I understand that I can leave at any time and do not have to answer all of the questions or participate if I don't want to.		
I permit the researcher to take photographs with me present in them during the project. I understand that in such a scenario, my facial features and identity will be obscured/blurred when used in the report.		
I am happy for the researcher to record what I say.		
I give permission for my words to be used in a report but I understand that my name will not be mentioned.		

Participant's Signature   Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature   Date

Approved ethics form for DE

SACI RESEARCH INTEGRITY APPROVAL FORM

[This form should be used where a supervisor/other gatekeeper feels it necessary to refer a proposal to the School's Research Integrity Committee]

Section 1 – Research Details

Name/s of researcher/s: Pankhuri Sanjay Jain

Date: 29th December 2016

Staff ☐

Student - Matriculation number: [redacted]

Undergraduate ☐ Master's ☐ Doctoral ■

Name & Number of module (if appropriate)

PhD. in Design and Creative Research

Title of project/dissertation/study:

Potentiality of Play: The study of influences of design in cross-cultural, play-based learning environments for children, within institutionalised education setups (such as Montessori schools).

Main aim of research:

To conduct cross-cultural, on-site Ethnographic Research at Montessori Schools in Scotland and India, by observing interactions (site-specific; at Montessori schools in Scotland and India), which will then lead to uncovering general learning patterns from the observation notes (unstructured data, potential photographs of the sites and schools, interviews of Montessorian teachers, onsite notes), and critiquing them

1

against theories discussed by the key influencers of play-based education; which will then lead to drawing conclusions from tentative claims.

Using Ethnography as a research methodology, the researcher aims to identify the ways in which design is implicated in playful learning processes. This process will then support the next stage of the researcher's primary research, which will consist of design and prototyping of toys and educational tools, to provide a more practice-based form of enquiry. Combining Ethnographic research with a Research through Design methodology will help provide an emphasis on cultures or practice which are sensitive to the site-specificity of the researcher's case studies.

Onsite, the researcher's role will be to be a silent observer 'on field' (as non-descript and non-intrusive as possible) and gather field notes and visual data.

Details of the research methods to be used: please consider all of the following in your response:

a. **how the data will be collected (please outline all methods e.g. questionnaires/focus groups/internet searches/literature searches/interviews/observation)**
   Data collection will take place through observation and field notes of how pupils interact with their space and how do artefacts/objects in the environment impact the pupil's behaviour, thoughts, learning processes and motivations. Documentation of artefacts within a classroom, will happen using tools like diagrams, sketches, doodles, and in some cases, capturing relevant contextual factors through photographs (permission will be taken beforehand with informed consent forms signed by the teachers, parents and children, on-site). The researcher will also use opportunities to potentially document some on-site user behaviour through photographs of before and after sessions of the classroom (before pupils enter the classroom and after

they are done interacting with the space), which will be taken based on permissions and consent taken from the teachers and school administration before the sessions actually begin.

b. data collection tools to be used

Data collection tools to be used are field notes, interviews with key facilitators and teachers on-site, and in some cases, photographs and video footage (which will take place only after getting informed-consent forms signed by parents and teachers).

c. where the data will be gathered (e.g. on the street/telephone/online/in the classroom/)

Within Montessori classrooms

d. who will undertake the data collection if not the researcher detailed in section 1 (list all involved)

The Researcher (Pankhuri Jain)

e. how the data sample will be selected (e.g. random sampling)

Since the sites are already specific to the study of play-based learning environments in Montessori schools, the sample data collected will be specific to the research.

f. the criterion for an entity to be included in the sample

The criteria has been set as Montessori Schools in India and Scotland, which are interested in participating in the research project.

g. how research subjects will be invited to take part (e.g. letter/email/asked in lecture)

The research subjects (pupils and facilitators / teachers) will be invited to take part by initially setting up a meeting with the intended school, via emails/ over the phone. After discussions with the schools on the topic of study and the research method, once they consent to participate, an onsite research schedule with the intended school will be set up. Next, Informed consent and permissions of all the entities involved (school administration, teachers and parents of the children, as well as the children, if deemed necessary) will be taken. Once the permissions are signed and consented, then the researcher will go onsite (the school) and conduct observation research.

h. how the validity and reliability of the findings will be tested

The validity and reliability of the findings will be tested by comparing them against theories discussed by the key influencers in the research literature and texts; which will lead to drawing conclusions from tentative claims. This will support the second stage of the primary research phase, which is Research through Design

i. if available, please attach a copy of the questionnaire/interview questions

Questionnaire for the teachers will be created based on observations during the undertaken onsite ethnographic research.

j. where the research might be published

This research might get published in Academic and Design journals. During the documentation and writing up stage of the undertaken onsite research, participants will be anonymised and images and video footage taken on-site won't be added to potential journal articles. In certain situations, if any images are at all to be inserted, to show a specific context, the identities of the participants will be completely obscured

to retain their anonymity. The participants wont be named within the text either, instead will be referred as P1 or Participant AB, as so on. In such a situation, relevant permissions will again be taken from the specific site (where the photographs were taken), before publishing any obscured images in any intended publication.

k. sponsorship or other financial aspects

This project is part of a fully-funded PhD study, which has now developed to the primary research phase. Supervisors are Prof. D. Benyon, Dr Kirstie Jamieson and Euan Winton. Since it will also consist of future travel to research sites within India, it will be funded through the SACI research budget for PhD students.

Section 2 – Research Subject Details

Who/what will be the research subjects in the research?

a. General Public/Expert Interviewees/Students of Edinburgh Napier (please give details)

School children and teachers of Montessori Schools in Scotland and India.
It involves children within the age group of 1 - 10 years, since it is primarily ethnographic research at Montessori Schools.

b.* Vulnerable individuals (please give details e.g. school-children, elderly, disabled, etc. *Please note that there is an additional, lengthy process for gaining approval of any work with such.

School children of Montessori Schools in Scotland and India.
It involves children within the age group of 1 - 10 years, since it is primarily ethnographic research at Montessori Schools.

c. All other research subjects (please give details)

Teachers and facilitators at Montessori Schools.

Will participants be free NOT to take part if they choose? The teachers and parents of the pupils will be asked for prior consent, to let the pupils participate. If the teachers and parents are happy and satisfied with the pupils participating, a separate permission from the pupils will not be necessary.
Explain how informed consent will be achieved. Before onsite research begins on any of the planned sites, informed consent forms will be sent beforehand to all pupils and their parents, teachers and school administration, to get their permission to conduct ethnography on-site.
Will any individual be identifiable in the findings, and if so, how will this be handled? All individuals will be anonymised and their images will be obscured in the findings by not using their names (referring to them as participant 1/individual A, etc) and all photographic and video footage (taken after getting informed consent from the participant's parents and school administration, to take on-site photographs and video) will have blurred facial or recognisable features of the participants.
How will the findings be disseminated? Each school, which becomes a site, will be sent a copy of all the written literature, video footage and images, to get their approval, before it gets taken forward within the PhD. documentation.
Is there any possibility of any harm (social, psychological, professional, economic, reputational, etc) to participants who take part/do not take part? Give details. No; the information is completely pedagogic in nature, as the researcher is looking at institutionalised Montessori Curriculums in Schools.
How / where will data be stored? Who will have access to it? Will it be secure?

What will be done with the data at the end of the project? Data will be stored at the university, on a university assigned, password-protected IMac desktop at the research office (G5- MERCHISTON CAMPUS) and only the researcher along with the supervisory team will have access to it.
Any other information in support of your application The Researcher is PVG certified from Disclosure Scotland, with the certification number: 1512 1331 5483 0357. Since the research is cross-cultural in nature, the researcher will also be visiting sites in India. Being an Indian national, the researcher is quite aware of the ethical and cultural differences between Scotland and India and is also aware that the University RI Framework will govern her research.
[redacted] Signature of researcher: Miss Pankhuri Jain.. [redacted] Signature of Director of Supervision: Dr. Kirstie Jamieson........................ Supervisory team: Dr. Kirstie Jamieson, Prof. David Benyon and Euan Winton

Section 3 – SACI Research Integrity Committee's Approval for Referred Research
Delete as appropriate: I approve this research
Name of SACI Research Integrity Leader (Professor) Alistair Duff Signature *ASDuff* Date 19/1/17
Signature of researcher/s to confirm understanding and acceptance of RIL's decision Date
Section 4 – URIC (University Research Integrity Committee) Approval
Does this issue need to be referred to the URIC (University Research Integrity Committee)? If YES Secretary to forward to URIC Secretary for referral with any appropriate paperwork
Date actioned
Reason for referral

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URIC decision   Signature of Convener of URIC   Date
Date researcher/s informed of URIC decision – include copy of email to researcher/s

9

Appendix 3: Research through Design paperwork

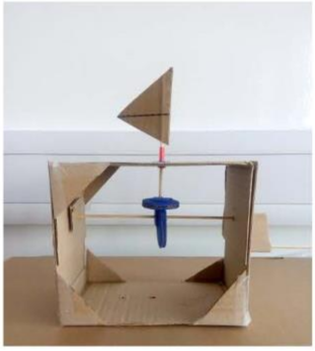
The following documents were submitted to the Research Ethics Committee at Edinburgh Napier University, to get permission to undertake RtD during this thesis.

- Workshop proposal and participant information sheet
- Consent form – Parents
- Consent form – CLE authorities
- Ethics form

Workshop proposal and information sheet

WORKSHOP PROPOSAL: POTENTIALITY OF PLAY
CONSTRUCT YOUR OWN AUTOMATONS

About Automata and Kinetic Toys:

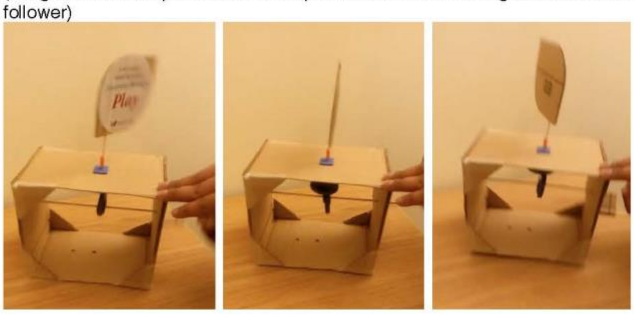


Automata/Automatons are simple mechanical sculptures, designed to bring objects to life through movement. As we learn to construct these machines, we get an opportunity to playfully explore simple mechanisms like linkages, axles and cams.

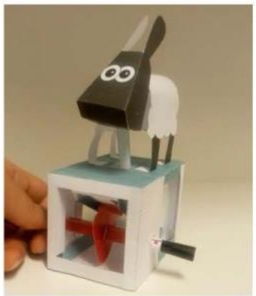
What I find most interesting about Automatons is their association to comprehending geometry and aiding the development of shape memory. Constructing movable sculptures by engaging with various shapes of different cams helps children develop their conceptual thinking and abstraction skills apart from strengthening their understanding of different geometric shapes and forms – since each specifically shaped cam and the way it is aligned in an automaton, can result in different kinds of movements like bounce, bob, spin, wiggle, and wobble.

Constructing these simplified and basic versions of Automatons helps one build movable, mechanical sculptures, which are a source of immense joy and pleasure for children. Learning by construction helps build conceptual skills and encourages learning and problem solving through trial and error. Children are then encouraged to add narratives and stories to their automatons, to make them more playful and engaging.

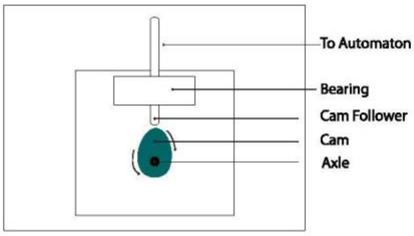
(Images below: simple rotation and up and down motion using circular cams and cam follower)



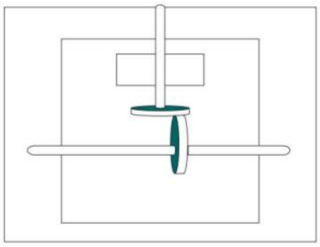
Some ideas on adding materials and narratives to Automatons: This is an example of a designed automaton – constructed out of paper and straws, where a cut out of a sheep has been added on top of the automaton – to create a movable model of an animal. These are some of the ways in which children will be encouraged to experiment with their automatons.



GEOMETRY THROUGH AUTOMATA INSPIRED MECHANISMS



The heart of any automaton is the Cam – which is a 2D Geometrical shape – typically a sphere, circle, soft edged triangle or an apostrophe shape, which creates movement when externally rotated. When the axle is rotated, the cam turns with it, which causes the Cam Follower to rise or fall as a result. Changes in the diameter of the Cam (relative to how the cam is shaped), cause the movement of rise and fall. Cams are gears arranged within automata, to create continuous/ repetitive movements like oscillations, up and down, tremors, wiggles and so on. The Geometrical shape of a cam will define the kind of movement its follower creates. Different cam shapes create different movements.



MATERIALS USED FOR THE WORKSHOP:

The Researcher will provide all the materials used for the workshop, which typically consist of art and craft materials, often seen in schools and learning centres.

1. Cardboard and MDF (pre-cut boxes and separate pieces to be assembled together)
2. Pre-cut Cams and Cam followers made out of craft foam, MDF or cardboard.
3. Bamboo or wooden skewer sticks - – for the Cam Followers.
4. Pre-cut craft wire - for the Cam Followers
5. Wooden Dowels – for the Cam Followers
6. Glue sticks and Craft Hot Glue gun (the glue gun will be handled by the researcher and or the facilitators present – to ensure maximum safety for the children)
7. Paper straws, foam sheets and pre-cut MDF blocks - to design bearings to keep the followers in place.
8. Paper cutters and craft scissors will be used if necessary, under the strict facilitation of the researcher and parents/ teachers present at the venue.
9. Other supplementary art materials like paper sheets, paper plates, cellotape, craft foam sheets, coloured felt pieces, beads, pipe cleaners, pompom balls, strings etc will also be provided for the children to explore narratives and add playful elements to their Automatons.

FACILITATION IN THESE WORKSHOPS

This workshop complies with the method of Research through Design, where the materials provided will allow children to engage, play and construct with Geometrical shapes to enrich their comprehension of differences in forms. The researcher will lead and facilitate this workshop. The researcher hopes to employ classical techniques used in the construction of Automata and Kinetic toys, to add an element of playfulness and abstractions to comprehending various aspects of Geometry and co-design these movable sculptures with children to construct their own movable mechanisms by using differently geometric shapes (here cams).

RECORDING LEARNING OUTCOMES:

The learning outcomes will be recorded by the researcher in the form of notes, sketches, and at times, through photographs and video clips (after relevant consent taken from the facilitators and parents if present). Each participating child will also be given a booklet to give feedback about their learning outcomes in the workshop. The children are free to answer as honestly as they wish. The researcher, as a form of data collection, will take the completed feedback booklets back. Each participant will be allowed to keep his/her designed automaton with him or her, once the researcher has documented it as a photograph.

DURATION OF THE WORKSHOP:
Estimated duration of the workshop is between 2 to 3 hours, based on the availability and arrangements with the venue / school.

AGE- GROUPS OF PARTICIPANTS:
The researcher is hoping to invite participants between the ages of 8 to 12 years, based on the school/venue's arrangements. In the case where younger participants between the ages of 5 to 7 years are interested, then the automatons will be partially constructed for the children, in order to simplify the workshop for them. The younger children can spend more time experimenting with different cams and adding playful and narratives to their automatons. Interest of the children and their willingness to experiment with the playful materials will be taken into consideration before hand, so that optimum learning is ensured as well as the element of playfulness in the activities isn't compromised.

How will the findings be disseminated?
Each venue will be sent a copy of all the written literature and images if they request for them, before it gets taken forward within the PhD. documentation.

Is there any possibility of any harm (social, psychological, professional, economic, reputational, etc.) to participants who take part/do not take part? Give details.
There is no possibility of any harm (social, psychological, professional, economic or reputational), since the information is completely pedagogic in nature; as the researcher is looking at institutionalised, play-based learning curriculums in Schools.

How / where will data be stored? Who will have access to it? Will it be secure? What will be done with the data at the end of the project?
Data will be stored at Edinburgh Napier University; on a university assigned, password-protected desktop at the research office and only the researcher along with her supervisory team will have access to it.

NAME & CONTACT DETAILS OF THE RESEARCHER:

Pankhuri Sanjay Jain
PhD. student,
Edinburgh Napier University
P.Jain@napier.ac.uk

NAME & CONTACT DETAILS OF THE RESEARCH SUPERVISOR:
Dr. Kirstie Jamieson
Lecturer in Design and Urban Studies

School of Arts and Creative Industries
Edinburgh Napier University,
Merchiston Campus, Colinton Road
Edinburgh Eh10 5DT

k.jamieson@napier.ac.uk

Consent form – Parents

Edinburgh Napier University Research Consent Form – Parents

RESEARCH TOPIC: POTENTIALITY OF PLAY. Participative workshops

Edinburgh Napier University requires that all persons who participate in research studies, give their written consent to do so. In this project, the consent of parents/ guardians of children participating in the research is required. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to allow my child to be a participant in the research project based on studying the potential of play-based learning curriculums. I allow my child to participate in these interactive workshops on designing toys and automatons. Pankhuri Sanjay Jain, a PhD. student at the School of Arts and Creative Industries at Edinburgh Napier University, will conduct this research and facilitate these workshops.
2. The broad goal of this research study is to explore ways in which design of spaces, toys and learning tools is implicated in playful learning processes. Specifically, I have been asked to allow the researcher to interact with and observe my child and his/her colleagues design toys during these facilitated workshops. During these participative workshops I will be present at the venue too (at public venues like Museums) and in case the workshops are being conducted at school premises, facilitators and teachers will be present at all times along with the researcher.
3. Each workshop won't be longer than 2 hours. Consent of the school administrative in-charge, parents of other students, teachers as well as the students themselves (when required) will be taken beforehand, prior to conducting any sessions on-site. A copy of all the signed parental consent forms will also be handed to the school administrative in-charge.
4. I have been informed that my child's identity and responses will be completely anonymised. My child's name will not be linked with the research materials, and my child will not be identified or identifiable in any report subsequently produced by the researcher.
5. I also understand that if at any time during the session, my child wishes to discontinue, he/she is free to leave/ stop the session. That is, my child's participation in this study is completely voluntary, and he/she may withdraw from it without negative consequences. However, after data has been anonymised or after publication of results, it will not be possible for the data to be removed as it would be untraceable at this point.

SPECIAL PERMISSION REQUIRED (please tick one of the 2 options)	YES	NO
I consent to allow the researcher to photograph my child, during her onsite research process. In this situation, any photographs taken will be completely anonymised and my child's identity and facial features will be blurred/obscured		

during the final documentation of this project, following the research integrity protocol at Edinburgh Napier University, where the researcher is based. This is to ensure complete protection of the child's identity.		

6. I have read and understand the above and consent to my child's participation in this study. My signature is not a waiver of any legal rights.

Name of the Participant:

Name of the Participant's Parent / Guardian:

Parent's / Guardian's Signature Date

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature Date

Consent form – CLE authorities

Edinburgh Napier University Research Consent Form –

Teachers / Facilitators / Venue administrators

POTENTIALITY OF PLAY. Participative workshops

Edinburgh Napier University requires that all persons who participate in research studies give their written consent to do so. Please read the following and sign it if you agree with what it says.

1. I freely and voluntarily consent to be a participant in the research project on studying the potential of play-based learning curriculums through these interactive and participative workshops on designing Automata. Pankhuri Sanjay Jain, a PhD. student at the School of Arts and Creative Industries at Edinburgh Napier University, will conduct these workshop sessions.
2. The broad goal of this research study is to explore ways in which design is implicated in playful learning processes. These workshops shouldn't take more than 2 hours. Consent of the school administrative in-charge, parents of the students as well as the students themselves (when required) will be taken beforehand, prior to conducting any workshop sessions on-site. The administrative in-charge will also have a copy of all the signed parental consent forms if requested.
3. I have been told that my responses will be anonymised. My name will not be linked with the research materials, and I will not be identified or identifiable in any report subsequently produced by the researcher.
4. I also understand that if at any time during the workshop sessions, I feel unable or unwilling to continue, I am free to leave/ stop the session. That is, my participation in this study is completely voluntary, and I may withdraw from it without negative consequences. However, after data has been anonymised or after publication of results it will not be possible for my data to be removed as it would be untraceable at this point.
5. In addition, should I not wish to answer any particular question or questions, I am free to decline.
6. I have been given the opportunity to ask questions regarding the procedure and my questions have been answered to my satisfaction.
7. I have read and understand the above and consent to participate in this study. My signature is not a waiver of any legal rights. Furthermore, I understand that I will be able to keep a copy of the informed consent form for my records, if I request to do so.

Participant's Signature ______________________ Date ______________

I have explained and defined in detail the research procedure in which the respondent has consented to participate. Furthermore, I will retain one copy of the informed consent form for my records.

Researcher's Signature ______________________ Date ______________

Approved ethics form for RtD

To : PANKHURI JAIN
From : A. DUFF

SACI RESEARCH INTEGRITY APPROVAL FORM

[This form should be used where a supervisor/other gatekeeper feels it necessary to refer a proposal to the School's Research Integrity Committee]

Section 1 – Research Details

Name/s of researcher/s: Pankhuri Sanjay Jain

Date: 1st May 2018

Staff ☐

Student - Matriculation number: 40128890

Undergraduate ☐ Master's ☐ Doctoral ☒

Name & Number of module (if appropriate)

PhD. in Design and Creative Research

Title of project/dissertation/study:

Potentiality of Play: The study of design's influence in cross-cultural, play-based learning environments for children, within institutionalised education setups (such as Montessori schools).

Main aim of research:

To advance the application of Montessori's geometrical menu in a system that tests the mechanisms of shape and movement through the construction of automata. This will be done through small workshops designed for children in the age group of 5-12 years, conducted across cultural organisations in Edinburgh and Glasgow.

The method of Research through Design (RtD) supports the forthcoming stage of the PhD's primary research, which consists of design and prototyping of toys and educational tools, to provide a more practice-based form of enquiry. Combining Ethnographic research (conducted previously in 2017) with a Research through Design (RtD) methodology will help provide an emphasis on practices which are sensitive to the site-specificity of the researcher's case studies

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MATERIALS USED IN THE WORKSHOPS

Materials used during these participative workshops will be the same as those commonly used in school art classes like Craft Paper, Cardboard, Craft Foam sheets, Straws, Paper Fasteners, Craft glue, Wooden sticks, Pre-cut Craft wire, Play dough, Coloured sheets, Markers and so on. The children will also get pre-cut and finished blocks, dowels and 2-D Geometric shapes (triangles, circles, ovals) during the sessions. These geometric shapes will be designed by the researcher and constructed out of child-friendly and widely available materials like MDF and cardboard to ensure maximum safety. Each of these shapes and blocks will be laser cut and will not have any sharp edges, chips or spikes, to ensure that the materials are children-friendly and safe to play with. If the use of tools like craft scissors and hot glue guns is required during the participative workshop, these tools will be handled only by the researcher, to ensure maximum safety for the children. All precautions will be taken to ensure that the toys and workshop sessions designed are completely safe. The aesthetic and design of these toys is based on tools designed for Montessori schools, so all the materials used will be child-friendly.

PROPOSED DESIGN OF TOYS IN THE WORKSHOP

Children will construct simple kinetic toys inspired from Automata during the workshop. These are simple mechanical toys made out of materials like cardboard, paper, MDF, craft foam and other commonly found craft materials. The proposed workshops are based on a Constructivist theory of education, which encourages constructing objects of knowledge to further one's learning. Constructionism endorses that children are more likely to formulate new ideas and engage in critical thinking skills and conceptual manipulation, when they are focused on constructing an external object.

In this workshop, children will be given an opportunity to play and tinker with a few different 2D geometrical shapes, and use them as cams to create simple movable toys. Sample structures of these kinetic toys will be pre-designed and displayed in the workshop by the researcher, and children will be encouraged to explore the materials, experiment with movements and play with them, before constructing their own personal automata. After the workshop, each child will be given a booklet to give the researcher feedback on the workshop, which focuses on the child's learning outcomes after the workshop ends. The researcher will collect these booklets as a part of the workshop data and feedback, and the children will be allowed to take back their constructed toys, after the researcher photographs the toys.

Attached with this ethics form, is a separate sheet with the details of the workshop proposal as well as required sample consent forms for the facilitators, teachers & parents for the ethics committee's kind perusal.

PROPOSED WORKSHOP SITES

The proposed RtD participative sessions will be conducted as facilitated workshops across public spaces and play festivals like the Science Museum in Glasgow, Edinburgh Museum of Childhood, Edinburgh Montessori morning sessions, Imaginate festival and so on. The researcher will be getting in touch with these potential sites before hand, discuss the workshop with them, create a schedule and provide all workshop materials. Only on approval of the venues and consent of all the involved stakeholders, will the researcher conduct these workshops. Parents of the children must be present during the sessions, especially when the venue is a public space like the Museum or the Imaginate festival.

RESEARCHER'S ROLE

Onsite, the researcher's role will be of a workshop facilitator as well as observer 'on field'. These workshops would consist of of five to six children in one session, aged approximately between 8 and 12 years, based on the school/venue's arrangements. In the case where younger participants between the ages of 5 to 7 years are interested, then the automata will be partially constructed by the researcher before-hand, and given to the children to tinker with, in order to simplify the workshop for them

Details of the research methods to be used: please consider all of the following in your response:

a. **How the data will be collected (please outline all methods e.g. questionnaires/focus groups/internet searches/literature searches/interviews/observation)**

   Data collection will take place through observation and field notes of how children interact with their toys/designed materials and how do artefacts/objects in the environment impact their behaviour, thoughts, learning processes and motivations. Documentation of the workshop within the venues, will happen through diagrams, sketches, doodles, and in some cases, capturing relevant contextual factors through photographs (permission will be taken beforehand with informed consent forms signed by the teachers, parents and children on-site). The researcher will also use opportunities to potentially document some on-site user behaviour through photographs of before and after sessions of the workshop (before children enter the space and interact with materials and after they are done interacting with the materials), which again will be taken based on permissions and consent taken from the relevant administration of the venue and/or the participant's parents before the sessions actually begin. After the workshop session, each child will be requested to fill out a small booklet to give feedback to the researcher about the workshop. The researcher will keep the booklets with her after children have given their feedback. These booklets will also represent data from the workshops and the children can take their designed automatas back with

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them.

b. data collection tools to be used

Data collection tools to be used are field notes, small feedback booklets (to be filled out by the children), conversations with facilitators, parents and/or teachers on-site, and in some cases, photographs and video footage (which will take place only after getting informed-consent forms signed by parents and teachers). Booklets will be given to the children to get their feedback on the experience and learning outcomes during the workshop. The researcher will take these booklets back, and the children are free to take their designed toys back home, after the researcher has photographed the designed toys.

c. where the data will be gathered (e.g. on the street/telephone/online/in the classroom/)

At workshop venues (public venues or school premises.)

d. who will undertake the data collection if not the researcher detailed in section 1 (list all involved)

The Researcher (Pankhuri Jain). During the workshop, children will be given a booklet for them to fill out their feedback from the workshop and what they learnt while designing automatons. Once completed, the researcher will take the booklets with their responses, back, as data.

e. how the data sample will be selected (e.g. random sampling)?

Since the sites are already specific to the study of play-based learning environments in schools and public venues, the sample data collected will be specific to the research.

f. the criterion for an entity to be included in the sample

The criteria are set as School going children between the ages of 5 to 12 years who are interested in participating in the research project. Workshops for children between the ages of five to seven will be organized as simpler sessions with partially constructed automata, and workshops for children between the ages eight to twelve years will be designed to be slightly more challenging, as children will be encouraged to build their automata from the ground up.

g. how research subjects will be invited to take part (e.g. letter/email/asked in lecture)

The research subjects (children) will be invited to take part by initially setting up a meeting with the intended venue in person or via emails/over the phone to discuss the workshops. After discussions with the venue on the topic and aim of the workshop and the research method, once consent to participation has been given, an onsite workshop date schedule with the intended venue will be set up. Next, informed consent and permissions of all the entities involved (school administration, venue administration, teachers and parents of the children, as well as the children themselves, when deemed necessary) will be taken. Once the permissions are signed and consented, then the researcher will go onsite (the chosen venue) and conduct participative workshops.

h. how the validity and reliability of the findings will be tested

The validity and reliability of the findings will be tested by comparing them against theories discussed by the key influencers in the research literature and texts as well as the researcher's ethnographic analysis; which will lead to drawing conclusions from feedback received and observations undertaken during the workshops. These participative sessions have been designed to support the second stage of the primary research phase, which is Research through Design

i. if available, please attach a copy of the questionnaire/interview questions

The children will be given a feedback booklet to record their responses, which will be taken back by the Researcher. Attached with the consent form are the workshop proposal and consent forms for facilitators as well as parents and children (when necessary).

j. where the research might be published

This research might get published in Academic and Design journals. During the documentation and writing up stage of the sessions, participants will be anonymised and images and video footage taken on-site won't be added to potential journal articles. In certain situations, if any images are at all to be inserted, to show a specific context, the identities of the participants will be completely obscured to retain their anonymity. The participants wont be named within the text either, instead will be referred as P1 or Participant AB, as so on. In such a situation, relevant permissions will again be taken from the specific venue (where the photographs were taken), before publishing any obscured images in any intended publication.

k. sponsorship or other financial aspects

This project is part of a fully funded PhD study. Supervisors are Prof. David Benyon, Dr Kirstie Jamieson and Euan Winton. The researcher has also received additional funds to purchase some of the materials for the workshop through SACI's research budget for PhD students.

Section 2 – Research Subject Details

Who/what will be the research subjects in the research?

a. **General Public/Expert Interviewees/Students of Edinburgh Napier (please give details)**
School going children from Montessori and Non-Montessori Schools in Scotland. It involves children within the age group of 5 - 12 years, since it is primarily study of play-based learning curriculums.

b. **Vulnerable individuals (please give details e.g. school-children, elderly, disabled, etc.** ***Please note that there is an additional, lengthy process for gaining approval of any work with such.***
School children of Montessori and Non-Montessori Schools in Scotland. It involves children within the age group of 5 - 12 years.

c. **All other research subjects (please give details)**
Teachers, parents of children and facilitators at Montessori and Non-Montessori Schools.

Will participants be free NOT to take part if they choose?

The teachers and parents of the children will be asked for prior consent, to let the children participate. The children are free to not participate if they decide to. If the teachers and parents are happy and satisfied with the children participating, a separate permission form from the children might not be necessary.

Explain how informed consent will be achieved.

Before any session begins on any of the planned sites, informed consent forms will be given beforehand to all children and their parents, teachers and venue administration, to get their permission to conduct ethnography on-site.

Will any individual be identifiable in the findings, and if so, how will this be handled?

All individuals will be anonymised and their images will be obscured in the findings by not using their names (referring to them as participant 1/individual A, etc.) and all photographic and video footage (taken after getting informed consent from the participant's parents and school administration, to take on-site photographs and video) will have blurred facial or recognisable features of the participants.

How will the findings be disseminated?

Each venue will be informed of how the findings are to be used within the PhD documentation and

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the venue and participants will be sent be sent a copy of the onsite findings, video footage and images if requested.

Is there any possibility of any harm (social, psychological, professional, economic, reputational, etc) to participants who take part/do not take part? Give details.

No; the information is completely pedagogic in nature, as the researcher is looking at the study of play-based learning practices and curriculums in Schools.

How / where will data be stored? Who will have access to it? Will it be secure? What will be done with the data at the end of the project?

Data will be stored at the university; on a university assigned, password-protected IMac desktop at the research office (G5- MERCHISTON CAMPUS) and only the researcher along with the supervisory team will have access to it.

Any other information in support of your application

The Researcher is PVG certified from Disclosure Scotland, with the certification number: 1512 1331 5483 0357. The researcher is also aware that the University RI Framework will govern her research.

[redacted]

Signature of researcher: Miss Pankhuri Jain..

[redacted]

Signature of Director of Supervision: Dr. Kirstie Jamieson.......................

Supervisory team: Dr. Kirstie Jamieson, Prof. David Benyon and Euan Winton

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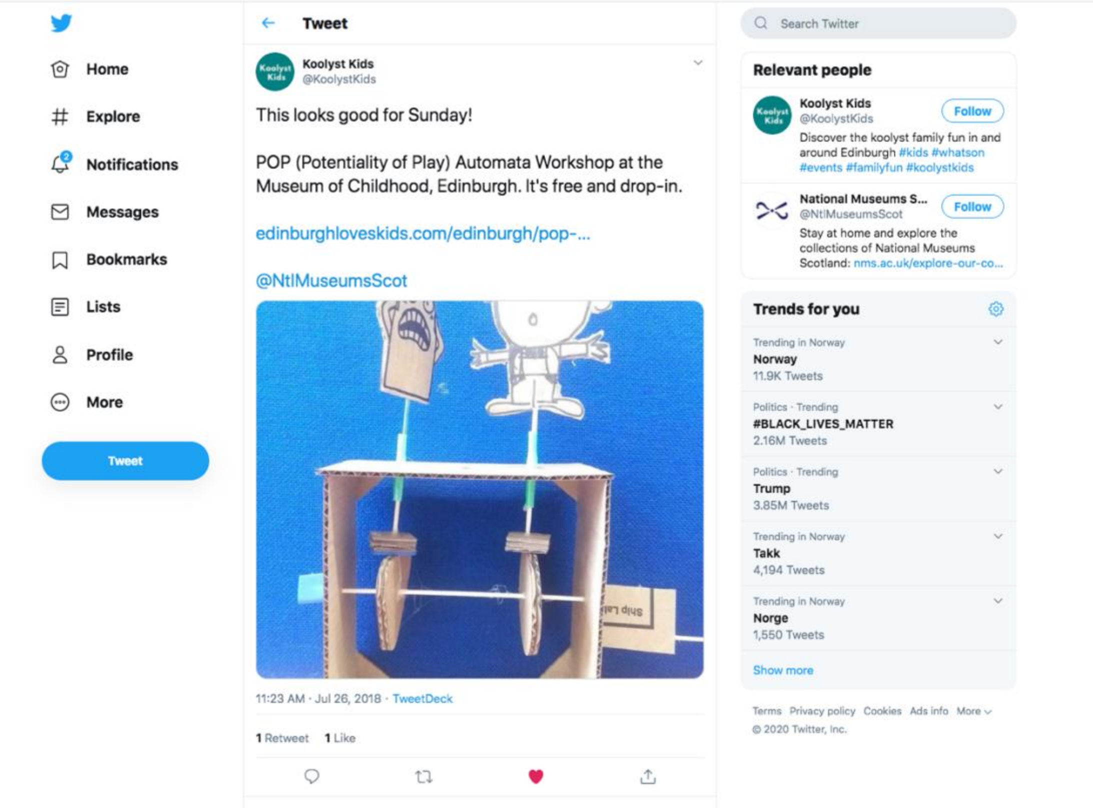
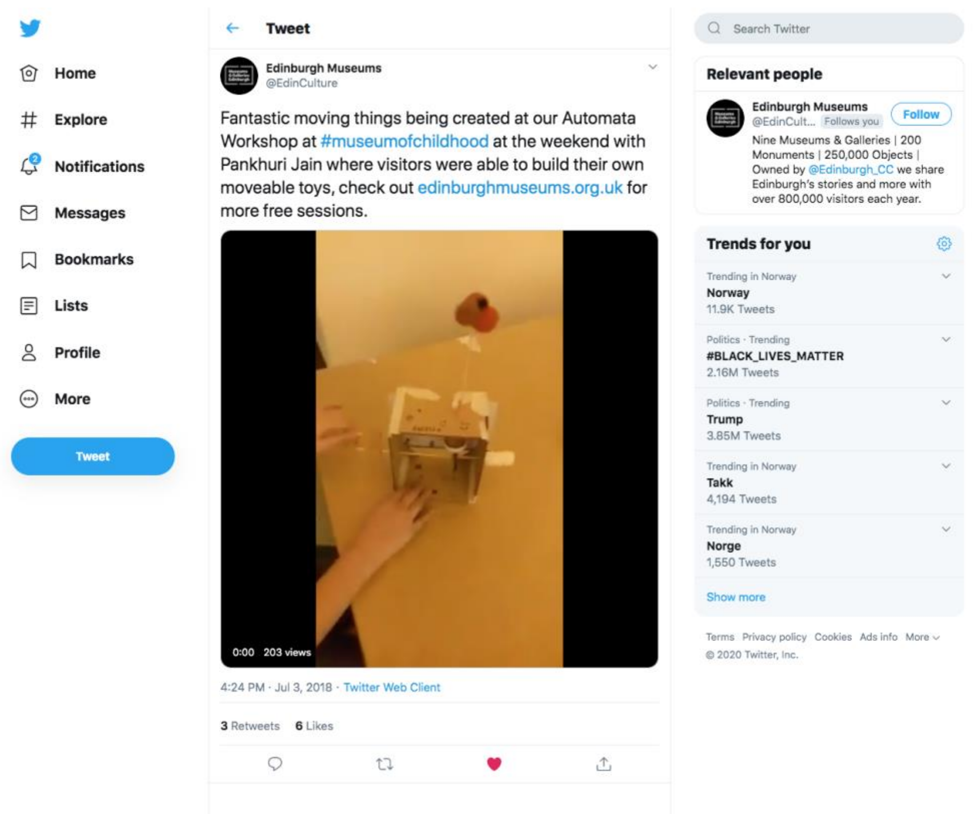
Section 3 – SACI Research Integrity Committee's Approval for Referred Research	
Delete as appropriate: I approve this research	
Name of SACI Research Integrity Leader (Professor) Alistair Duff [redacted] Date 1 May 2018	
Signature of researcher/s to confirm understanding and acceptance of RIL's decision Date	
Section 4 – URIC (University Research Integrity Committee) Approval	
Does this issue need to be referred to the URIC (University Research Integrity Committee)? If YES Secretary to forward to URIC Secretary for referral with any appropriate paperwork	
Date actioned	
Reason for referral	
URIC decision Signature of Convener of URIC	

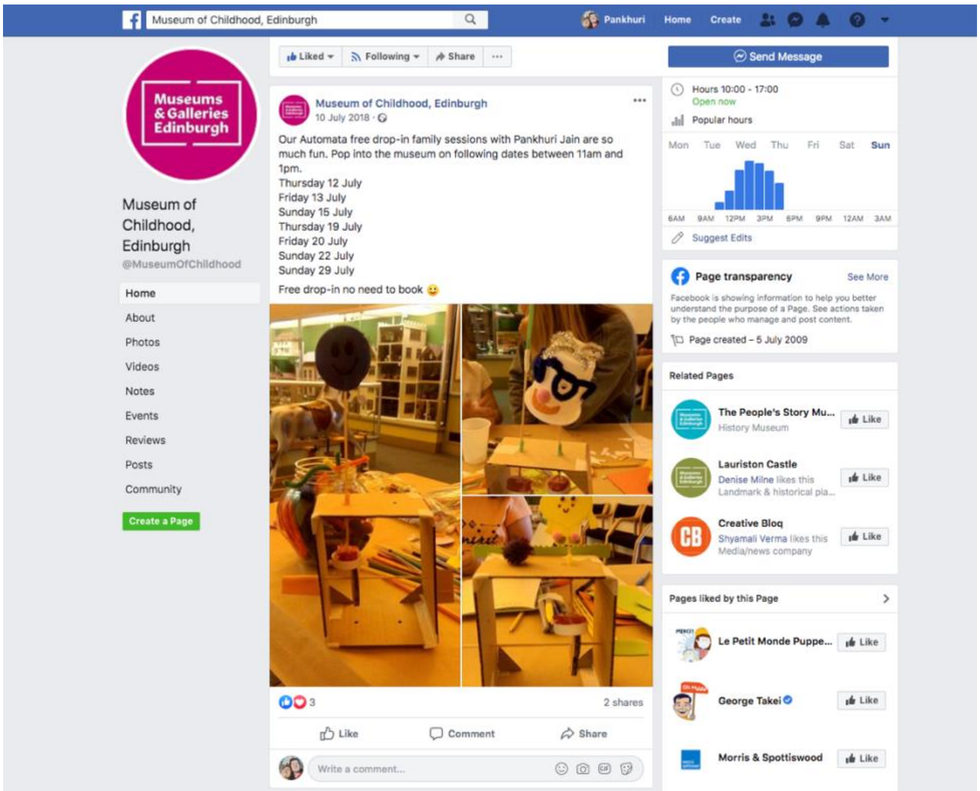
8

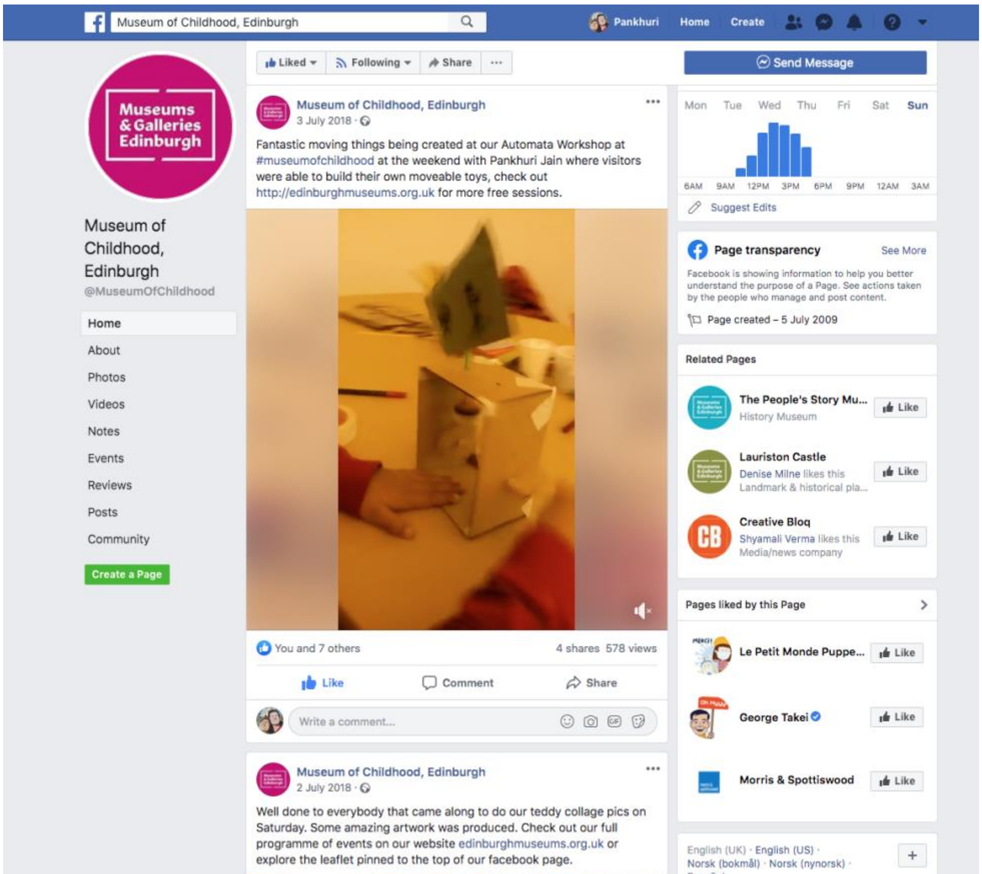
Date
Date researcher/s informed of URIC decision – include copy of email to researcher/s

Appendix 4: Advertising for POP workshops on social media by the Museum of Childhood, Edinburgh






Museum of Childhood, Edinburgh
Pankhuri
Home
Create
Liked
Following
Share
Send Message
Museums & Galleries Edinburgh
Museum of Childhood, Edinburgh
@MuseumOfChildhood
Home
About
Photos
Videos
Notes
Events
Reviews
Posts
Community
Create a Page
Museum of Childhood, Edinburgh
10 July 2018
Our Automata free drop-in family sessions with Pankhuri Jain are so much fun. Pop into the museum on following dates between 11am and 1pm.
Thursday 12 July
Friday 13 July
Sunday 15 July
Thursday 19 July
Friday 20 July
Sunday 22 July
Sunday 29 July
Free drop-in no need to book
3
2 shares
Like
Comment
Share
Write a comment...
Hours 10:00 - 17:00
Open now
Popular hours
Mon Tue Wed Thu Fri Sat Sun
6AM 9AM 12PM 3PM 6PM 9PM 12AM 3AM
Suggest Edits
Page transparency
See More
Facebook is showing information to help you better understand the purpose of a Page. See actions taken by the people who manage and post content.
Page created – 5 July 2009
Related Pages
The People's Story Mu...
History Museum
Like
Lauriston Castle
Denise Milne likes this
Landmark & historical pla...
Like
Creative Bloq
Shyamali Verma likes this
Media/news company
Like
Pages liked by this Page
Le Petit Monde Puppe...
Like
George Takei
Like
Morris & Spottiswood
Like


Museum of Childhood, Edinburgh
Pankhuri
Home
Create
Liked
Following
Share
Send Message
Museums & Galleries Edinburgh
Museum of Childhood, Edinburgh
@MuseumOfChildhood
Home
About
Photos
Videos
Notes
Events
Reviews
Posts
Community
Create a Page
Museum of Childhood, Edinburgh
3 July 2018
Fantastic moving things being created at our Automata Workshop at #museumofchildhood at the weekend with Pankhuri Jain where visitors were able to build their own moveable toys, check out http://edinburghmuseums.org.uk for more free sessions.
You and 7 others
4 shares 578 views
Like
Comment
Share
Write a comment...
Museum of Childhood, Edinburgh
2 July 2018
Well done to everybody that came along to do our teddy collage pics on Saturday. Some amazing artwork was produced. Check out our full programme of events on our website edinburghmuseums.org.uk or explore the leaflet pinned to the top of our facebook page.
Mon Tue Wed Thu Fri Sat Sun
6AM 9AM 12PM 3PM 6PM 9PM 12AM 3AM
Suggest Edits
Page transparency
See More
Facebook is showing information to help you better understand the purpose of a Page. See actions taken by the people who manage and post content.
Page created – 5 July 2009
Related Pages
The People's Story Mu...
History Museum
Like
Lauriston Castle
Denise Milne likes this
Landmark & historical pla...
Like
Creative Bloq
Shyamali Verma likes this
Media/news company
Like
Pages liked by this Page
Le Petit Monde Puppe...
Like
George Takei
Like
Morris & Spottiswood
Like
English (UK) · English (US) ·
Norsk (bokmål) · Norsk (nynorsk) ·

Appendix 5: Extra material

During this thesis, I shared some of my design work and sketches on my online portfolio. The following links can be accessed to have a look at the DE and RtD fieldwork, as it developed over the course of this thesis:

DE fieldwork:
https://www.pankhurijain.com/copy-of-vibe

RtD pilot study at the Counterplay Conference in 2016:
https://www.pankhurijain.com/copy-of-potentiality-of-play

RtD fieldwork:
https://www.pankhurijain.com/copy-of-potentiality-of-play-1