Towards an Internet of Glass Things: Glass Artworks as Digitally Communicating Objects

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TOWARDS AN INTERNET OF GLASS THINGS: GLASS ARTWORKS AS DIGITALLY COMMUNICATING OBJECTS

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Author declaration

According to the regulations, I declare that during my registration I was not registered for any other degree. I have not used material in this thesis for any other academic award.

Declaration about collaborative work

Some of the research presented in this thesis was advanced in joint craft and technology workshops with other practice-based researchers or artists, however, my role as researcher has remained independent during any collaborations. When artworks were built with technical advice, advisors are acknowledged in the text. The concepts for the artworks were my own and the technology is open source. The contribution to knowledge is not found in the technology itself, but the creative way I have applied it to glass art.

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Abstract

The research explores the combination of digital technologies with glass art to generate interactivity, animacy and playful experiences. From the mid-nineties artists and designers started blending digital technology with crafted artefacts to enable interaction between artwork and audience, at times mediated through the Internet. The last two decades saw the development of the 'Internet of Things' (IoT), web-connected devices that are environment-sensing and communicate with each other independently of users. The contextual survey revealed that to date there are few projects or papers exploring the potential of integrating glass as an artistic medium with interactive digital media. My aim was to use a multiple-methods practice-based methodology to investigate the creative possibilities of incorporating digital interactivity in glass art.

A series of artworks selected from my recent practice using physical computing for digital interactions are described, demonstrating methods and narratives that expand possibilities for storytelling. The thesis investigates how novel interactive technologies embedded in glass may engage viewers and communicate content. A number of ways that glass lends itself to blending with computational materials were explored.

Investigation into embedding conductive traces in glass by adapting glass-making processes to create circuitry for smart interfaces was undertaken. Blending IoT technology with glass enables connectivity between artwork and audience offering the potential for telepresence. Research carried out during the COVID-19 global pandemic explored networked working methods and also applied research into the effects of COVID lockdowns on touch in the generation of digitally-augmented artworks.

Projects in this study contribute to the expansion of the contemporary glass field in the 21st Century. Combining glass and digital technologies including IoT offers potential for expression and expansion of artistic ideas. These are articulated for practitioners working

with glass, curators, academics and designers interested in embedded computer systems. An ‘Internet of Glass Things’ is proposed as a term to describe interactive glass artworks.

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Thanks are due to the technical advisers, creative technologists, programmers, artists, tutors and technical staff who provided advice or assistance to realise artworks, including Dr Jeff Sarmiento, Dr Thomas Dylan, Andy Card, Craig James, Alistair MacDonald, Dr Mark Hursty, Chris Hofmann, Zoe Garner and James Maskrey.

I am grateful to my collaborators Prof Kristine Diekman, Lisa Mansfield and Dr Angela Thwaites for the privilege and fun of working together on such interesting projects. Thank you to Kristine for providing the photographs and videos of the *1.5 Degrees of Concern* exhibitions in the United States.

Thanks also to Vicky and Mike Craven for allowing me to record interviews with them for the *1.5 Degrees of Concern* project and to Sound Archivist Kate O'Neill for obtaining permissions to use oral history recordings from Essex Records Office.

Lastly, thanks to all my family, especially Mike McManus, who has encouraged and supported me throughout, Toby for sharing his expertise in TouchDesigner and 3D modelling software and Kezia who helped with proofreading.

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1 Introduction

1.1 Research context

I embarked on this PhD at the University of Sunderland within the National Glass Centre from the perspective of a glass artist of twenty years, but also from a long career as a visual artist and theatre practitioner that encompassed visual theatre, puppetry, image/video projections, animation, film, multisensory theatre and interactive art. Involvement of other people, participation and collaboration have been important elements of these practices, including community or pedagogical involvement.

The formation of my art practice was influenced by early experience on the pioneering Art and Social Contexts course at Dartington College of Arts in the 1980s. This favoured widening accessibility to the arts, the value of group work, process over product, developing ecological and environmental awareness, contemporary cultural studies, and critical art practice based on placements in non-art social environments modelled after Latham and Stevini's APG (Artists Placement Group) (Crickmay, 2002; Harding, n.d.). Dartington gave me a foundation for crossing disciplinary boundaries (e.g. into social anthropology for a PhD on emergent art and national identity in Jamaica, (Waugh, 1987) and also provided my first opportunities for cross-artform collaboration with theatre and dance.

Whilst my art practice has always been rooted in making and materiality, a desire to create work accessible to a wide audience with direct communication between artist and audience led to my initially gravitating to the field of puppetry. Only later did I develop a personal practice making sculpture in glass for selling exhibitions, though never feeling comfortable with the exclusivity of the art market or the commodification of artwork. For many years, I supported myself through arts businesses putting on visual theatre shows and running projects in educational and community settings with people of different ages and abilities, often collaborating with other artform artists, composers, musicians, dancers, writers and actors. My two predominant interests of 'art' and 'people' led to my embracing narrative and time-based media, first puppetry, then theatre, video and animation, to tell stories ranging from folk tales, autobiography, heritage to local and global issues.

Interactivity and animacy became common threads across disciplines as a means to engage with the audience. I viewed puppetry as a kind of 'animating sculpture', as it involves the skill of the puppet-maker to create a representational structure articulated in such a way to enable the illusion of life to be conjured in the mind of an audience by the skill of the puppeteer. Figure 1 shows my earliest 'puppetry' animating Picasso's mural *Guernica* with performing structures in a production referencing contemporary documents about the bombing of the Basque town and the artist's paintings and etchings, for the Belfast Fringe Festival. Figure 2 shows some puppets I made for our own and other theatre companies over my career.

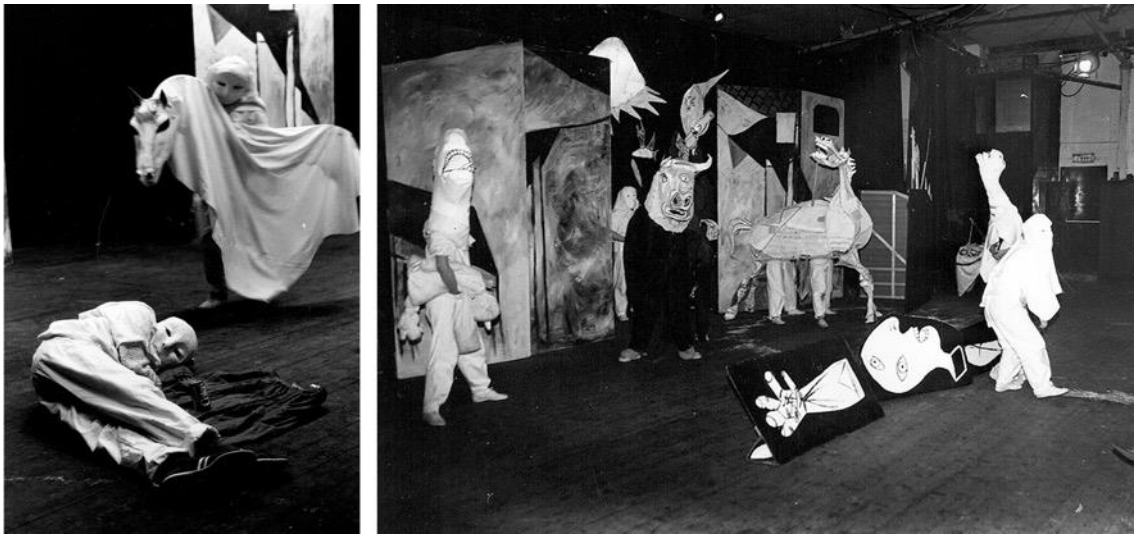

Figure 1 Liz Waugh and Mike McManus*, Guernica,* 1985, Performance at the Crescent Arts Centre, Belfast

Figure 2 Liz Waugh McManus Puppets. (Top left) 2002, *Rose Blanche*, for Obelon Arts and Box Clever Theatre Co. collaboration; (bottom left) 1999, *Great Expectations*, Level 5 Theatre Co.; (right) 2018, *A Brief Timeline of Enemies and Friends*, Passion Productions.

Figure 3 Liz Waugh McManus and Mike McManus, 2010, still from *Openings,* Animation.

A fascination with creating the illusion of life led to exploring animation, an early example of which was the film *Openings* (Fig. 3), made with Mike McManus in 2009-10 through a guerrilla-style stop-motion process over two days, animating a Victorian/Edwardian household collection of curious objects amassed over two centuries (McManus, 2010). Stop-motion expanded over the next few years to more complex digital animation where images and video were layered with effects in postproduction. I began to project video compositions for theatre shows or artworks onto fabric or objects, e.g. *Tabernacle* (Fig. 4) a multimedia installation with video projection, bounced off a convex mirror, around the inside walls of a dome tent, giving the illusion it contains the elements water, wind and fire with figures mysteriously appearing in the midst.

Figure 4 Liz Waugh McManus*,* 2014, *Tabernacle,* Dome tent, 10 min video loop, projection equipment, convex mirror.

In the 2000s, concurrent with running Obelon Arts, I developed a sculpture practice, moving from clay/bronze to cast glass, learning skills through masterclasses and conversations with established artists: Irene Frolic, Tessa Clegg, Clifford Rainey, Stephen

Durrow, Max Jacquard, David Reekie and mentors Emma Woffenden[1] and Angela Thwaites. I was drawn to glass's capacity for solid forms with visible interiors and a range of transparent, translucent or opaque surfaces (Figs. 5 and 6). It offered many associations derived from properties or usage, e.g. fragility, vulnerability, shattering, sharpness, danger, visibility, exposure, liquidity, reflectiveness, vanity, glamour, containment, protection, preservation, or scientific enquiry.

Figure 5 Liz Waugh McManus, 2003, *Baptism,* cast glass on slate.

I first combined media and matter, video and glass, following a suggestion by my then mentor Angela Thwaites[2] to 'try something new' for *Recollect 2010*, an exhibition at Burgh House and London Glassblowing Gallery curated by Emma Woffenden and Matt Durran. I found that glass's special relationship with light, the degrees of translucency and reflectiveness possible, produced very ethereal, captivating effects with moving image projections, creating a sense of aliveness, a quality I had previously sought in animation and puppetry. I developed work (Fig. 7) exploring objects in the collection of curiosities first animated in *Openings* (2010). I crafted objects based on the originals and used moulds to cast these replicas in glass to become projection surfaces.

[1] Emma Woffenden mentored me in 2005 through Firstsite Gallery.
[2] Angela Thwaites mentored me in 2010 through the Contemporary Glass Society.

Figure 6 Liz Waugh McManus, 2006, *Openings,* kiln cast glass, (30 X 15cm). Photo: Graham Portlock.

As the series progressed, I played with the relationship between the digital and analogue aspects, e.g. taking photographs of both the original objects and glass replicas to incorporate in the animations or video-mapping the animations to fit the glass as in *Sisters*, (2014, 2018), Fig. 7, creating the element of surprise when the doll's house appeared to open up to reveal the interior.

Introducing digital media to create installations with film and animation projections onto related glass sculptural objects extended the capacity of my glass art beyond imagery to sound and time-based visual content. This allowed me to convey additional biographical and historical references and drew upon my experience of projecting onto a range of materials for theatre productions. I also built on strategies for engaging audiences through playful interactive projections and other multisensory experiences in theatre productions. In *Mirror* (Fig. 8), a piece about ageing and identity, I adapted a system using a webcam as a sensor and software used in a multisensory show, *Tick Tock!* to create an art piece which responded to a viewer's arm movements, whereby the image could transition between portraits of the subject as a teenager and older person.

Figure 7 Liz Waugh McManus, 2014-2018, *Sisters,* (Video still). In *Sisters*, mapped video projection onto crafted glass building facades enabled the unfolding of narrative elements over time.

Figure 8 Liz Waugh McManus, 2014, *Mirror.* In *Mirror,* a sensor and software allowed spectators to alter the projected image by playing with the artwork through their physical movements.

Combining digital media with glass sculpture, creating installations with film and animation projected onto related glass objects, and introducing interactivity, led me to the start of this research journey. When I expressed my interest in further researching interactivity for my glass practice, Senior Lecturer and Researcher, Jeffrey Sarmiento invited me as a guest artist to join a Craft Futures research workshop 'Crafting Conductive Circuits and Capacitive Surfaces' for staff and doctoral students held jointly between the Universities of Sunderland and Northumbria in July 2017. This showed me the potential of DIY electronics and conductive materials as means of introducing interactivity into glass artworks. It also opened my eyes to the potential of discovering new ways to introduce narrative tangibly through connecting glass artwork to video, audio or webpages.

A paper delivered at Making Futures conference gives a fuller description of this workshop that explored potentials for blending techniques of artisanal glassmaking with digital manufacture and electronics (Sarmiento, 2017). Initiated by Justin Marshall, Professor of

Design, and Jeffrey Sarmiento, with training on the Arduino microcontroller system and interactive sensors by creative technologist Thomas Dylan and glass techniques by Sarmiento, participants experimented with physical and digital materials resulting in test pieces and prototyped artworks. Results ranged from conductive graphite powder imagery fused in glass, stroke and rotational touch sensors of copper fused in glass, a 'light writer' using a Touch Board microcontroller, fused glass and LED strip to create a colour mixing instrument, to a capacitive cast glass and copper wire object which called up a webpage.

A follow-up Craft Futures workshop with staff and PhD researchers from both universities took place in May 2018, by which time I was a research student. It focused on IoT (Internet of Things) and explored how glass processes may be combined with digital interaction technologies to create IoT interfaces and interactions. Outcomes of the workshop included colour-changing glass samples, coated with thermochromic paint heated through resistance wire inclusions (Fig. 9); and a system linking a Particle Photon (an Arduino with a WIFI chip for IoT) with an Adafruit MPR121 capacitive sensor connected to crafted glass sensors to trigger sound, images or video hosted on webpages (Fig. 10). I trialled the system to trigger images and sounds from the local area on a laptop from an Internet page during the Glass Heap Challenge on Roker Beach organised by staff and researchers from the University of Sunderland.

'Crafting Interfaces and Digital Interactions with Glass' in Autumn 2019 was the last in this series of inter-university workshops. Over five days, training in Micro:bit by Thomas Dylan (coding, controlling LEDs, send/receive radio message, capacitive touch, light sensing etc.) was followed by practical sessions exploring ways glass may be combined with digital interaction technologies in ways that ultimately could result in interactive artworks. We employed various glass techniques (blowing, screen printing enamels and powders on glass, glass casting, sand-carving, water jet cutting and fusing) combined with conductive ink or copper wire.

The series of workshops explored the aesthetic and material qualities of glass for combining with digital interaction to create meaningful objects. They could be said to result in a variety of 'epistemic objects' (Richter and Allert, 2011) which fed into the ideas and technologies elaborated in the projects discussed in chapters 3 to 6 of this thesis. The backdrop to the series was "Crafting the Digital" (Wallace, Marshall and Rogers, 2015),

meaning "… (bringing the sensitivities of craft to the sphere of digital interaction) and Digital Crafting, (i.e. using the opportunities afforded by digital design and production tools within art/craft practices)" (Sarmiento, 2017).

Figure 9 Liz Waugh McManus, 2018, Colour change experiment using thermochromic paint on glass with resistance wire fused inside connected to a power supply.

Figure 10 (Left) Crafted touch and proximity sensor of graphite powder in fused glass. (Right) Connecting the sensor to a Particle Photon microcontroller to trigger images on a web page, 2018, Glass Heap Challenge, Roker Beach.

The impact of digital technology has been significant across craft and all creative industries. Digital imaging, design software and manufacture have become an established part of creating designs and prototyping creating a new aesthetic and opening up new forms of expression (Openshaw, 2015). More recently AI (Artificial Intelligence) image generators are making an impact. Some artists, makers and designers are moving beyond the use of software to using code as another material in their library along with more traditional ones to create generative artworks (Wallace et al., 2015). This has been assisted by a global maker movement (Make magazine, Maker spaces, Maker Faire, Fablabs and spin-offs) where amateurs, 'tinkerers' and artists explore electronics with other ways of making to find solutions for everyday problems. There has been a growth in affordable accessible open-source technology for physical computing, microprocessors, sensors etc., produced by new companies started by artists and engineers, with related online communities. This has supported artists in starting to 'craft the digital' by embedding electronics and conductive traces into traditional craft materials, bringing together digital methods of fabrication with craft methodologies in the fields of textiles (Buechley and Eisenberg, 2009; Buechley and Perner-Wilson, 2012a; Greenhalgh, 2016; Orth, 2001; Perner-Wilson et al., 2011; Taylor and Robertson, 2014; Veja, 2015), wearables (Berzowska, 2007; Berzowska and Coelho, 2005), jewellery (RTD Conference and Vones, 2017; Vones, 2015; Wallace, 2007), and paper (Coelho et al., 2009; Qi and Buechley, 2014). Human Media Interaction researchers from the University of Twente, Minuto and Nijolt (2013) concluded there is a need for more research into methodologies for creating new structures and ways of interacting with them.

Integrating electronics into traditional crafts is a way to develop new kinds of devices, broaden technology culture, and increase technological literacy among populations with little or no electronics experience (Buechley and Perner-Wilson, 2012; Qi et al., 2018). MIT Media Lab has been at the forefront of this research, in particular the High-Low Tech group, 2009-2014, which researched the blending of traditional crafts (mostly paper and textiles, but also painting and woodcarving) with embedded electronics (Buechley and Perner-Wilson, 2012; Maeda and Burns, 2004; Orth, 2001). British Universities such as Northumbria, Falmouth, Dundee, West of England, Heriot-Watt and Brunel have also led in research in smart materials and embedded electronics. Glass and Ceramics Department at the University of Sunderland has a digital agenda, with research outputs in CAD water jet cutting, 3D printing and digital imaging. For example, digital glass and ceramics research

includes that by staff and alumni Vanessa Cutler, Joanne Mitchell, Jeffrey Sarmiento, Erin Dickson on water jet cutting, Angela Thwaites on 3D printing for glass, Colin Rennie on 3D scanning and digital fabrication, Sarmiento and Kevin Petrie on digital image transfer, Theo Harper on 3D ceramic printing and Andrew Livingstone on clay and video.

Crafting the digital has coincided with a 'material turn' in computing and HCI (Human Computer Interfaces) over the last decade evidenced by a growth of research, conferences and publications in TEI (Tangible Embedded and Embodied Interaction) and TUIs (Tangible User Interfaces) (Wiberg, 2016). TUIs expand the affordances of physical objects, surfaces, and spaces so they can support direct engagement with the digital world. MIT's Tangible Media Group develops MUIs (Material User Interfaces) where the interface itself is a material in which digital information has a physical manifestation so a user can interact directly with it.

1.2 Research questions

My research is situated at an intersection between glass/mixed media and interactive media art, realised through physical computing and DIY electronics. It concerns methods of blending glass artwork with digital technologies to create interactive artworks and also ways the resulting interactions may both engage viewers and evoke narratives, atmospheres or meanings for them.
The different goals of the research are expressed in the following research questions:

Q1 How may qualities of glass and glass-forming processes lend themselves to blending with digital technology or embedded electronics?
Q2 How may glass be used with embedded electronics to create interactions that engage viewers?
Q3 How may blending glass with embedded electronics communicate narrative content through various media?

My research is positioned in the context of developments and applications into computing and design since the 1990s of blending electronics and conductive materials in various crafts, cited above. In the field of glass art research, the application of electronic circuitry, computational materials, internet connectivity or interactive sensors is now also emerging, explored for instance in Craft Futures and The Glass Electric workshops (2018 Pilchuck

Glass School catalogue, 2017; Sarmiento, 2017), though it is far less prevalent than within contemporary fine art practice, (new) media, textiles or jewellery. As the glass art field expands from traditional studio practice, artists are embracing digital media, video, sound, and moving image. Blending craft with new technologies, a small number are exploring digital interactivity. Glass is a particularly productive material for creative practice-based research, as it can incorporate conductive materials (such as copper and graphite) through a myriad of forming techniques including waterjet cutting, etching and electroforming. It also offers many properties for digital augmentation. MIT researcher David Rose (Rose, 2014, pp 71-143) has documented various 'superpowers' with which digital technology may augment physical objects. Glass has the superpower as a shape-shifter owing to its amorphous state of matter, not solid, not liquid, allowing for a vast range of different states and viscosities. It can be formed through an extensive cannon of techniques into flat sheets, bubbles, enclosed forms, tubes, solid three-dimensional or delicate crystalline forms and can be opaque, reflective, mirrored, transparent, coloured etc. Its attributes include transparency, protection, containment, reflection, sparkle, waterproofness, and optical magnification and diminution. Copper is sufficiently ductile to be embedded in glass in small quantities allowing the integration of conductive traces without causing cracking. These characteristics offer special qualities for digital augmentation.

Digital art, craft and technology are becoming increasingly hybridised. Technologies once available to specialists are becoming more accessible to artists, makers, amateurs and tinkerers. Developments in modularisation of electronic components circumvent the need for industrial-scale processes to produce electronic products. The technological possibilities afforded by these new embedded and physical computing components suggest a plethora of ways they may be combined with glass to make interactive artworks. However, a goal of this study was to explore aesthetic and conceptual possibilities rather than technical innovation, and not to produce gadget-like pieces or to design functional objects, but use the technologies with glass to engage viewers while communicating narrative content. Similarly, Wallace (2007, pp. 59-60) advocates hybrid digital-craft artefacts for human-relational attachment, communication, and personal emotional significance rather than as gadgets providing fleeting amusement for their technological novelty.

Circuits, computing and smart craft materials can be used in artworks to sense stimuli, connect to internet data or network people and places. The Internet of Things (IOT), a

phrase coined in 1999 by Ashton, MIT Auto-ID Center co-founder (Ashton, 2009), refers to computers gathering information by themselves through sensors and internet connectivity. IoT consists of small embedded controllers that can sense the environment, 'talk' to each other[3] and share and receive online data. Designers are discovering many new applications by embedding electronics in everyday things to enable them to communicate via internet connectivity. IoT need not be limited to domestic design or environmental planning applications. My research explores the potential for developing an 'Internet of Glass Things' - glass sculptures as digitally communicating objects, through incorporating sensors and connectivity into glass art installations. Further entanglement of the physical and digital worlds in artwork may be seen in developments in Augmented (AR), Virtual (VR) and Mixed (XR) realities. These offer exciting possibilities, but are beyond the scope of this research, as is Artificial Intelligence and Machine Learning, although future research in these areas is explored in Chapter 8.

I have coined the phrase 'Internet of Glass Things' to describe glass artwork that is interactive through the integration of sensors, microcontrollers, and actuators. There are established terms for other crafts augmented with computational materials, such as e-textiles short for electronic textiles, smart textiles or paper circuits. However, there is no equivalent term in common usage for glass. I considered using e-glass, however, this term is already used for 'electrical glass' fibre for synthetic composite reinforcement in electrical insulation applications or 'low-e glass', which has a coating to lower transmission of UV and IR light. Smart glass is already used for a product with a coating which changes the opacity of the glass when an electrical current is applied. Glass circuits as a term is limited by its usage to describe circuit boards on a glass substrate. Internet of Glass Things was preferred as a more open term which can refer both to glass physically blended with electronic circuitry and the use of glass alongside electronics in interactive systems.

Q1 My first question, 'How may qualities of glass and glass-forming processes lend themselves to blending with digital technology or embedded electronics?' seeks to build on research begun during the Craft Futures Workshops discussed above, to "Produce pieces of work with greater fidelity and finish that draw on the shared knowledge gained of both the digital and analogue processes" suggested by Sarmiento (2017). Although this included iterative processes, it did not include structured material and process testing, but

[3] i.e. by digital communication protocols.

continued the creative practice approach that favoured contextual relevance over technical innovation.

This research also investigates how the incorporation of DIY electronics into glass artworks can enhance both expressive potential and audience engagement. A driver for the research is the application to glass art of new technologies which have recently proliferated and become available to a demographic with less in-depth knowledge of electronics, but it has been important to subject it to my existing artistic concerns and modes of working.

Q2 The second question 'How may glass be used with embedded electronics to create interactions that engage viewers' not only includes the mental discourse that happens when a viewer contemplates artwork, but the additional layer of viewer/object interaction when an artwork is activated through digital technology. I characterise my approach to the research in the context of my past practice in which I aimed to engage with an audience through creating and animating artefacts, images and puppets for theatre and through exhibiting multimedia sculptural installations. This practice often incorporated technology (e.g. video, projection, interactive software) integrated with physical objects, rather than screen-based, to create artwork with multiple channels for conveying metaphor or narrative with personal emotional significance.

Exploring physical computing and embedded electronics/computational materials alongside glass offered new ways of engaging with an audience and animating an artwork to extend my practice. Initial projects (in Chapters 4-5), explored the quality of animacy, enabled through hybrid analogue and digital making, to engage viewers. In later projects, (Chapters 6-7), this included the physical relationship with artwork, whereby sounds mapped onto objects were released through touch or proximal gesture. Touch-activated glass artwork will challenge the customary relationship between visitors at a glass exhibition and the art objects, where the norm is 'look, don't touch' the glass. I reflect that some curatorial decisions may be needed to circumvent audience reticence to touch glass artworks and encourage audience engagement, such as the use of signage, labelling, facilitators or explanations added to the catalogue.

Q3 The third research question 'How may blending glass with embedded electronics communicate content?' expands on one of the avenues for future research identified by

Sarmiento, to “think more critically about the ways in which glass interfaces to digital interactions have meaning and significance” (2017). It concerns ways in which the integration of interactive media enhances its expressive potential, meaning the capacity of an artwork to convey stories, trigger associations, memories, emotional resonance or connect people to places, experiences and aspirations.

These second and third research questions fall in the context of wider interactive and media art which has developed since the 1960s, with specific relevant examples discussed in Chapter 3, the contextual review. Conducting the review opened my mind to the range of concepts, technologies and strategies explored throughout the history of interactive art. The landscape of interactive art not only revealed varied technologies, content and themes, but also ways that the process of interactivity could be used to engage the audience. Through reviewing literature, I identified commonly occurring attributes of interactive art. These qualities or characteristics offer ways to engage audiences. I selected ones which related to my past practice and current interests (Interactivity, Playfulness, Enchantment, Animacy, Embodiment, and Telepresence) to explore in practical projects that would address my questions concerning communicating content and engaging viewers.

1.3 Aims and objectives

Aims:

- To investigate the creative possibilities of incorporating interactivity or connectivity in glass artwork.
- To utilise fabrication techniques in both glass and DIY electronics for developing digitally-communicating glass artworks.
- To blend traditional and new glass techniques with electronics to introduce interactivity for triggering outputs, such as video, light or sound, activate motors or produce colour changes.

Objectives:

- Create new interactive digitally-communicating glass artwork.
- Investigate ways electronics may be embedded through adapting traditional and new glass-making processes.

- Investigate creative applications of connecting with internet data or environmental sensors.
- Engage viewers through animacy and playfulness.
- Observe, evaluate and analyse audience interaction with some artworks.
- Investigate and adapt methodologies for embedding digital communication in other crafts.
- Record and disseminate findings to expand the creative vocabulary of artists, designers or educators.
- Explore new methods of working in a post-COVID environment.

1.4 Thesis Structure

Following this introductory chapter outlining the background to the research, research questions, aims and objectives, the thesis is divided into seven further chapters:

Chapter 2 explains my choice of the multi-method practice-based methodology used to investigate the development of an Internet of Glass Things and answer the research questions discussed above. The overarching methodology of bricolage included 'doing it with others', comprising networked/proximal artistic collaboration, workshopping, alongside prototyping, tinkering and evaluation methods.

Chapter 3 is a contextual review with two main sections. It begins by surveying the wider field of interactive art and its theoretical underpinnings, discussion and key attributes of interactive art that I have chosen as the framework for engaging viewers. These attributes - Interactivity, Playfulness, Enchantment, Animacy, Embodiment, and Telepresence – inform my strategy for the practical projects in this study. The last section is a brief introduction to the development of computational crafts and a survey of digital glass art including digitally interactive glass, introducing it to the academic context and identifying the gap this research aims to address.

Chapters 4 to 7 set out the practical research projects. Each is divided broadly into an Introduction to the Aim, Description, Engagement and Analysis.

Chapter 4 is a discussion of the project *Stateless Vessel*, an artwork about the Mediterranean migrant crisis. This artwork built on experiments blending electronics and glass processes carried out during the Craft Futures digital crafting workshops and subsequent developments in the studio. *Stateless Vessel* engages the viewer through visual animacy of moving shadows of blown and cast glass elements, achieved through physical computing using a microcontroller and LED pixel strip.

In Chapter 5, I discuss *Jeopardy,* the first finished artwork where I introduced interactivity, using a microcomputer (Raspberry Pi), glass, animation and mixed media. *Jeopardy* is an artwork designed to explore an interactive system responding to global events through data streamed from the Internet. It explores telepresence and animacy through physical and visual responses representing seismic data from around the world, highlighting the precarity experienced by those living in earthquake zones.

Having explored connection and response to Internet data, Chapter 6 charts the development of artworks which respond to the physical presence of a viewer, specifically their touch or proximity, using a Touch Board microcontroller. The chapter describes two methods of introducing conductive traces into glass artworks, copper electroforming, a technique I first learnt during The Glass Electric class at Pilchuck Glass school discussed in Chapter 3 and intaglio with conductive ink, the development of a method we had used during the Craft Futures digital crafting workshops. *She's Got the Wrong End of the Stick …* and *Hearing Instrument*, glass and copper interactive sonic artworks about living with deafness, are discussed. The *She's Got the Wrong End of the Stick …* project also included explorations of chemical interaction in the production of a series of cyanotype using glass and copper-crafted artefacts and items associated with a form of deafness called otosclerosis. These 'sun prints' were made during the Summer heatwave of the 2020 COVID-19 lockdown. *Bin Bag Hug,* also a glass artwork with interactive sound is included in this chapter as another method of embedding conductive traces in glass. It built on research into conductive ink for 'paper circuits' and printmaking (etching) methods.

Chapter 7 covers a series of projects developed during the COVID-19 pandemic. I had originally intended that my final project would be a glass installation interactive on two levels, with live-streamed internet data and embodied interaction with physically-present viewers. The pandemic changed the course of my research in a number of ways. For a long

time, I was unable to access the university in person for technical support and a planned exhibition was cancelled where I had intended to collect data on audience response to my artwork. However, the pandemic also opened up new opportunities and altered the direction of my research in positive ways. Unable to meet physically, I attended conferences and seminars online which I would not have been able to access at physical venues in other parts of the country and world. This led me to meet new international collaborators, further exploring telepresence and to find new ways to make collaborative artworks, resulting in international exhibition opportunities and wider exposure. I made work related to the pandemic, but ultimately it prompted a change of direction in my practice to tackle issues of climate change and the environment, which continues today.

With the pandemic hindering in-person support from a creative technologist, rather than explore new technologies with glass as originally planned, I continued to use the Touch Board microcontroller for artworks with interactive audio, but progressed my research by exploring in greater depth how content could be communicated through blending glass with interactive media. The resulting three related practical projects discussed in Chapter 7 were *When We Touch Again*, *1.5 Degrees of Concern* and *After the Storm.*

Chapter 8 reflects on how the research questions have been answered and documents my conclusions, the impact of the research and suggestions of areas for future research. It traces ways that the research has changed my artistic practice. Areas for future research that are beyond the scope of this inquiry are outlined. Some relevant contexts are suggested where artists or designers may wish to apply an Internet of Glass Things. Work in progress *Deben Matters* is discussed, the project addressing two levels of interactivity, with livestreamed internet data and embodied interaction with physically-present viewers. The chapter ends with the contributions to knowledge made by this thesis and the associated artworks created during the PhD.

There are three Appendices:
Appendix 1 has a glossary of technical terms.
Appendix 2 includes details for some artworks in this study about electronics, code and ways of introducing conductive traces in glass.
Appendix 3 has transcripts of audio for sonic artworks in the study.
Appendix 4 contains documents relating to audience and participant feedback.

2 Methodology

Janneke Wesseling (2016), Chair of Practice and Theory of Research in the Visual Arts, defined artistic research as 'the critical and theoretically positioned reflection by the artist on her practice and on the world, in art and in the written text.' This research is practice-based, seeking new ways to make artwork and critically examining the process in order to combine digital technologies and analogue practice. The research sits inside the digital craft domain in the Glass and Ceramics department at the National Glass Centre, which is discussed in Chapter 3. Whilst informed by theories drawn from a range of disciplines and artistic expressions, outlined in the contextual review in Chapter 3, my research questions are answered through successive interactive art projects.

2.1 Practice-based research and the reflective practitioner

Academic and writer on practice-based research and interactive arts, Linda Candy stresses the role of the artefact (object, installation or performance) in demonstrating contribution to knowledge in practice-based research in the field of interactive art (Candy and Edmonds, 2011, p.36). She also explains how practice-based research is conducted through exploratory and experimental making processes which provide opportunities for reflection and evaluation, and inform new questions that are addressed, in turn, by further making, reflecting and evaluating (2011, p.37). Candy points out that this process where new questions evolve during making varies from traditional research methods where questions are established in advance. My research questions were framed following experiments in blending glass and electronics at the aforementioned and subsequent Craft Futures research workshops, however, the way they were answered flowed from reflections on a succession of artworks developed through playful processes discussed below. Candy explains Shon's reflective practice as underpinning practice-based research whereby the creative practitioner through 'reflection-in-action' makes explicit some of their tacit knowledge embedded in action in order to make changes for improvement (2011, p.43), an approach employed across disciplines from glass (Thwaites, 2018) to new media (Graham, 1997).

Ingold characterizes things and ideas as ever-emerging together through the ongoing improvisational process in artefact making "on the one hand in the flows and transformations of materials and on the other hand the movement of the imagination on

the sensory awareness", rejecting traditional Western hylomorphic understanding of artefacts as materializations of their maker's preconceived ideas (Institute for Northern Culture, 2013, 4:09-4:22).

The artworks in this study were not made following a typical systematic sequential 'research for design' model whereby a problem is identified and analyzed, a solution proposed, and a prototype made, tested and probably refined iteratively (Scrivener, 2011, p. 64). Artist and academic, Stephen Scrivener in his theoretical inquiries into art and design practice-based research acknowledges the problem-solving theory-led approach limits the potential for new knowledge and understanding in visual arts PhDs, by focusing on the generation of new theories and ignoring the role of artworks themselves in innovation and new knowledge exchange. He recognized that inquiry through making and reflecting in "creative production" is "engaged with a plenitude of social, cultural and political issues, concerns and interests in a highly associative manner…" that are manifested and presented to others in artwork (2011, p.68). Therefore, he concludes that "non-propositional, non-argumentative, non-linguistic modes of thinking, doing and expressing are essential to the acquisition, recognition and exchange of new knowledge and understanding in the art and design spheres" (2011, p.68).

Therefore, I followed an 'art and design knowledge production' model, proposed by Scrivener as an alternative to the problem-solving theory-led approach (2011, p.70), whereby everyday practice is problematized to generate the unexpected. I introduced the novel combination electronics into my existing glass, multimedia and socially-engaged practices to yield new understandings. Scrivener applies Schon's notions of 'repertoire' and 'appreciative system' to doctoral research where creative practitioners reflect upon, interrogate and consciously expand both their appreciative system and their repertoire iteratively through their project (Scrivener, 2002).

Following Scrivener, I added new digital technologies to my 'repertoire' and used them in accordance with the sensibilities of my artistic 'appreciative system'. Building on methods and techniques already established in my art practice, e.g. kiln-forming glass or animation, this study has brought me new knowledge and techniques of DIY electronics and digital making. It has also required me to adopt methodologies not used previously, such as

tinkering and prototyping, and to synthesise into my visual art practice ways of working, e.g. collaboration, that I had previously used in other disciplines such as theatre.

2.2 Bricolage

My overarching methodology is Bricolage. In *The Savage Mind*, Lévi Strauss (1966) discusses approaches to observation and reflection using the metaphor of the 'Bricoleur' (handyman, tinkerer or DIY-er) who tackles diverse tasks with materials and tools they have at hand, contrasted with the 'Engineer' who conceives and procures sets of custom tools and materials in advance of each specialized project. Since then, the concept of 'bricolage' has been elaborated and represented as a multi-method qualitative research methodology across diverse fields, including art and design, contrasting with the positivist scientific approach of the 'Engineer'. The bricoleur or 'do-it-yourself researcher' uses:

> **tools of his methodological trade, deploying whatever strategies, methods or empirical materials are to hand. … if new tools have to be invented, or pieced together, the researcher will do this…the choice of which tools to use, which research practices to employ, is not set in advance. The choice of research practices depends upon the questions that are asked, and the questions depend on their context … what is available in the context and what the qualitative researchers can do in that setting** (Denzin and Lincoln 1994 quoted by Gray and Malins, 2004).

Bricolage is a methodology suited to the messy complexities of the interdisciplinary, multi-layered, entangled and emerging nature of my art practice. Denzin and Lincoln (2018, p.45) distinguish different types of bricoleur: methodological, interpretive, theoretical, narrative, critical and political, the first three of which are particularly relevant to this study. "The interpretive bricoleur produces a bricolage, that is, a pieced-together set of representations that are fitted to the specifics of a complex situation…The methodological bricoleur is adept at performing a large number of diverse tasks, ranging from interviewing to intensive self-reflection and introspection" (Denzin and Lincoln, 2018, p.45). The theoretical bricoleur reads widely and brings different interpretive paradigms and perspectives to the problem (2018, p.45).

Methodological tools in this enquiry include reflective practice, tinkering, artistic prototyping, collaboration (artistic or pedagogic), and evaluation through observation and questioning. Theoretical analyses are drawn from art, performance, media and film studies, anthropology and psychology. Multi-methods have enabled me to progress research through diverse projects that have built from exploring potentials of physical computing, microcomputers, microcontrollers and associated sensors for my artwork, to

experimenting with techniques for introducing conductive materials to glass to make interactive interfaces, to artworks on complex themes which focus on audience interaction and engagement. Practice-based PhD studies in art and design at the University of Sunderland employing bricolage as a methodology include Collier (2011), Dickson (2015) and Harper-Davis (2022). The notion of bricolage elides with the material practice in this enquiry e.g. avoiding glass specialism and employing mixed/multimedia with heterogenous glass-forming techniques tailored to each project; or tinkering with DIY electronics, rather than engineering designed projects; or using recycled materials out of environmental concern.

2.3 Doing-it-with-others

This research uses several methodologies that come under the umbrella 'Doing It With Others' which have grown over the course of this study from past experiences of collaboration, in devising for theatre productions, film-making, socially engaged, community participatory or pedagogical arts projects and workshops. Collaborative working practices represent a general trend in contemporary art operating in a networked age. Collaborative strategies, political and social ethics of authorship and distribution in Open Source software development and participatory art have been compared and explored by Smith (2011). Open source technologies and Internet learning mean that in contemporary art and craft, authorship is expanding beyond the traditional 'one artist, one artwork' model to collective art-making. Furthermore, artists adopt collaborative practices to tackle big contemporary issues such as social inclusion, economic justice or climate crisis. Artist collectives are gaining exposure in mainstream art, e.g. all five nominees for the Turner Prize in 2021. The nature of new digital technologies also necessitates cross-disciplinary expertise and collaboration is commonplace in fields of computational art, physical computing and new media, evidenced in hack/makerspaces and art and design research labs. As Candy states "Interactive art is an emergent art form that increasingly depends on digital technology. Creative practitioners who seek to exploit the potential of that technology for their art are often faced with considerable obstacles to be overcome. Many go down the route of collaboration with experts in computer technology whilst others become expert themselves" (Candy and Edmonds, 2011, p.28). Bradbury and O'Hara (2019) also discuss the Do it Yourself culture of art, making and innovation communities and the necessity for collaboration and skill sharing in many new media projects.

2.3.1 Tele/presence: networked and proximal artistic collaboration

"As artists working in network culture we work between individual, coordinated, collaborative and collective practices of expression, transmission and reception" (Catlow and Garrett, 2012).

Catlow and Garrett of (new) media organisation, *Furtherfield,* as an extension of the DIY net art ethos, proposed DIWO (Do It With Others) in a 2006 campaign as "a contemporary way of collaborating and exploiting the advantages of living in the Internet age that connected with the many art worlds that diverge from the market of commoditised objects – a network enabled art practice, drawing on everyday experience of many connected, open and distributed creative beings and intentions" (Catlow and Garrett, 2012).

The approach of Networked Workshopping and Collaboration developed following the COVID-19 pandemic when artists and researchers circumvented being unable to meet in the same physical space for explorative workshops/hacks by developing the practice online. While the COVID-19 pandemic closed down physical face-to-face local workshopping opportunities, new global online possibilities and interactions opened up. *Future Focus: Art Hack Practice III* (*Future Focus*, 2020) webinar organised by UoS staff/alumni Suzy O'Hara and Victoria Bradbury with FutureEverything considered implications of the pandemic and post-pandemic times for art hack working practices, particularly on community, engagement, collaboration or education during this time when more turn to online spaces. Since 2020, my artistic collaborations and pedagogical projects have been conducted using blended online/proximal methods. My inquiry into telepresence via Internet of Things technology had begun the previous year. My research through physical workshopping events was replaced by an ongoing *Touch Collaboration* project, discussed in Chapter 7, with Professor Kristine Diekman and Lisa Mansfield, using synchronous and asynchronous networked communication methods to discuss and explore methods of making interactive art and sound, plan new work and write proposals. We also shared telematic performances of Work in Progress with each other. Artist collaboration, proximal as well as networked, continued with Dr Angela Thwaites.

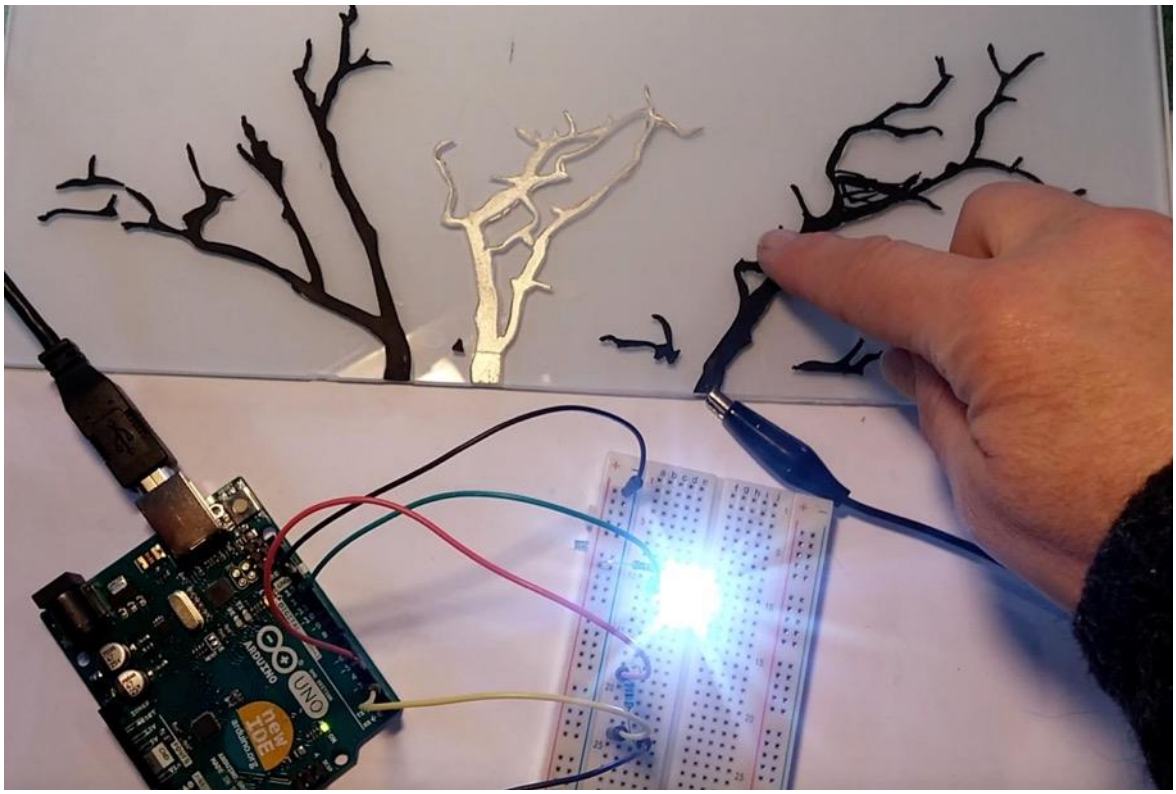

Figure 11 Liz Waugh McManus, 2018, Experiment to trigger a Light Emitting Diode through touch, Arduino, breadboard, sand-etched glass and conductive ink that was made during the first 'Crafting Conductive Circuits and Capacitive Surfaces' workshop.

2.3.2 Exploratory workshops

As mentioned above, my introduction to the potential of DIY electronics for interactive glass art was on the 'Crafting Conductive Circuits and Capacitive Surfaces' explorative workshop (Fig. 11). This and subsequent series of explorative workshops to which I contributed with Jeff Sarmiento, Justin Marshall and Thomas Dylan, ('Internet of Things' 2018 and 'Crafting Interfaces and Digital Interactions with Glass' 2019) played an important role in progressing this inquiry. In exploratory workshops, diverse artists, researchers and academics come together to share time, space, tools and materials to playfully address a particular topic without a predetermined goal. This distinguishes workshops from collaboration, where collaborators share a goal and work towards a more specific outcome. This culture of jointly engaging in a particular focus, sharing ideas, knowledge and resources is part of the trend in art working practices derived from the Maker movement. Generosity, inclusivity, creative engagement with technologies and digital fabrication characterise this movement, although in practice, aims, priorities, working practices and outputs are diverse (Bradbury and O'Hara, 2019). The term 'Hack' could be used, but is avoided because, although its use is more general now, the word originally referred to

competitive commercial situations where teams of researchers would compete over 24 hours to produce solutions to specific briefs. Arrigoni (2017, pp. 19 -22) gives an historical overview of Hack and Maker Spaces, Fab and Media Labs.

Explorative Workshops though not explicitly collaborative, provide opportunities for knowledge sharing through discussions, skill sharing, demonstrations and observation, acting as a temporary artistic research lab. Not to be confused with the pedagogical practice of 'running a workshop', this method refers to a collegiate group, in this case staff and PhD researchers at the Universities of Sunderland, Northumbria and Newcastle, learning about and researching a subject together, playfully experimenting with techniques and affordances.

Explorative workshopping has been significant in progressing research in the early to mid-stages. Research questions, aims and objectives were formulated during and following reflection on the process of exploring various microcontrollers and sensors; coding using the Arduino IDE[4], MakeCode and Scratch (Arduino, 2023; Microsoft MakeCode, n.d.; Scratch, n.d.), trialling methods to blend conductive materials with glass to create crafted glass circuits and connecting them in temporary systems to create outputs such as audio, light effects, colour changes in thermochromic materials, or links to networked videos or images.

2.3.3 Coding

Code, the text used in computer programming languages, is produced by programmers to send instructions to computing hardware in a process of writing, compiling, testing, reworking, editing and updating. In the following chapters, I discuss 'animacy' as a key attribute of interactive art and as a characteristic that can be used to engage viewers. At a fundamental level, 'code' is the factor that animates all the artworks in this study (apart from the cyanotypes in Chapter 6). Over time code performs the background processes that run the artworks, executing commands that connect to Internet pages, stream live data or operate sensors and outputs. Graham and Cook (2010, pp. 97-98) discuss computability, real-time and liveness in media artworks and note the 'real-time generative nature and performativity of the computer programme itself'. The phrase 'performativity of code' derives from Arns' essay applying the notion of linguistic performativity to the analysis of computer programs and software art: "Code as an effective speech act is not a

[4] Integrated Development Environment

description or a representation of something, but on the contrary, it directly affects, and literally sets in motion or it even 'kills', a process" (2004, p. 186).

In developing the projects described in this thesis, I often began by using or adapting Open Source code available on the Internet, e.g. tutorials on video sharing platforms or example sketches available on the Arduino IDE, where code is written to upload to an Arduino microcontroller. The programming languages used were Python for a Raspberry Pi microcomputer and Arduino (based on C++) for the Touch Board microcontrollers. I experimented with code sketches for Touch Boards provided by Bare Conductive and produced by an independent programmer for another project. I enlisted help from experienced programmers to achieve my intentions for some of the final artworks, (*Stateless Vessel* in Chapter 4, *Jeopardy* in Chapter 5 and *1.5 Degrees of Concern* in Chapter 7) explaining what I needed the code to perform. The final sketches or scripts were produced in a back-and-forth collaborative process whereby they sent me code to test with an artwork and I fed back what did or did not work. I then modified the code until it performed as desired, often with suggestions from the programmer. I have credited the programmers with respect to the specific projects in each chapter and in the examples of code in Appendix 2.

2.3.4 Pedagogical workshops

Pedagogical workshops, another form of 'doing it with others*',* participatory or socially engaged practice have been significant throughout my career and played a valuable part in this research. Workshops provide opportunities for dialogue and knowledge exchange between the facilitator and participants. Teaching a subject requires reflection, reinforces knowledge and provides a platform for new ideas to develop. During the last four years of the PhD, I ran several projects based on knowledge acquired during the research, on e-craft, DIY electronics and interactivity. Such projects provided avenues to disseminate my research by formulating participatory activities to make interactive artworks using conductive materials. During the period of research for this thesis I have conducted workshops with primary and high school students and a children's arts club, (not documented in this thesis), and as part of my research with University of Sunderland students for *When We Touch Again*, discussed in Chapter 7.

2.4 Prototyping and Tinkering

The improvised experiments carried out in exploratory workshops gave rise to ideas for developed artworks discussed in Chapters 4, 5 and 6, *Jeopardy, Stateless Vessel* and *She's Got the Wrong End of the Stick…* These artworks could be described as prototypes, not in the sense of iterations in a design process or model for production, but in the sense of instantiations or archetypes of ideas, e.g. *Jeopardy* developed from the idea to connect to real-time Internet data to create an effect in glass, *Stateless Vessel* to explore lighting effects with glass and LED pixel strips and *She's Got the Wrong End of the Stick….* to create a glass and copper interface to trigger audio. Arrigoni (2017, p 3) states "Prototypes intended as an outcome in itself, rather than a step towards manufacture, are regularly generated within Research through Design (RtD) and Practice-based Research (PbR), as tangible instantiations of hypothesis or testing environments to explore and evaluate ideas". However, as artworks with their own layered narratives, they can be read on many levels so it would be reductive to view them as simply prototypes. The goal is the creative exploitation of new technologies for artwork and not technical innovation.

Tinkering, an exploratory playful approach to a problem, is a method used in DIY electronics which aligns with the playful approaches to devising already in my artistic practice. Tinkering, not only with electronics, but with glass and mixed media continued throughout the arc of exploring possibilities in the Tactile-Sonic projects discussed in Chapters 6 and 7. MIT Media Lab researchers Resnick and Rosenbaum (2013, pp. 164, 165) describe Tinkering as a 'project-based, experiential approach to learning' that includes conversation with the material:

> **The tinkering approach is characterized by a playful, experimental, iterative style of engagement, in which makers are continually reassessing their goals, exploring new paths, and imagining new possibilities…Tinkering is a playful, exploratory, iterative style of engaging with a problem or project. When people are tinkering, they are constantly trying out ideas, making adjustments and refinements, then experimenting with new possibilities, over and over and over …. play is a style of engaging with the world a process of testing the boundaries and experimenting with new possibilities.**

Tinkering may be collaborative - Maker forums evidence that Tinkerers are not averse to seeking advice about how to achieve their project goals. Tinkering gives flexibility to take on new ideas and directions during a process so that the final result may diverge slightly from the original plan.

2.5 Evaluation of audience response

In answering my second question, I considered audience response to the interactive glass artworks in this study. Audience feedback had been an important aspect of my puppetry and theatre experience and led to a desire to understand how the performative interactive IoGT artwork would be received. I wanted to gauge whether the interactive artworks functioned technically as planned, how absorbed visitors were with the artworks and whether they engaged them intellectually or emotionally. Candy and Edmonds (2011, p.74) stress that understanding public engagement with interactive art systems is vitally important both to the creative practice of artists making interactive art and curators trying to deliver engaging experiences. Prototyping and evaluating audience interaction confirms whether or not the artist's intentions are achieved and helps to improve their design (Muller, 2006). I had intended to formally evaluate visitors' reactions to interactive glass artwork using a method developed at Creative and Cognition Studios (C.C.S.) of the University of Technology, Sydney, (Costello and Edmunds, 2007, p. 82) called 'video-cued recall'. In this method, an individual or a pair is video-ed interacting with an artwork and then shown the video as a prompt to discuss their experience. I planned to do this at an exhibition in 2020 at Shipley Gallery of work by researchers who took part in *'Crafting Interfaces and Digital Interactions with Glass'* workshop*,* however this was cancelled due to the COVID-19 pandemic. I therefore changed the focus in answering, 'How may glass be used with embedded electronics to create interactions that engage viewers?', shifting the balance from audience feedback to the artworks to my creative choices and subjective reactions as an artist.

However, while the focus of this study was from the point of view of the artistic practice in creating interactive artworks in glass, there has been some qualitative evaluation of how participants and visitors responded to the works which informed my analysis of each project. Feedback was sourced from informal questioning and observation of viewers, written comments left in a gallery visitors' book and observations made by museum staff. For *Stateless Vessel* and *Jeopardy* (Chapters 4 and 5), I received informal feedback from people who viewed the artworks at my studio or videos of them on my website. Qualitative data for the interactive glass art project *When We Touch Again* in Chapter 7 was collected through a participant questionnaire (see Appendix 4). I also gave the participating students a list of questions concerning visitor response to the artworks and they collected some

comments at the first pop-up exhibition for me (Appendix 4). I made first-hand observations of interactions and had discussions with visitors at exhibitions: two pop-up exhibitions in the foyer of the Glass and Ceramics Department for *She's Got the Wrong End of the Stick… Hearing Instrument, Bin Bag Hug* (Chapter 5) and *When We Touch Again* (Chapter 6); the British Glass Biennale for *She's Got the Wrong End of the Stick…;* and Wolverhampton Art Gallery for *After the Storm* (Chapter 7). As I could not personally attend exhibitions that took place in the US, Diekman shared forty-three photographs and forty-seven video clips of visitors interacting with *1.5 Degrees of Concern* (Chapter 7). Diekman shared her own observations and discussions with visitors at both exhibitions of *1.5 Degrees of Concern*. We explored installing an ipad or notepad as part of the *1.5 Degrees of Concern* installation at MSUM in order to capture audience responses, but this was not possible. I arranged that the museum would provide its data about the overall exhibition, audience numbers and comments, however this was not forwarded. I video-called the museum assistant at Bonita Museum and Art Center and took notes of her observations about ways visitors interacted with the *1.5 Degrees of Concern* installation. I photographed the comments in the visitors' book for Collaborations exhibition at Wolverhampton Art Gallery and transcribed comments that specifically referred to *After the Storm* (Chapter 7) to refer to in my analysis. Formal testing of how audiences respond to IoGT artwork using the 'video-cued recall' method is proposed as an area for future research in 8.4.3.

3 Literature/Contextual Review

3.1 Introduction

Interactivity is at the core of this study into digitally communicating artwork and the development of an Internet of Glass Things. Interactive art is a field that can be traced to the late 1950s with roots stretching back to the nineteenth century. Historical surveys trace streams and influences between (New) Media, Computer Art, Digital Art and Interactive Art (Candy and Edmonds, 2011; Kwastek, 2015). Linda Candy and Ernest Edmonds include a historical timeline of Digital Art History up to 2000 by Nicholas Lambert, including selected key figures, artworks, events and publications associated with cybernetics, computer art, systems art, gaming and so on (Candy and Edmonds, 2011, pp. x-xi). This is followed by a discussion by Edmunds of the chronological development of the field to 2011 (pp. 20-32). Edmunds starts with Marcel Duchamps' motorised *Rotary Glass Plates* (1920), progressing through artworks involving the active audience participation such as Nicolas Schöffer's *CYSP 1* (1956), a dynamic sculpture that interacted with a dancer using photoelectric cells and microphones as sensors. Edmunds moves on to works in the 1960s employing electronics, such as Gordon Pask's cybernetic *Colloquy of Mobiles* (1968), and computer-driven interactive sculpture, e.g. Edward Ihnatowitz's *The Senster* (1970) before describing how interactive art burgeoned with the advent of personal computers, including image processing systems which could detect a viewer's body movements to generate image transformations.

My survey of developments in the broader field of interactive art was conducted to develop understanding of the context of my practice in order to inform and direct my research in several ways, by:

- enabling me to consider some of the theoretical underpinnings of interactive art
- revealing possibilities of what may be achieved by applying existing interactive and electronic art practices with glass art
- enabling me to consider key terms for creating a methodological framework for and analysis of my practice
- considering strategies for engaging viewers in interactive art
- identifying research gaps

I will present the survey through the lens of the key terms I have identified in this study - Interactivity, Playfulness, Enchantment, Animacy, Embodiment, and Telepresence. The discussion of key terms is presented in the form of a contextual survey of relevant art practice. Figure 12, below, shows a chart of concepts drawn from literature related to attributes and qualities for audience engagement in interactive art. Many concepts align although nomenclature may differ between authors. The attributes in green are those identified and explored in this study. In addition to Animacy, Enchantment and Playfulness, Ambiguity and the Sensuousness of materials are notions discussed in analysis of the artworks produced.

3.2 Discussion of key terms for strategies of engagement

3.2.1 Interactivity

The words 'Interactive' and 'art' together can evoke several different ideas. The term is used in reference to participatory arts, computer arts, and new media to denote widely different artworks, ranging from analogue that require physical activation to screen-based where the viewer[5] simply makes decisions in the digital formation of the artwork.

It can be argued that all art is interactive in the sense that it takes place between the artwork and the mind of the viewer. As Fenemore (2007) says, in distinguishing between dialogical and social interaction in art, "watching is an interactive act, using as it does tactics of self-consciousness, self-reflection, self-monitoring, thinking, processing, understanding and working in a dialogical mode where meaning is produced somewhere between the observed and the observer, the artwork and the spectator". However, my focus is not solely the conceptual and affective interaction between viewer's mind and an art work, but also entails technological and physical interaction, discussed below.

[5] In the thesis for variety I use 'viewer', 'spectator', 'participant', 'recipient', 'viewer-cum-participant' and 'audience' interchangeably to denote the person interacting with an artwork. Viewer and spectator are used even when senses other than sight, such as hearing or touch, are also involved when interacting with an artwork.

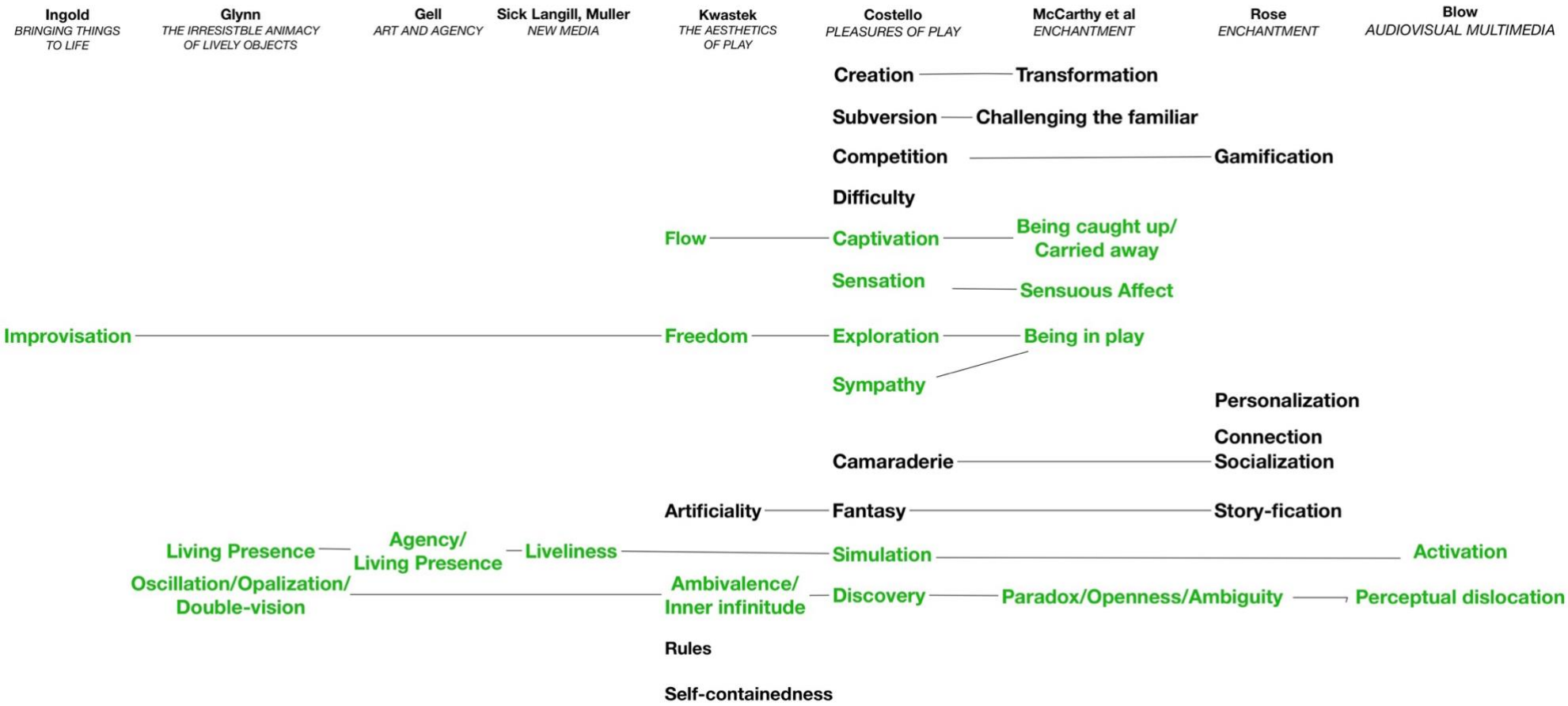

Figure 12 Audience engagement attributes identified from literature review (Blow, 2014; Costello and Edmonds, 2007; Gell, 1998; Glynn, 2019; Kwastek, 2015; McCarthy et al., 2006; Rose, 2014; Seck Langill and Muller, 2016). Text in green are the attributes explored in this research

The type and degree of audience interaction have been debated in interactive art and new media circles since the 1960s. Some interactions are simple cause-and-effect reactions, in some the audience can make a limited number of choices predetermined by the artist, referred to as the 'illusion of interactivity' (Manovich, 2002), and others are more open so there is a genuine interplay where audience/viewer can make real-time decisions which generate changes in the artwork. Candy and Edmonds (2002) elaborate on categories of interaction in art systems first defined by Cornock and Edmonds (1973) ranging from 'Static' where the artwork is unchanging, through 'Dynamic-Passive' where it is influenced by mechanisms or environmental factors in ways predetermined by the artist, to 'Dynamic-Active' where there is a feedback-loop so that a participant can influence the artwork, to Dynamic-Interactive (Varying) where the artwork is modified by the process of participant interaction. They state that the audience in some sense completes the creative process through their actions, speech or mere presence affecting the performance of the artwork. Graham (1997) discusses different models of interactivity in computer-based art and proposes the metaphor of a conversation between audience and artwork.

Stimulus-response artwork allows the audience to 'play' with it, even in a structured way rather than in a developing 'conversation'. The way the audience relates to an IoT artefact may differ from an interactive art system which has a binary relationship between recipient and the interface. An IoT device is characterised by connectivity and may have multiple input sources and be able to send data to multiple parties while operating autonomously from the user (Ghajargar, Wiberg, and Stolterman, 2018, p.24). The user may be actively engaged with such a smart device, or simply collect feedback it has gleaned from the system of information sources to which it is connected.

Since interactive art relies on the action of the recipient, it unfolds and exists in real-time in contrast to visual artwork more passively viewed in a gallery context. Kwastek (2015) in her introduction to *Aesthetics of Interaction in Digital Art* discusses the blurring of boundaries between the visual and the performing arts since the 1960s. She distinguishes Interactive Digital Art from other participatory art forms such as Action Art or Performance Art by the fact that the artist is not usually present as author when the audience/recipient experiences the artwork. Kwastek, like Cornock and Edmonds (1973), notes the participant completes the artistic process in an interactive artwork since the artistic concept is realised through their action. Kwastek proposes that participant interaction requires analysis of the

aesthetics of interactive art to use approaches across different disciplines, including those of 'play' theorists.

Stern (2013, pp. 5-6) defines interactive art/installations as

> **including works of electronic and digital art that feature: various forms of sensors or cameras for input; computers, microcontrollers, simple electronic circuits or other digital or analogical terminals for processing; and any form of sensory output – audio, visual, tactile, olfactory, mechanical, or otherwise; where all are placed together in a system that responds to the embodied participation of viewers, either in real-time, and/or over lengths of time.**

The artist creates an autonomous system with the inputs, processors and outputs whereby the performance of the recipient encounters the technological performance of the work.

Pioneering artists have created interactive artworks since the 1960s using the 'new' technologies of their time. For example, in Rauschenberg's *Soundings*, EAT, 1968 (Fig. 13) embodied participation takes the form of vocal interaction, enabling visitors' voices of different frequencies picked up by microphones to trigger backlighting of images screen-printed on Plexiglas.

Figure 13 Robert Rauschenberg, 1968, *Soundings,* EAT. Rauschenberg enables visitors' voices of different frequencies picked up by microphones to trigger backlighting of images screen-printed on Plexiglas.

Stern stresses the physical activity of a viewer-participant to realise such works in his definition of interactive art and excludes performances using interactive technology which are simply watched by an audience (2013, p.6). His primary interest is in 'embodiment', not simply framing interactive art by the technology through which it is realised, but by what it

does in the participant's body. On the other hand, Kwastek (2015) includes many examples of performances in her book on the aesthetics of interaction in digital art, though her emphasis is also on digital technology and she likewise excludes the non-digital interactivity found in art 'happenings'.

Kluszczynski (2010), like Stern, stresses that while the artist creates the framework for an interactive artwork event, it is brought to life and completed by the actions of the audience, (viewers, participants, performers, executors, or (co)creators of an artwork-event). He discusses and analyses a broader spectrum of digitally-interactive artwork than Stern to define eight strategies used by the artists to create the frameworks to engage audiences and which organise in different ways the common elements of interactive art - interface, interactions, data organisation (database, hypertext, cybertext), software/hardware system, relations among participants, and performance/spectacle. Kluszczynski defines these strategies by considering ways artists have used these elements over the history of interactive art from the 1980s to identify patterns useful as repertoires of model possibilities of interactive art for artists and analytical tools for scholars.

The strategies Kluszczynski defines, (not definitive, as new technologies and forms evolve), are Instrument, Game, Archives, Labyrinth, Rhizome, System, Network, and Spectacle. Not all foreground the physical aspect of 'embodied participation of viewers' emphasised by Stern (2013, pp.5-6), although all interactive art intrinsically relies on the viewer's actions. The category closest to Stern's definition above is strategy of Instrument, when an interface for interaction takes the form of a device for the user to create their own performance, e.g. through generating audio, animated visuals, live video or robotic action. However, although these usually involve physical interactions, Kluszczynski also includes web-based art, e.g. Mark Napier's *The Shredder* and *Digital Landfill* from 1998 (*Potatoland*, n.d.) when a custom browser is created as a tool by which the user can manipulate data in a non-standard way. Participant interaction is integral to most of the strategies, as Kluszczynski asserts "an interactive artwork finds its final formation only as a result of participative behavior of the viewers" (2010, p.1). However, in his strategy of Spectacle participant action is only minimal in the creation or transformation of the artwork experience and is absent in the strategy of System.

In some of Kluszczynski's categories, the way data is organised is highlighted. Strategy of Archive artwork consists of curated information and images for the user to explore in a

hierarchical database structure; with Labyrinth - information is organised in a non-linear fashion as hyperlinks and the audience usually has less prior knowledge or control over the interactive experience; with Rhizome, the most open-ended multi-directional system (referencing rhizome theory of Gilles Deleuze and Felix Guattari (Deleuze and Guattari, 1987; Kluszczynski, 2010), cybertext is used, "open forms of shaping data sources which could undergo development and expansion beyond their current limits during an interactive experience" (Kluszczynski, 2010, p.15). The strategy of Rhizome is most interactive in the sense that the participant is active in generating the artwork rather than making limited changes of pre-programmed effects.

Figure 14 David Rokeby, 2001, *n-cha(n)t*. Suspended computer monitors with speech recognition and generation software, and microphones.

'n-cha(n)t' (2001) by David Rokeby (Fig. 14), is an example of a Rhizomic interactive artwork. Suspended computer monitors displaying video of ears indicating they are listening via microphones, chant in unison unless interrupted by a loud sound or voice of an audience member. Interaction includes generative response as speech recognition software on the receiving computer deciphers the audience's speech and starts free associating with words, throwing all the other computers into individual responses. This represents an early artistic adoption of speech recognition artificial intelligence, which is discussed further below. The computer system demonstrates independence and self-sufficiency, presenting its own perfection that is characterized by balance and harmony, but also able to interact with the audience.

Strategies of Network and Games, foreground the element of 'relations among participants' (Kluszczynski, 2010, pp, 1, 7, 21). The Network strategy comprises an activist political, social, ecological approach by using digital communication and locative media in participatory hybrid events. Artworks using the Game strategy are not games themselves, but a metadiscursive method of undertaking different issues not directly connected with the game (2010, p. 8). An example given is (*Can You See Me Now?*, 2003) by Blast Theory, a mixed reality game of chase using GPS and wireless technology to explore virtual/physical presence and absence, with real competitors running around a city, tracking, through handheld computers, online players, with both mutually visible on an online city map.

Kluszczynski formulated his strategies just as IoT technology started to develop. IoT has changed the binary nature of interaction between an artwork interface and a user. An IoT device is characterised by connectivity, able to link multiple input sources and send data to multiple parties while operating autonomously from the user, who may or may not be actively engaged with it. The word 'interactivity' implies a viewer's direct engagement with an artwork, but in cases where an artwork autonomously collects data from sensors, or the internet, and communicates within a technological system, the interactivity is internal. Kluszczynski uses the term interactive even for artworks where no physical activity by the participant is necessary to their realisation. He includes this form in his taxonomy as interactivity takes place within the technological system, therefore termed by him strategy of 'System'. Examples of strategy of System are Steve Heimbecker's *Wind Array Cascade Machine* on (2004), a work similar to David Bowen's *tele-Present Wind* (2018) discussed below in the 'Telepresence' section.

Problems may arise when attempting to use Kluszczynski's strategies as an analytical tool to categorize interactive artworks. The landscape of interactive art is complex and rapidly evolving as artists adopt new technologies. Many of Kluszczynski's strategies and exemplars are outdated, though interesting from the viewpoint of the historical development of interactive art. Artists create their own strategies, driven by meaning-making or focus of their practice. As Kluszczynski himself admits in his conclusion, "the merging of strategies is a very significant tendency - nowadays numerous works are created today on the edges of many strategies" (Kluszczynski, 2010). Defining strategies and creating taxonomies of interactive art at a certain point in time is useful to consider what is achievable from different permutations of the elements of interactive art. However, in practice it may be

more useful to simply analyse the content and audience experience of individual interactive artworks rather than categorise them.

As technologies are constantly being developed, new 'strategies' for interactive art will evolve. Taxonomies and categories of interactive art will go out of date as the landscape shifts. At the time of writing this thesis in 2023, the rate of development of Artificial Intelligence (AI) and its accessibility to lay people is accelerating rapidly and has started to have transformative social and pedagogical impacts. AI includes powerful technologies and software including Machine Learning, virtual assistant, video and image recognition and analytics and Deep Learning such as Natural Language Processing (speech, voice and text recognition).

AI tools are impacting art and design, particularly in generative art algorithms based on machine learning from datasets of existing art images and video. AI tools are being used by artists not only to generate two-dimensional or screen-based work, but for interactive installation. Rafael Lozano-Hemmer has been making what he coined 'technological theater' since the 1990s, both using and subverting AI tools such as machine learning and facial recognition software, "making technologies of control, surveillance and content creation tangible in a physical way" (*How Technology Feels*, 2022). Lozano-Hemmer's *Code/Decode* (Fig. 15) uses custom-made generative software, 3-D tracking and projection to create an interactive immersive environment based on an essay about media and agency by cultural studies scholar Stuart Hall (*Rafael Lozano-Hemmer - Encode/Decode*, n.d.). The

Figure 15 Rafael Lozano-Hemmer, 2020, *Encode/Decode.* Projector, 3D sensor, computer running software written in TouchDesigner.

movement of floating letters react to the movements of the viewers and coalesce to form sentences from the essay.

AI can be integrated with IoT for smart systems in public and domestic environments. There is potential for integrating AI with an Internet of Glass Things, but that is beyond the scope of this study and an area for future research (see section 8.4.4.). In this current research, interactivity relates to effects enabled by digital technology whereby something in the artwork is triggered by it sensing either an action by a viewer, a change in the environment or in a stream of live data from the Internet. System is the strategy applied in *Jeopardy*, discussed in Chapter 5 and Instrument most closely fits the artworks discussed in Chapters 6 and 7 which respond to the physical touch or gesture of the viewer to generate audio clips so that they can create their own rendition of the interactive work. Interaction could be a simple stimulus-and-response effect or more complex, equivalent to a dialogue with stimuli and responses going back and forth. Although an artwork may invite physical gestures of the viewer to activate it, the interactivity here is mediated by digital technology. Outputs triggered in the interactive process may be audio, video, or colour changes, all related to the viewer's sense of vision or hearing, however tactile, olfactory or kinaesthetic are also possible.

The following sections on Playfulness, Enchantment and Animacy elaborate on three key attributes of interactivity for audience engagement with artwork that I identified from the literature review and contextual survey of interactive art. They are drawn from a greater number of characteristics for engaging viewers that researchers have written about and I listed in Fig. 12 (Blow, 2014; Costello and Edmonds, 2007; Gell, 1998; Glynn, 2019; Kwastek, 2015; McCarthy et al., 2006; Rose, 2014; Seck Langill and Muller, 2016). I have chosen Animacy, Enchantment and Playfulness as pertinent to my current and former art practice in digital-glass art, animation, puppetry and theatre audience engagement, which was discussed in Chapter 1.

3.2.2 Playfulness

Playfulness is an important consideration in how absorbing an interactive artwork is for the audience. Kwastek (2015, pp. 74-79) draws on play theorists Caillois, Huizinger, Buytendijk and Scheuerl to identify characteristics of play which relate to the aesthetics of interactive media art, which I have listed in Fig.12. The characteristics of most relevance to this research are related ones of Flow and Ambivalence/Ambiguity, which are discussed further

in following sections. Kwastek (2015, pp. 78-79) cites the concept of Ambivalence as a fundamental characteristic of play which "constantly oscillates between material and form, seriousness and pleasure, reality and artificiality, rules and chance, nature and intellects". Ambivalence of play also exists in the inseparability of the player absorbed in their play, which Kwastek associates with psychologist Mihaly Csikszentmihali's concept of Flow, referring to the phenomenon of total absorption in an activity (2015, p. 79).

'Play' itself is an ambiguous term semantically with meanings pertinent to aspects of interactive art; the viewer plays with an interactive artwork. This might be in the sense of performing the artwork as in playing a game, or as free imaginative exploration. The artwork itself can be 'playful' in intention. Playing can denote reproducing something that is recorded. Kwastek discusses performance and performativity, acting or 'playing' in front of an audience which also features ambiguity in the consciousness of both the act and what it represents (2015, p. 81). However, in interactive art, the audience member or viewer is in fact the performer who performs the work.

Performance theorist Richard Schechner draws on anthropologist Victor Turner's work to discuss transformative experiences, liminoid and liminal, in industrial and non-industrial societies. The notion of liminality was introduced by French folklorist/anthropologist Van Gennep in *Les Rites de Passage* published in 1909 (Gennep, 2019), with his analysis of ceremonial transitions between social groups and status in traditional societies. Van Gennep identified three stages in rites of passage – 'separation' from regular society, the transitional 'liminal' period when the identity of the individual or group is dissolved, distinctions become blurred and ambiguous and finally 'aggregation' when the initiates are reintegrated through ceremony into society with a new status. Turner expanded the concept to modern societies using the term liminoid for transformational experiences which take place in distinct spaces and times set aside in education, science, leisure, festivals, and the arts (Turner, 1974). Turner states "the analysis of culture into factors and their free or 'ludic' recombination in any and every possible pattern, however weird, that is of the essence of liminality" (pp. 60-61) and, experimental and creative, "liminoid phenomena… are often parts of social critiques … exposing the injustices, inefficiencies, and immoralities of the mainstream economic and political structures and organizations" (Turner, p. 86). Turner's friend and collaborator, Schechner, founder and director of the Performance Group, applied his theories to the experience of theatre, where an

individual's identity is temporarily suspended during a performance to become opened up to possibilities of transformation (Schechner, 1994). Writing of contemporary theatre, he states, "Transformations in theatre occur in three different places, and at different levels: 1) the drama, that is in the story, 2) in the performers whose special task it is to undergo a temporary *rearrangement* of their body/mind … in the audience where changes may be temporary (entertainment) or permanent (ritual)" (Schechner, 1994, p.170). While an interactive artwork may not include actors, it includes performance, has an audience and may include narrative, sonic or visual. I argue in Chapter 7.3.3 that a viewer actively playing with an interactive artwork (performing) may become a transformative experience, particularly if the artwork includes narrative media.

Costello as part of PhD research analysed play theorists' categories to define thirteen categories on the pleasures of play (See Fig. 12), outlined in a paper (Costello and Edmonds, 2007) that focuses on the design of pleasurably playful interfaces within an interactive art context. Costello and Kwastek analysed artwork which altered in direct response to audience's physical actions. However, their categories are also relevant to artworks which interact in other ways. Creation, Subversion, Captivation/Flow, Sensation, Exploration, Sympathy, Simulation and Fantasy /Artificiality in particular relate to the concept of Enchantment, a term taken up by Interaction Designers in the first decade of the 21st century.

3.2.3 Enchantment

The term Enchantment was defined by Human Computer Interaction researchers McCarthy et al. (2006) as "an experience of being caught up and carried away, in which, although we are disoriented, perception and attention are heightened". McCarthy et al. list sensibilities needed when designing for enchantment, some of which resonate with Costello's categories for playful engagement. They also note the importance of engaging the whole person - intellectual, emotional and sensual.

Rose (2014, p. 10) used the term Enchantment for digital objects, referring to their augmented powers, equivalent to fairy tale enchanted objects such as flying carpets or invisibility cloaks. He offers a framework for creating Enchantment in objects through connection, personalization, socialization, gamification and storyfication (Rose, p. 194).

A characteristic of fairytale Enchantment is that ordinary objects come to life (dancing shoes, gingerbread men, tableware, brooms etc.). This characteristic of 'liveliness', relating to Costello's play pleasure of *Simulation* is identified by Seck Langill and Muller (2016) as a strong current in new media aesthetics. This perceived 'living effect' can be 'enchanting, uncanny, destabilizing or compelling' (Seck Langill and Muller, p. 35). This characteristic of 'animacy' in interactive art is discussed in more detail below.

The word 'enchantment' has connotations both of something entrancing or captivating, but also mysterious, not fully understood or deceptive. Taking an anthropological approach to understanding art, Gell (1992) asserts that artistic objects hold power over people through the 'enchantment of technology and the technology of enchantment'. He posits that "The enchantment of technology is the power that technical processes have of casting a spell over us so that we see the world in enchanted form" (Gell, p. 44). Using a case study of canoe prow boards of the Trobriand Islanders, Gell examines the power of dazzling optical effects produced by the technical prowess of the canoe board carvers/painters. These optical effects combine with local cultural beliefs to convince other islanders that they are evidence of magic. Gell also cites examples from Western art of the way that the viewer forms an idea of how an art object comes into being and the appreciation of technical skill produces an enchanting effect because it transcends their understanding. Gell refers to the artist as an 'occult technician' due to the way they transform materials and the ideas associated with those materials, in mysterious ways sometimes ascribed to 'divine inspiration' or 'magic' - "the essential alchemy of art, which is to make what is not out of what is, and make what is out of what is not" (Gell, p. 53).

Beyond an artist's technical virtuosity, new technological processes themselves often appear enchanted or supernatural. According to *Smoke and Mirrors, The Psychology of Magic,* an exhibition at the Wellcome Institute, (11 April to 15 September 2019), tracing links between magic, spiritualism and psychology, the rise in belief in the possibility of contacting the dead was related to the development of not easily explained communication technologies such as the telegraph and telephone. Despite the ubiquity of computing devices and increasing technological literacy in the general population, the processes of digital communication remain mysterious to many. Arthur C. Clark noted in 1962 that "Any sufficiently advanced technology is indistinguishable from magic" (Clarke, 1962). Brooks (1975, p. 8) noted the magic in computer programming, "One types the

correct incantation on a keyboard, and a display screen comes to life, showing things that never were nor could be". Similarly, IoT artefacts, able to digitally communicate with each other or the Internet without direct human agency, appear 'enchanted'.

Bradbury (2014) discusses the power imbalance between programmers of computational devices and their users, who cannot access, understand or alter the coded infrastructure of their apps. She draws on experience of ventriloquism and literature comparing new media and puppetry to discuss mechanisms, invisible to the spectator, of coding or ventriloquism to produce vocal utterances. Employing the ventriloquism analogy, she distinguishes between interactive works where the artist is ventriloquist and the participant is the dummy that releases the artist's voice or, when the artist's coding allows the participant more power, the artist is the dummy and participant the ventriloquist, and finally when the code itself becomes the ventriloquist that manipulates the participant's speech.

Although the audience understands that a ventriloquist's dummy is an extension of the ventriloquist, the dummy offers the illusion of autonomy. My past artistic practice includes 'animating sculpture' through puppetry, which involves the skill of the puppet-maker to create a representational structure articulated to enable the illusion of life to be generated in the mind of an audience by the puppeteer. This suspension of belief which enables the viewer to ignore their rational knowledge that the puppet is an inanimate crafted object and attribute life to it is a kind of 'enchantment'. Gell expanded on his theory about the enchantment of technology in Art and Agency (Gell, 1998) to describe ways artworks can have 'agency' to act on and affect recipients just as living beings do. He describes in detail the possible permutations of active (agent) and acted upon (patient) relationships of artist, artwork (which he refers to as 'index'), recipient and 'prototype' (entity represented in the index). The kind of agency an artwork may have ranges from psychological, e.g. its power to impress by its technical virtuosity as mentioned above, to physical, e.g. a person being healed by kissing a religious icon. Gell elaborates on his theory of the enchantment of technology in the notion of 'captivation', beyond being the product of the artist's technical virtuosity to an effect of the artwork itself through its stylistic virtuosity. This stylistic virtuosity may take the form of vivid lifelike representation or of abstract patterns and repeated motifs which produce animated perceptual effects. (Gell, p. 78). Either may give the artwork a sense of 'living presence' which captivates or fascinates the viewer.

3.2.4 Animacy

Gell's focus on how objects acquire agency was challenged by Ingold (Ingold, 2010). Ingold rejects the artificial differentiation of the world into objects as bounded entities when in reality it is an intermingled knot of things, which are permeable and mutable, materials and forces which are already flowing with life.

There is a growing body of literature relating to animism and digital artefacts (Marenko and van Allen, 2016; Kusahara, n.d.; Marenko, 2014; Sosnowska, 2015; van Allen et al., 2013). Marenko (2014) discusses the deployment of animism in interaction design as a research method, a mythmaking narrative, and an "embodied fiction" that drives innovation. Van Allen discusses the speculative *Anithings* project which builds on innate human instinct for using animistic metaphors to ascribe inner life and intentionality to technology we do not understand, to inform the design of an ecology of interactive devices with individual personalities and behaviours (van Allen et al., 2013). Marenko's paper examines the pervasive yet invisible impact of the relationship between us and the growing number of IoT devices in the Ubiquitous Computing landscape. Citing Gell's 'enchantment of technology' she describes our sensorial experience and magical thinking regarding them. She talks about the experience of a 'neo-animist' paradigm where our relationship to smart devices, which are both animate and inanimate, changes as they become responsive communicating subjects as well as objects and the boundary between them becomes more fluid. She cites Ingold's description of animism:

> **The dynamic, transformative potential of the entire field of relations within which beings of all kinds, more or less person-like or thing-like, continually and reciprocally bring one another into existence. The animacy of the lifeworld, in short, is not the result of an infusion of spirit into substance or agency into materiality, but is rather ontologically prior to their differentiation** (Ingold, 2006, p. 68).

Marenko highlights the need to accommodate to the shift in subject-object relationship between us and autonomously-communicating digital artefacts by a neo-animistic paradigm, whereby the boundaries between the social human world and inanimate material one break down and everything relates in ecosystems of human-thing entanglements.

Artistic responses to technological animism include the Device Art movement in Japan. Japanese animism was referenced with respect to AI and computationally-animated objects in the contextual literature for the AI: More than human exhibition at Barbican (16

May to 26 August 2019). Sosnowska (2015) discusses the Device Art movement and wider Japanese thinking about new technologies with reference to the influence of Shintoism and the animistic worldview. Both Marenko (2014) and Sosnowska (2015) emphasise somatic multisensory engagement as a prominent attribute of these animistic artefacts. The Device Art movement, started by artist engineer Hiroo Iwata in 2004, is described by media art scholar/curator Machiko Kusahara as a form of media art, e.g. the image in Fig. 16, that integrates art and technology as well as design, entertainment, and popular culture, in a playful way (Ars Electronica, 2014; Kusahara, 2006; UCLA Design Media Arts, 2018). Device Art is counter to Ubiquitous Computing, where technology is hidden, by visualizing technology. 'Tsukumogami', tools in Japanese folklore that have acquired a spirit were referenced by Cara Chin in her animations about IoT smart devices going rogue, e.g. Sentient Mecha Furniture (Fig. 17).

Figure 16 Eric Siu, 2008*, A Couple of Irons,* one with a camera, the other with a screen. An example of Device Art subverting domestic objects and inviting playful interaction.

Figure 17 Cara Chin, 2019, *Sentient Mecha Furniture,* Kinetic and audio installation. Exhibited at Baltic 39, Newcastle. Photo credit: Colin Davison.

Glynn (2019) for his practice-based PhD on animacy and interactive robotic artworks researched the aesthetics of animation, an aspect hitherto omitted in studies of the aesthetics of interactive art, e.g. (Kwastek, 2015), surmising the reason for the omission being that in academic circles perceiving life in inanimate objects is considered childlike. Citing cognitive studies, he shows that perception of animacy is an automatic, in his words irresistible, response to movement and that it is associated with fast stimulus-response reflexes which form the foundations of our social perception, (Glynn, 2019, pp. 16-17). Information from the eye's retina is processed in the visual cortex by cells specialised for movement and depth perception in early visual processing. This visual detection of motion evolved for social perception, enabling animate and inanimate, mates, prey and predators, to be distinguished. These instincts are the basis of animacy's potency and aesthetic enchantment. Having for many years worked professionally in puppet theatre, I was interested in Glynn's reflections on puppetry studies and interviews with puppeteers in his search to understand the art and aesthetics of animacy and how this feature of human psychology may be manipulated for aesthetic affect. Enchantment derives from ambiguity, an ontological paradox, the oscillation between the spectator's perception of the perceived animacy of the puppet and the rational knowledge that it is an inanimate object. The resulting feeling may be of wonder or uncanniness, believed by some to derive from a primitive fear of the dead being brought back to life (Glynn, p.188). This ambiguous sensation of animate-yet-inanimate, where the viewer sees an object and imagines life, has

been referred to by various puppetry scholars as ‘oscillation’, ‘opalization’, and ‘double-vision’ (Glynn, p. 163).

Gell refers to artists as ‘occult technicians’ (Gell, 1992, p. 49), citing examples of a photorealist painter’s representational illusions or a portraitist’s power to capture someone’s likeness, linking technical with social power. For Gell, “The magic exerted over the beholder by [the] picture is a reflection of the magic exerted inside the picture, the technical miracle… of the transubstantiation” (Gell, p. 49) of pigments, or other art materials, into other substances. Whereas Glynn focuses on the viewer’s perceptual reflexes in perceiving life, and Gell on the artist’s technical abilities to produce enchantment, both analyses rely on the artist’s (or puppeteer’s) skill in exploiting the perceptual apparatus of the spectator.

Artist duo Janet Cardiff and George Bures Miller create electronically animated tableaux and objects which give a sense of presences and absences (Haus der Kunst, 2012). They incorporate visible old-fashioned low-tech technology, but with hidden high-tech state-of-the-art technology operating behind it, e.g. robotics. Their kinetic installation *The Marionette Maker* (Cardiff and Bures Miller, 2014) explores the theme of creating life. It comprises a full-scale caravan housing a myriad of figurative characters in a haunting environment, including a marionette maker (a marionette himself), hunched over a desk drafting designs attempting to create life around him and a full replica of Cardiff sleeping at one end. Evidence of an absent inhabitant, the real maker, lies about the caravan (Fig. 18).

Figure 18 Janet Cardiff and George Bures Miller, 2014, *The Marionette Maker*. (Photo: Gerard Julien/AFP)

Glynn recognizes the continuing power of puppetry to evoke a living presence, stating, "In the face of unrelenting modernisation and reductive tendencies to resist the instinctual and emotional basis of aesthetic experience, puppetry reveals the visceral, primordial nature of the material world and its agency" (Glynn, p. 193)**.** In puppetry, there are different factors operating in producing the sensation of a living presence, the instinctive perception of animacy in motion and the experience of embodiment and emotion where we can make empathic inferences between our own bodily agency and others, including both anthropomorphic and abstract puppets. Veltrusky writing in 1983 about the audience's role in bringing life to a puppet, "The puppets' motions convey a meaning of internal impulse corresponding to the impulse that produces the live beings' movements... and, by contiguity, this implied meaning reflects in the spectator's mind on the puppets themselves, thus tending to attribute to them life of their own" (Veltrusky, 1983; Glynn, p. 164). Glynn is primarily concerned with movement, but quotes puppeteer Basil Jones on the power of stillness in puppetry, how an audience is immersed 'into an empathetic relationship with the object' can sustain the presence of a puppet for a period of time even when it is still, recalling these as dramatic moments (Glynn, p. 171). In my experience just as the spectator infers motivation and purpose from a puppet's movements, they can infer pensiveness and reflection from its stillness.

Figure 19 Ruari Glynn, 2011, *Motive Colloquies,* exhibited at the Pompidou Centre. Three Microsoft Kinect Xbox 360 sensors hidden in the base of the plinth with primitive reactive algorithm enabled the delta robot to react to visitors' movements.

In his robotics practice at the Interactive Architecture Lab at Bartlett School of Architecture, Glynn found that 'anthropomorphism' was not required to elicit empathy or perception of life. Unstable visual phenomena and ambiguity attract attention and create liveliness in abstract forms also, e.g. the robot in Fig. 19. Since the late twentieth century, many puppeteers have moved away from figure puppets in favour of animated found objects, shadows and matter (sand, water, clay etc.), scenography, costume, and digital elements. Astles (2010) quotes Bell in *American Puppet Modernism* "any use of object, material or concrete matter in order to enact symbolic and performative processes functions as a puppet". This branch of puppetry called 'object theatre' often involves animating things in a mimetic way to evoke human movement or personality. However, at the other end of the scale to anthropomorphism are more abstract performances. Astles observes that puppetry has often come to mean a multi-disciplinary animated environment with multiple performance elements in "dynamic transmission and focus of energy throughout the stage in concordance with the requirements of the performance" (Astles, p. 28). An animistic environment is created where different elements are brought to life by the puppeteer to become stage presences alongside actors acting in relationship with each other. Objects

and matter are not made to mimic human or animal creatures, but given a presence based on their materiality and interaction with other elements on stage. This is equivalent to exploring ‘thingness’ rather than human mimesis in robotics. Puppeteer and live art practitioner Song (2014) in her PhD thesis on animating everyday objects in theatre explores this choreography of performer, space, time, objects and audience to create meaning, paying particular attention to the material properties of objects. Referring to Ingold, (Song, p. 19), she focuses attention on the ‘flux of objects in action’. The performance 'Lighter than the Air' (2015) is an example, where she manipulates one red and eleven grey balloons exploring the flux of air and breath through their suspension, buoyancy, weight, inflation and rupture in a meditation on life and death.

Sound may also be used to create animacy. Former film-maker, Tamar Harpaz is an artist who uses glass, lights and lenses, found domestic objects, sound and mechanisms to animate her work and create unsettling optical illusions. Her installation *Current* (2019) at the Henry Moore Institute (Fig. 20) was a choreography of sounds and movement in an installation of found objects animated by a pulse of electricity. Telegraph technology using conductivity and resistance is the animating force with the pulse powering electromagnets to make a circuit. Once this is completed, the objects are activated and begin to sound out a covert coded message. While wiring and mechanisms were laid bare and not hidden from viewers, the installation still gave a strong sense of an uncanny animated presence/absence.

Mike Blow in his practice-based PhD refers to cognitive and synaesthesia studies to explore perception of sound and three-dimensional objects in multimedia artworks. He discusses how sound ‘activates’ the sculptural object, bringing it to life for the viewer (Blow, 2014, p. 95). He draws distinctions between sound which reinforces and that which contradicts the sculptural object. He identifies ‘perceptual dislocation’ produced when sound is in tension

Figure 20 Tamar Harpaz, 2019, *Current,* exhibited at the Henry Moore Foundation, Leeds. Photo: David Cotton.

with, rather than in harmony with, the sculptural object as a way to engage the viewer and create a third perceptual form as the disparity is resolved in their imagination. This concurs with the similar attributes of 'ambiguity' or 'paradox' identified by researchers to captivate the audience (see Fig. 12). Blow argued, the addition of sound to the sculptural form in "multimedia artworks can present a larger field of creative opportunity than single-media works, due to the enhanced interplay between the two media and the viewer's a priori knowledge" (p. 2).

I reflected on ways artists and researchers have explored Playfulness, Enchantment and Animacy in interactive art, drawing on theories from performance, puppetry, HCI, and visual neuroscience. These concepts inform how the practical projects in the following chapters have been developed to engage spectators, for instance in achieving Animacy through movement, or sound. The concept of ambivalence or ambiguity is present in all these attributes, for example, Enchantment happens when an ambiguous perception of animate-yet-inanimate is felt, or when technology is beyond the viewer's understanding or, in Playfulness, in the absorption of the player in their play, which can have a transformative effect. The final 'key attributes' for audience engagement in this study, Embodiment and Telepresence, are discussed below. Embodiment is a feature of 'playful' physical engagement of a viewer with interactive art. Embodiment is implicit to Animacy in empathic inferences between our own bodily agency and others (people, things or representations). Bodily characteristics of 'sensation and sensuous effect' were identified in the literature review (Fig. 12) as characteristics important to audience engagement.

3.2.5 Embodiment

Embodiment is a term which covers many interrelated experiences of thinking, feeling and acting, including sensory experience of our bodies, cognition conditioned from our motor sensory awareness, affective sensations in our bodies in response to what we see, metaphor and the materialization of thought.

Artist and scholar, Simon Penny argues against Cartesian mind-body dualism in favour of phenomenological understandings of cognition, that it is embodied and situated (Penny, 2017, p. 190). For example, abstract concepts like balance are metaphors that arise from bodily experience (p. 378). He refers to real-time computational artwork as 'behaving' cultural artefacts (p. 353), which the audience encounters through sensorial spatio-temporal experiences, more immersive and subjective than with static artforms (p. 363). This he refers to as 'embodied interaction'.

Interactive art encompasses the viewer's body in ways that a purely visual artwork seen at a distance does not. The audience's movement, voice or senses additional to sight are usually integral to the realisation of an interactive artwork, whether it is a case of their body becoming the trigger for a digitally-mediated output, as in *Flourish* (2013) Fig. 21 below, or whether their physical presence is translated digitally into avatars, as the

competitors running around Tokyo onto the online map of the city in *Can You See Me Now?,* discussed in section 3.2.1.. My interest in whole body or multimodal engagement in art derives from previous experience in theatre, particularly from a strategy for audience engagement using an innovative model pioneered by Oily Cart Theatre, described by Brigg (2013 pp. 74-83). As an alternative to the passive spectatorship of traditional fourth wall[6] theatre, the audience participates in tactile, kinaesthetic and olfactory experiences. Recent scientific research has examined physiological, psychological and social aspects of physical touch. Goldstein studied the effect of hand-holding between couples while one had pain inflicted. They found that touch resulted in synchronised respiration and heartrates and furthermore increased empathy so the onlooker was able to accurately gauge the pain level of the sufferer (Goldstein et al., 2017). Studies have shown that touch can promote trust and co-operation between people, influencing perceptions (Linden, 2015). Conversely, deprivation of touch may produce feelings of isolation, anxiety and depression (Field et al., 2020), experienced by many during the COVID-19 lockdowns, which is explored in the *When We Touch Again* project, discussed in Chapter 7. Touch is explored as a means of engaging viewers both physically and empathically in the projects discussed in Chapters 6 and 7 which respond to the actions of spectators.

Much of the interactive art referred to above in this chapter has the physical engagement of the spectator at its core. Some explore the intersection of real and virtual bodies. One of a few interactive artists working with the medium of glass, (Fig. 21), Camille Utterback, states,

> **By developing physical-digital systems that engage people's bodies instead of just their fingers and eyes, I hope to refocus attention on the embodied self in an increasingly mediated culture. Many of my interactive installations respond to participants' locations in the installation space, to spatial relationships between participants, or to actual gestures and body language. By creating installations that use video tracking software to respond transparently to a user's entire body, I create a visceral connection between the real and the virtual** (Utterback, 2023).

Artist Rafael Lozano-Hemmer, discussed in section 3.2.1., who often works with dancers and choreographers, creates performative artworks that depend on materiality and the physical presence of the audience. He creates tangible interfaces which that bring the body into cyberspace as opposed to technologies that separate the body, such as a screen or VR headset (Cordova, 2022).

[6] The imaginary wall separating actors on stage from the audience.

Figure 21 Camille Utterback, 2013, *Flourish* is a 70-foot long site-specific artwork at the Liberty Mutual Group headquarters in Boston, Massachusetts, comprising interactive projection onto multiple layers of glass.

Artworks not physically interactive with the viewer, may also spark embodied responses, either through cognition formed from sensory memories or through basic reflexes. Many perceptions are informed by memories of sensory information garnered over a lifetime of experiencing the world and may be cross-modal. Marks (2000) discusses haptic visuality (termed 'embodied spectatorship'), visuality that functions like the sense of touch by triggering physical memories of smell, touch, and taste**.** For a small percentage of the population, haptic visuality extends beyond memory to a physical experience of 'mirror-touch synaesthesia' where they report tactile sensations in their own body when seeing another person being touched (Ward et al., 2018). As discussed by Glynn (2019, pp. 116-19; p. 163; p. 237) humans' reflexive instinctive attention to movement, developed for awareness of mates, predators or prey, stimulates visceral and aesthetic experience and is a source of our perception of animation in inanimate objects. Glynn also refers to unstable visual forms such as optical illusions as producing reflexive perceptions of animacy (2019, p. 204), as Gell did earlier in his analysis of complex patterns that give the appearance of animation (1998, p. 77-80). Glynn argues that ambiguity is central to animated art forms, with animacy arising from the discrepancy between the fast heuristic reflexive perception of animacy and slower higher order cognition learnt from a lifelong embodied interaction with the world (2019, p. 239). Glynn argues that ambiguity engages viewers and drives participation, encouraging observers to seek to resolve the uncertainty through their own actions (2019, p. 239).

Other scholars of interactive art have thought about embodiment in ways that are beyond this current inquiry, but may be relevant for future research. Artist and teacher, Roy Ascott focuses on the intersection of the virtual and physical worlds. He coined the term 'moist media', for the combination of 'dry' artificial intelligences and 'wet' living systems (Ascott, 2000, p. 3). He predicted that through nanorobotics, quantum computing and biology that dry pixels and bits would merge with wet atoms and genes to create post-biological life forms, sentient buildings and post-human bodies (p. 6).

Embodiment as a theme or as a strategy of engagement applies on various levels to the practical projects in this study, from the use of touch and gesture to activate or release sounds in Chapters 6 and 7, to the visual ambiguity for drawing spectators into an installation (e.g. *1.5 Degrees of Concern, After the Storm*), to stimulating empathy through touch (e.g. *Bin Bag Hug, 1.5 Degrees of Concern*) or representation of vulnerable figures (e.g. *Stateless Vessel, Jeopardy*), to synaesthesia or perceptual compensation (*She's Got the Wrong End of the Stick …*) and audience perception of visual or sonic animacy in all the artworks.

The following section on Telepresence traces the development of technologies that expand the notion of Embodiment by enabling bodies to communicate, operate or sense across distances. It gives examples of ways telematic technologies have been adopted in the arts and their relevance following the COVID-19 pandemic.

3.2.6 Telepresence

Since the early days of interactive art, telepresence has been explored and became particularly pertinent during COVID-19 with the desire to create distanced distributed artwork or performances. The COVID pandemic accelerated several research projects into telematic performance methods (Jamieson and Smith, 2012; Papagiannouli, 2020.; Sermon et al., 2022; Telepresence Stage, 2022). Telepresence through telerobotics has existed since the 1940s when it was developed for the safe handling of radioactive materials and has since then been applied to warfare, space and ocean exploration and VR embodied immersive experience (Goldberg, 2000). A telerobot is sent instructions (originally through telephone and satellite technology, now usually via the Internet) by a trained human operator to perform live actions in a distant environment and returns feedback from sensors so the operator can gauge the consequences. In November 2018, an experimental

initiative to bring new opportunities to people with disabilities was begun in a Tokyo café with *OriHime-D* robots operated remotely as waiters by people with limited or no mobility (Life Where I'm From, 2019), see Fig. 22. Goldberg (2000) gives an extensive, but on his admission incomplete, list of around 40 artists who were at the turn of the millennium exploring telerobotics.

Figure 22 *OriHime-D* robot- waiter and paralyzed operator (Ory, 2018).

Ascott was a pioneer of interactive art and telematics since the 1960s who coined the term 'technoetics' for the distributed mind made possible by cyberspace. 1966-67, Ascott proposed remote artistic collaborations using computers and telecommunications prior to the World Wide Web (Ascott & Shanken, 2003, pp.145-150). Ascott's *La Plissure du Texte* (1983) was an interactive collaborative artwork of text and ASCII-based[7] images, based on 'exquisite corpse' with artists at eleven globally-distributed locations (pp. 65-67).

With advancing technology for virtual reality, web cameras and streaming, in the 1990s-2000s artists found new ways to explore telepresence. Paul Sermon's *Telematic Dreaming* (1992), using a two-way video and audio line (teleconference ISDN system) at V2 in Rotterdam, explored physical presence and telepresence in a live video and sound installation between two beds, one in the gallery and the other in an apartment. Later Robert Whitman's *Passport*, 2011, with Experiments in Art and Technology (*E.A.T.*, 2013) staged simultaneous performances inside a theatre and outside on the banks of the Hudson incorporating livestreamed projections from each location. In *This Year in Jerusalem,* a reference to the Jewish saying 'Next year in Jerusalem' expressing the hope for their people to be united in Israel, Bielicky (2013) used Internet-streamed live webcam footage of the Western Wall in Jerusalem projected in a gallery in Prague synthesised with live 3D projections of gallery visitors generated from a motion-capture system. Bielicky's installation conflated two geographical locations, enabling visitors to find themselves in Jerusalem via their avatars.

Lozano-Hemmer's *Border Tuner* 2019 (Fig. 23) utilizes AI software and digital encoders to connect people's voices and heartbeats across the US-Mexico border in the binational metropolis of El Paso, Texas, and Ciudad Juárez, Chihuahua (*Border Tuner, Cross-Border Art and Performance, Ciudad Juárez-El Paso*, n.d.; *Rafael Lozano-Hemmer - Border Tuner / Sintonizador Fronterizo*, n.d.; Kaplan, 2021; Yusa et al., 2022). Yusa, Yu and Sovhyra state that "The use of AI in this work allows for real-time translation and interaction, creating a seamless and dynamic experience for visitors" (2022, p.60). I believe this claim is erroneous as I can find no reference to real-time translation in any documentation about the cross-border communication. Participants at three interactive stations on each side of the border

[7] ASCII, American Standard Code for Information Interchange, is a character code standard for electronic communication.

Figure 23 Rafael Lozano-Hemmer, 2019, *Border Tuner*, Xenon 7kW robotic searchlights, dials with digital encoders, webcams, GPS, speakers, microphones, custom-software.

use dials to control giant robotic searchlights. When the searchlights connect to form a bridge, a communication channel with a machine learning algorithm automatically opens allowing participants to converse with each other. Also, each side has a podium with vibrating hand sensors and two lights bulbs, called *Remote Pulse*. When a participant places hands on the sensors, one light pulses to their heartbeat. If a person across the border uses the sister podium, the second bulb pulses and the opposite sensor plate vibrates with their heartbeat, allowing the person's physical presence to be felt. *Border Tuner* thus amplifies connections between people and uses interactivity to challenge hostile narratives about migration and border walls.

IoT technologies are now enabling artists to explore telepresence in new ways, with interaction mediated over the Internet, questioning the need for physical proximity between the artworks, and/or human recipients. IoT technology enables devices, through sensors and connection with the Internet, once set up, to collect data and trigger actions, without human intervention. IoT enables artists to distribute different parts of the same artwork across geographically-distant areas, with sensors in one location and actuators or other devices triggering responses in another.

David Bowen is an artist who explores telepresence, collecting real time data from sensors in outdoor natural settings and using it to trigger kinetic sculptures in gallery settings. e.g. 'tele-Present Wind' which

> **reproduces the movement of wind using real-time data collected from a series of mechanized stalks. Basically, 126 x/y tilting mechanical devices are attached to dried plant stalks installed inside a gallery while parallel stalks are connected to an accelerometer installed outdoors. The accelerometer detects the swaying stalks outside and transmits the motion to those inside the gallery, resulting in a unison of movement at distanced locations in real-time.** (BOOOOOOOM!, 2018)

Tele-present Wind (Figs. 24 and 25) has many similarities to Steve Heimbecker's early installation *Wind Array Cascade Machine* (2004) which collected data from 64 sensors (microelectronics with accelerometers), but live-streamed the data to an audio-visual installation rather than kinetic one. Heimbecker's artwork used the data to create a visual effect using LEDs as a metaphor for the wind waves. This comparison demonstrates how similar data may be used artistically for embodying contrasting outputs or visualisations.

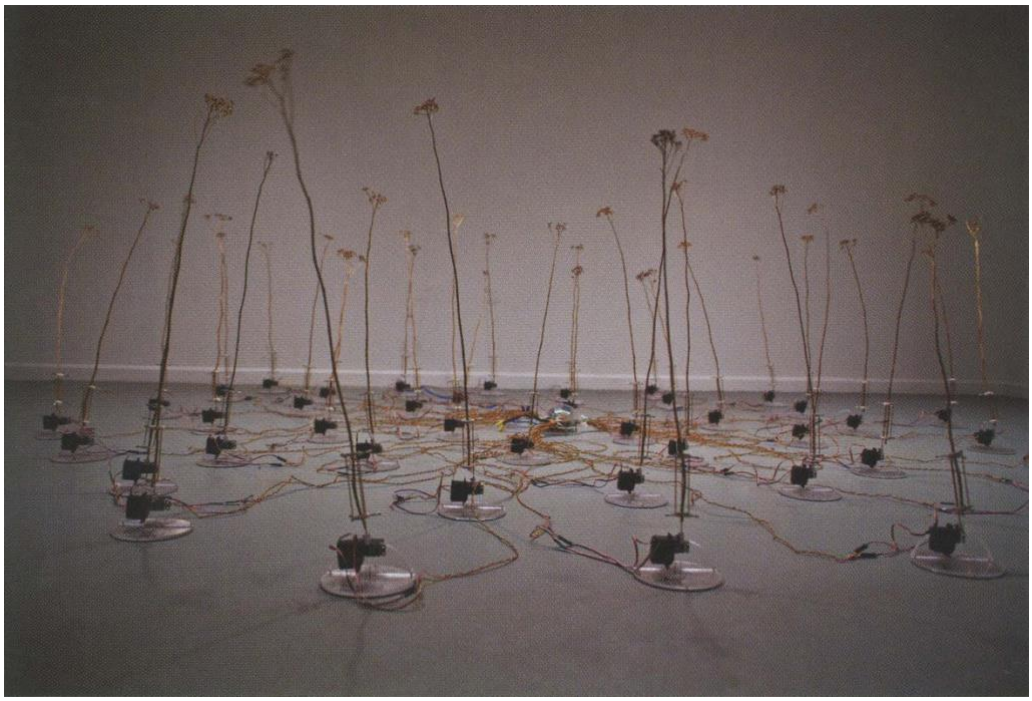

Figure 24 David Bowen, 2010, *tele-Present Wind,* Gallery installation.

Figure 25 Wind sensor from Bowen's *Tele-present Wind*, 2018

IoT technology has enabled distributed artworks and distanced audiences to interact in real-time. Canadian artist, Jane Tingley employs playfulness in engaging members of the public for her three distanced, but connected sculptures *anyWare* (Tingley, 2019), which have sensors that alter lights both on the sculpture being played with and on two similar ones located in other cities. This enables an interaction to take place by two distanced people responding to each other's actions on the artworks.

Telepresence is explored in several of the artworks in this study. The potential of the Internet connectivity of IoT for telepresence is explored in *Jeopardy*, an artwork that visualises seismic events happening in different parts of the world in real-time, described in Chapter 5. During the COVID-19 pandemic, *When We Touch Again*, in Chapter 7, addresses the issue of 'touch hunger' brought about by social distancing and lockdowns. Successive lockdowns necessitated the adoption of strategies for telepresent working practices for teaching, collaborating and performing. Telepresent collaboration practices were employed in *When We Touch Again*, *After the Storm,* part of 'Collaborations' project between artists situated across Britain, and in the Touch Collaboration project which culminated in *I.5 Degrees of Concern* bringing together artists from three continents, all discussed in Chapter 7.

Following the discussion of Interactivity earlier in this chapter which looked at a broad spectrum of interactive art and key attributes for audience engagement derived from it, the final section of this chapter focusses specifically on the field of interactive glass art. The digital has now become integrated across all the arts, including craft. Digital production tools are already well-established in glass practice and some glass artists are exploring digital interactivity, a few examples of whom are discussed below. From a literature survey, it is apparent interactive glass art has not been the focus of much academic research to date, a gap which I seek to address in this study.

3.3 The gap in digitally-interactive artwork in the field of glass art

Weibel discusses in his 2006 essay how the digital has become embedded in every artform (Mute, 2012). He traces the classical roots of traditional Western attitudes and hierarchies of Arts and Sciences to the current time in which the distinctions between art forms, and to an extent even sciences, have broken down. In this post-media condition,

> **Just like the case of the old technical media of photography and film, the pivotal successes of the new technical media consisting of video and computer are not just that they launched new movements in art and created new media for expression but that they also exerted a decisive influence on historical media such as painting and sculpture. To this extent the new media were not only a new branch on the tree of art but actually transformed the tree of art itself (2012).**

The digital now is integrated into every art form and has resulted in blended boundaries, "mixing the media-specific idiosyncratic worlds of the media" and resulting in "multiple examples of combinations all driven by digital technical innovations" (2012). Thus, the digital has been introduced to the media specific world of glass art in multiple ways.

However, to date there have been few in-depth studies of glass and new technologies. Vanessa Cutler's book (2012) concerns digital production techniques for glass. Art historian Manuel Fadat wrote *Sio: Verre et Nouvelles Technologies Dans La Creation Contemporaine* based on interviews with around fifty artists using digital technologies from around the world including myself and other researchers associated with the University of Sunderland (Fadat, 2017). His survey includes both those using digital production technologies, and artists creating installations using glass with sound, video, AI, lasers, biotechnology and more. Fadat also explores the history of glass and technology and their current cultural and philosophical contexts.

3.3.1 Digital fabrication in glass art

The use of digitals tools in design and fabrication have been adopted by many contemporary artists working in glass, some of whom feature in Fadat (2017) and Cutler (2012), for example, Anna Maslowski, Daniel Cutrone, Geoffrey Mann, Philippe Garenc, Annie Cattrell, Bathsheba Grossman, Marcus Kayser and others, some of whom are discussed below. Digital tools, C.A.D. (computer-aided design) for glass design and fabrication include 2-D/3-D modelling and rendering software, 3-D scanning; C.A.M. (computer-aided machining) or C.N.C. (short for computerised numerical control) for water jet cutting glass or making stencils for sandblasting or printing glass; 3-D print (in glass itself, in PLA for models or clay for casting moulds); laser engraving; and photographic stencil preparation for screen-print. Computer modelling technologies enable works to exist, digitally and physically in virtual and physical worlds. Virtual embodiments of works may be interacted with, at least by the artist.

Many University of Sunderland staff and alumni use, and some have researched, digital fabrication tools alongside traditional glass techniques. Colin Rennie's artwork (Fig. 26) blends traditional glassblowing skills with digital technologies, 3D scanning and 3D modelling with waterjet cutting.

Figure 26 Colin Rennie, 2017, *Magnitudo,* Glass and metal.

Angela Thwaites (2018) uses Rhino design software and 3D PLA printing to make models for casting glass shapes not possible through analogue means (Fig. 27).

Figure 27 Angela Thwaites, 2017*, Flat globey with ladders.*

Figure 28 Erin Dickson and Jeffrey Sarmiento, 2011-2014*, Emotional Leak,* Waterjet cut float glass, metal, rubber (400 x 136 x 136 cm)

Erin Dickson (Dickson, 2015) and Jeff Sarmiento use data processing, 3D modelling and water jet cut glass in their work, *Emotional Leak,* (Fig. 28). Sarmiento combines 2D and 3D print with waterjet cutting (Sarmiento, 2019). Vanessa Cutler, Fig. 29, Mark Hursty, discussed below, and Joanne Mitchell have developed methods in conjunction with water jet cutting to produce innovative forms (Cutler, 2006; Mitchell, 2017). This existing body of research at the University of Sunderland into digital methods in glass art formed the context out of which the exploration of interactive glass artworks developed.

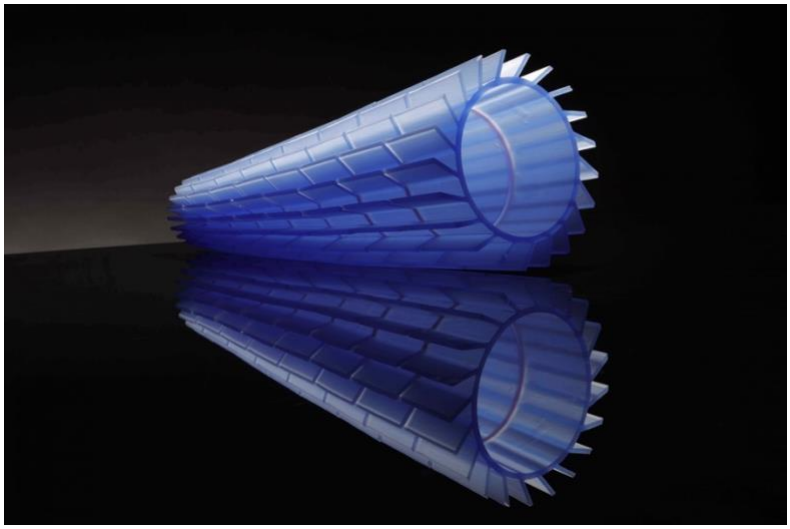

Figure 29 Vanessa Cutler, 2020, *Gender,* Waterjet cut and cast glass. Photo: Simon Bruntnell.

With the increasing use of such digital tools, the field has expanded from traditional studio glass practice. My survey of glass magazines, art/electronica exhibition catalogues and social media pages has revealed individual interactive works in glass and a few glass artists with sustained practice in this field. No PhD studies pertaining to glass and interactivity or electronics were found, although there is evidence of informal research and increasing creative practice in the field, a few examples of which I give below, following a section on electronic crafts.

3.3.2 Interactive electronic crafts

Given the lack of academic papers or theses for digitally-interactive glass art, my initial study began with surveying the body of literature for more developed digital crafts including electronic textiles, paper circuits and electronic wearables. The first generations that developed blending computational materials with crafts were part of MIT's Media Lab, such as pioneers of e-textiles, Maggie Orth (2001) in the 1990s and later Joanna Berzowska (2005, 2007; Berzowska and Bromley, 2007; Berzowska and Coelho, 2005) , and the MIT

High-Low Tech group 2009 to 2014 that included Leah Buechley (Buechley and Eisenberg, 2009) , Hannah Perner Wilson (Buechley and Perner-Wilson, 2012), Jie Qi (Qi and Buechley, 2014; Qi et al. 2018) among others. The High-Low Tech Group explored "the intersection of computation, physical materials, manufacturing processes, traditional crafts, and design" with the aim of making engineering more accessible and electronics more expressive (High-Low Tech Group, 2023). These researchers influenced the growth of amateur electronics, for instance Buechley designed the LilyPad system and Qi 'Chibitronics', or 'paper circuits', methods of embedding conductive traces and components with paper, and Hannah Perner-Wilson, with Mika Satomi, under the collective name Kobakant, published an online resource for e-textile methods, for making traces, sensors, actuators and code (Kobakant, 2023). Qi explores the aesthetic and narrative qualities of embedding microcontrollers and circuits with paper or in books (Fig. 30). Eindhoven University PhD researcher Kristi Kuusk (2016) combined e-textiles with crafted QR codes and Augmented Reality technologies to integrate interactivity using smart device apps linking physical textile with 3D projections and audio for storytelling purposes. In the UK, Sarah Kettley at Edinburgh, Jayne Wallace at Northumbria and Katharina Vones at Dundee Universities explore computational material and traditional jewellery techniques for wearables, looking beyond technological innovation or function to recognize aesthetic, social and cultural roles of artefacts (Kettley, 2007; Vones, 2015, 2017; Wallace, 2007; Wallace et al., 2015). Wallace focuses on wellbeing applications of digital jewellery, related to the sense of self. She is concerned with enhanced emotional connection through stimulating interactions between jewellery and wearer. *Remember Locket* (Fig. 31), designed for someone with dementia, displays a sequence of images from their life, as a bridge between past identity and present family and carers. Her practice suggested directions for glass, which, already integral in lockets, picture frames, perfume bottles, mirrors etc., has a long association with memory and selfhood.

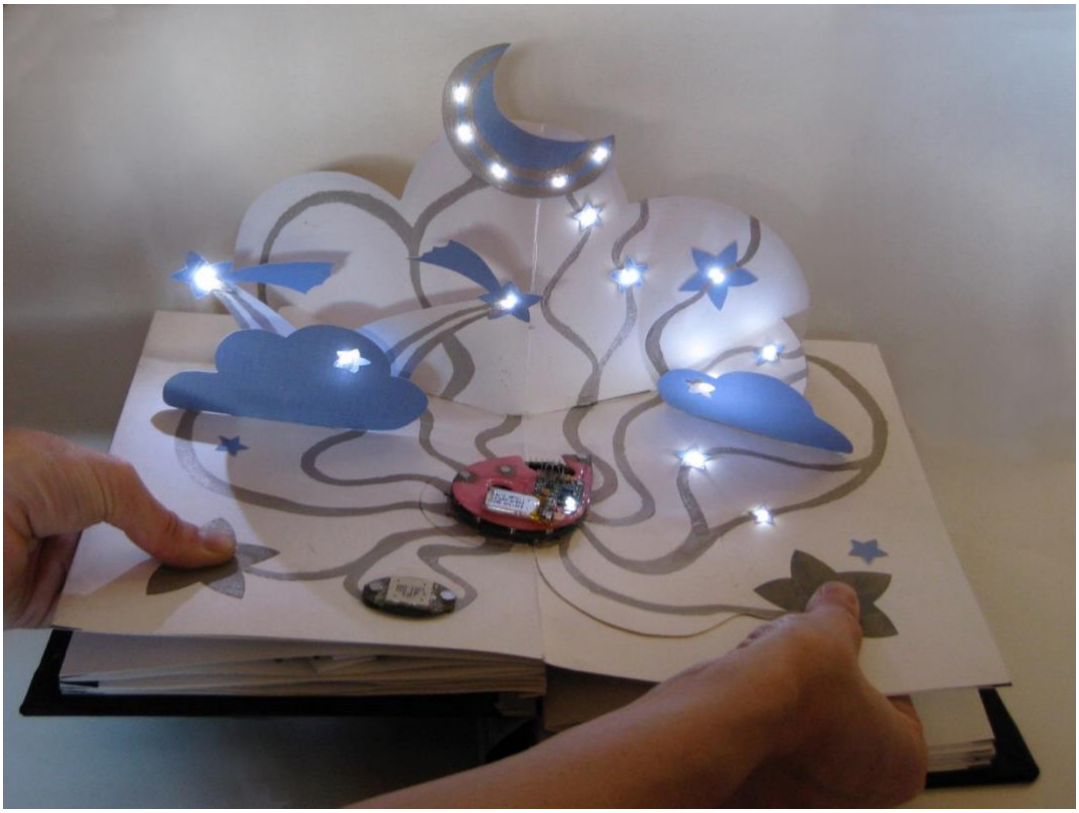

Figure 30 Jie Qi, *Pop up book.* Book, microcontroller, LEDs, conductive ink.

Figure 31 Jayne Wallace, 2010/11, Remember Locket. Photo credit: Jayne Wallace.

Artists working with clay and interactive technologies include Adinka Van't Klooster (2011) and Ingrid Murphy, who has explored QR codes, Augmented Reality and microcontrollers in her ceramic pieces. For example, in *Syn-Tea-Sizer* (Murphy, I and Piggott, J., 2018), Murphy made use of the conductivity of gold lustre glaze to turn items of a tea set into capacitive touch sensors connected to a Touch Board to trigger sounds and *The Campanologist's Tea Cup* (Murphy, 2015) uses the sonorous qualities of ceramics along with piezo microphones and Arduino microcontrollers to enable a viewer to trigger sound sequences by pinging a teacup.

This body of research introduced me to possibilities and methods of blending electronics with traditional craft materials, including design concepts, materials and methods. Buechley and Perner-Wilson's (2012) assertation that embedding electronics in craft was a method to increase digital literacy was true in my case. I had no previous experience of electronics, but, in conjunction to accessing many online tutorials of the burgeoning maker community, learnt from the literature and practices described above. I began experimenting with conductive embroidery and paper circuits alongside conductive traces in glass and began to run workshops with young people on 'squishy circuits' (electronics embedded in play dough), e-puppets, light-up greeting cards, interactive collage and, for a dance project, felt wristbands that lit up with movement.

3.3.3 Digitally-interactive glass art

Although I did not discover as many researchers exploring digitally-interactive glass as e-textiles, I did find examples going back to the 1990s. Whilst Rauschenberg's interactive *Soundings*, cited earlier, uses a transparent glass aesthetic, the earliest example of interactive art using actual glass that I found is *musicBottles* (Fig. 32), first iteration 1999, by MIT Tangible Media researcher Hiroshi Ishii (Ishii, Mazalek and Lee, 2001). It deploys glass bottles as tangible interfaces for users to control music tracks. The bottles are on a special table and when a cork is removed, music is played. It comprises electromagnetic tags embedded in the bottles identifying each one and detecting the removal of the corks.

Figure 32 Hiroshi Ishii, 1999*, musicBottles*

Traditional stained glass was explored recently as a tangible interface for HCI (Human Computer Interaction) practitioners, using copper foiling or lead came as conductive traces for circuits connecting to a microcontroller outputting to LEDS, with speculative use for a weather indicator and mood light, lock safe key pad and coded display prototypes (Gagnon-King et al., 2023).

Norberg '*s I Do Not Know What It Looks Like When Someone Dies - Electric Chair* (1998, 2008) is not strictly interactive, but is included here as an instance of glass and electricity producing a reaction in a work. It comprises chairs made of bent glass tubing with Kanthal high resistance wire inside, connected with wires to a dimmer switch controlling 26V/5A electricity (Fig. 33). Switched on by an operator, the wire heated the glass over the day, so it softened and slumped backwards, and when switched off, cooled and cracked.

Figure 33 Anna Norberg, 1998, 2008, *I Do Not Know What It Looks Like When Someone Dies - Electric Chair*

Also not interactive but relevant to this study, Helen Maurer's kinetic artwork, uses glass, projected light and moving turntables to create animacy, e.g. in *Looking Out and In Again* (2022) exhibited at Venice Glass Week 2023 (Parabolatrust, 2023). Her practice combines glass, light, sound and film, drawing on a background of visual and performing arts.

As the use of physical computing becomes more widespread, glass artists use microcontrollers to control sound or light. *Magic Lantern* (2015) was a collaboration between media artist Victoria Bradbury and glass artist Mark Hursty, comprising a projection platform with waterjet cut glass, coloured glass shards, servo motors, Arduino microcontroller and light to create projections (Fig. 34). Through colour and shape coding, the glass represents data, collected from weather and location tracking sensors through a collaboration with researchers at The Centre for Doctoral Training in Cloud Computing for Big Data at Newcastle Science Central (Bradbury and Hursty, 2023; Hursty and Bradbury, 2015).

New York based James Akers, neon artist and Urban Glass instructor, uses electrical circuits to give his sculpture abilities such as to make noises, play videos, or scan an object. Some works require interaction with viewers, such as *Your Magic is Real* (2019) which requires multiple viewers to hold hands to reach distanced touch sensors to complete an electrical circuit that powers a neon and LED light display (*James Akers: Your Magic Is Real*, n.d.).

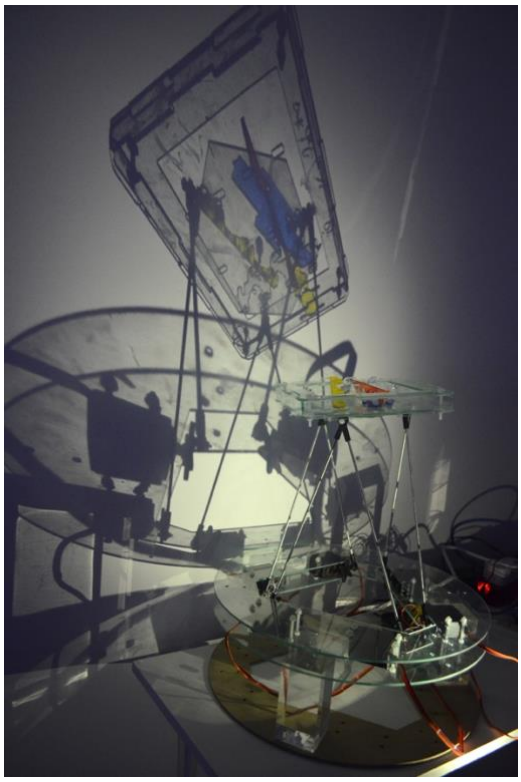

Figure 34 Victoria Bradbury and Mark Hursty, 2015, *Magic Lantern,* Glass, servomotors, Arduino microcontroller.

In the Introduction, I described ways physical computing has impacted craft and the genesis of this study into glass and interactive technologies in the Crafts Futures workshops run by the Universities of Sunderland and Northumbria. As well as University programmes, the growth of glass art with digital technologies has been nurtured by classes run by glass organisations such as North Lands Creative Glass (e.g. 'Lie of the Land' class with Helen Maurer and Angela Moore; 'Glass Meets The Future' film festivals) and Pilchuck Glass School, where artistic experimentation with new media has taken place from the outset, (e.g. Mind to Matter, 2007; Glassimations, 2011, 2013; Glass:Optics of the lens, 2013; Transcoding Glass 2017; The Glass Electric 2018, 2019 and LIVE (līv) Glass, 2023, classes). The first Glass Electric class in 2018 (Fig. 35) which I attended was instrumental in furthering this research. It was run by Sunderland alumnus Dr Mark Hursty, University of North Carolina, with Dr Thomas Dylan from Northumbria University and was indirectly an extension of our ongoing research between Universities of Northumbria and Sunderland exploring the applications for glass for Internet of Things (IoT) applications (*2018 Pilchuck Glass School Summer + Fall Program Catalog*, 2017; Bradbury, 2023; Dylan, 2023). Students learnt to electroform copper on glass to make circuits connected to Arduino

microcontrollers, forming sensors to set off various physical or screen-based outputs. During this class I began the artwork discussed in Chapter 4.

Figure 35 Mark Hursty and Thomas Dylan teaching The Glass Electric Class 2018, Pilchuck Glass School

My search found several glass artists using copper as conductive traces for electronics: Swedish Ammy Olofsson created a blown glass 'arduino' with copper wire circuitry as a MA student project, sharing the method as an Instructable (Lakrisal, 2023; Olofsson, 2016). British artist Jenny Walsh collaborated with Dr Eirinn McKay to create *Line of Sight* which lights up in response to vertical or horizontal movements of the viewer and is based on visual cortex neural network research (Cashin-Garbutt, 2022). Canadian Carole Freve incorporates copper electroforming and circuitry on glass for interactive lighting effects (Beaudet, 2018; Paquin, 2018). Fadat (2017, p.101-102) discusses media artist Nandita Kumar whose *eLEmeNT EaRTh*, a poetic diorama in a glass bottle, contains screen-printed copper circuits on transparent acrylic for sound outputs.

Interest in glass art to incorporate sound or interactivity is revealed in recent editions New Glass Review, Contemporary Glass Society publications and the 21st Century Glass social media posts. For instance, in New Glass Review 42, Carrie Iverson's *Resonance* (2020) installation uses archival sound, photographs printed on glass, and glass sheets with

transducers to act as speakers; or Terese Longva and Roar Sletteland 's *Talk to Me* (2022) installation at S12 Gallery in Bergen with cast glass jaws which become animated when a visitor enters the space (Contemporary Glass Society, 2022); and the 21st Century glass Facebook page shared Tony Oursler's *b0t / fl0w - ch@rt* exhibition of a glass robotic AI sculpture with miniature flat screens and exposed computer circuitry, from 2017 show at Galerie Forsblom. *Shield* (2016) by AEsa Bjork and musician Tinna Thorsteindottir won the Toyama Glass Prize in 2018 and is composed of glass sheets which act as both video projection surfaces and sound boards for transducer speakers. Content was created by EEG recording of the artists' brainwaves in various emotional states while simultaneously video-ing their movements, then converting the brainwaves into soundwaves (Bjork, 2018).

3.4 Summary and parameters of this research

In this chapter, I have explored key terms and concepts of Interactivity, Playfulness, Enchantment, Animacy, Embodiment, and Telepresence and ways they interrelate, briefly indicating how interest in these concepts derives from my past practice in glass, puppetry and theatre. These inform my practice-based research in glass and new technologies discussed in the following chapters. The broad review of interactive art situates this research within a wider emerging field. This survey offers strategies open to glass artists seeking to work with interactive technologies. The section on embedding electronics with traditional craft materials reveals existing practices and also highlights the gap in studies relating to glass blended with computational materials. The review of literature demonstrates a growing, yet currently under-researched, field of glass artists working with new technologies, microcontrollers and interactivity.

4 Creating animacy through visual effects (*Stateless Vessel*)

Link to video clip of *Stateless Vessel* for reference:
https://www.lizwaughmcmanus.co.uk/stateless-vessel

4.1 Introduction to aims

Experiments, discussed above, using microcontrollers to trigger effects in or with glass formed the basis to attempt a resolved artwork with a developed narrative that exploited the use of electronics in glass artwork. This research into blending electronics with glass artwork, while rooted in my artistic practice required me to expand my methodology to include new methods such as tinkering and 'prototyping'. Wensveen and Matthews (2014) identified that a prototype can have four distinct and overlapping roles in research: as an experimental component to test for a specific hypothesis; a means of enquiry for open-ended exploration; as a research archetype to demonstrate or illustrate a research concept; or as a vehicle of enquiry to drive the research direction.

Developing *Stateless Vessel***,** and the projects in Chapters 5, 6 and 7, was a process of using prototyping as a vehicle of inquiry - it has been through the practical making and construction process that the relationship between glass and electronic components has been developed and refined. However, the process also resulted in producing research archetypes, for example, *Jeopardy,* discussed in the next chapter, demonstrates the research concept of creating a glass artwork which interacts with the Internet. In this sense, the process has been both research, first characterized by (Frayling, 1993), 'through' art and design whereby creative production can be understood as a research method, and 'for' art and design in which the end product is an artefact within which the thinking that led to its making is embodied. Knowledge has not been gained through an engineering or design methodology of construction and trial of multiple prototypes, although there were iterative trials and modifications of constituent components, but through putting into practice and exploring research ideas. Crafting the artefacts, rather than simply conceptualising or visualising, tested the functionality of the electronic components, but also the aesthetic effects. To discover the principles or requirements for building a glass artwork which is interactive or animated necessitates thinking through the design possibilities, and making, testing, and restructuring the artwork to iteratively clarify understanding. This process was documented, analysed and critically assessed.

My goal in *Stateless Vessel* was to create a glass artwork about the Mediterranean migrant crisis, a theme with which I had engaged in previous artworks. I had previously volunteered at a centre that supports integration and empowering refugees, asylum seekers and migrants from many parts of the world. The humanitarian situation and national political responses were current as people fled conflict in Syria and poverty in North Africa in small boats, which often capsized resulting in migrants being drowned unless they were picked up by coastguards or NGO rescue vessels. However, at the time of this project, 2018, the NGO vessels had all been 'grounded' in ports with their flags of registration no longer recognised by many European countries which wanted to stop the flow of migrants. A crisis was unfolding as NGO Search And Rescue vessels were accused of people-trafficking while the NGOs claimed that many more lives would be lost at sea if they could not operate. Hence the name of the piece, *Stateless Vessel*, refers to the fact the SARs were being rendered stateless, as, in some sense, were the migrants. Since the time of making *Stateless Vessel*, migration has expanded to people crossing the English Channel in small boats. New narratives emerge with people fleeing war, political unrest and the effects of global warming on their birth lands.

One aim that addressed my research questions was to blend traditional and new glass techniques with electronics to trigger outputs, such as video, light or sound, activate motors or produce colour changes. Through the course of developing *Stateless Vessel*, my idea concretised to using a microcontroller to create lighting effects with glass, building on experiments with LEDs during Craft Futures workshops. This drew from my previous experience of lighting and movement effects in shadow puppetry and animation.

I also investigated linking the artwork with live data showing the whereabouts of NGO Search and Rescue vessels, such as Sea Watch 3, in the Mediterranean Sea through Fleetmon or Vesselfinder. These apps use AIS (Automatic Identification System) data from Terrestrial or Satellite receivers to track ships' positions and MMSI or IMO numbers when they are near coastlines. However, as the ships were all grounded, there was no movement to track so I abandoned this aspect.

4.2 Description of *Stateless Vessel*

Central to this artwork is a small representation in glass (45 cm) of a migrant rescue boat filled with figures, which I proposed to animate using a microcontroller to connect to data, lighting, audio or video.

The genesis of this artwork was on a course at Pilchuck Glass School, where the glass boat was blown to my design, by Mark Hursty assisted by Chris Hofmann, and I started to make the figures (Figs. 36 to 42). There is a playful congruence of a toy-scale inflated blown glass vessel and a real inflatable RIB boat.

Figure 36 Mark Hursty assisted by Liz Waugh McManus, 2018, blowing the RIB boat at Pilchuck Glass School.

Figure 37 Mark Hursty assisted by Chris Hofmann, 2018, blowing the RIB boat, creating deck with wood plunger built by Liz Waugh McManus.

I first modelled the figures in clay, from which I made moulds and into which hot glass from the furnace was pressed. Replicas of one of the figure models were made using a 3D scanner and 3D PLA printer. I made more figures and moulds on return to University of Sunderland which were filled with glass by Senior Technician James Maskrey. Glass pressing into moulds was a new technique to me and gave a less defined, ‘watery’ effect than kiln-casting which was my usual process.

Figure 38 Figures modelled in clay by Liz Waugh McManus from which two-piece plaster moulds were made directly or from scanned and 3D printed versions.

Figure 39 Liz Waugh McManus, 2018, 3D printed and copper electroformed figures made at Pilchuck Glass School.

Figure 40 Mark Hursty and Liz Waugh McManus, 2018, pouring glass into a mould before pressing, at Pilchuck Glass School.

Figure 41 Liz Waugh McManus, 2018, Work in progress, clay figure, mould and glass cast.

Figure 42 Liz Waugh McManus, 2018, first iteration of the rib boat in clear glass with blown glass life jacket behind, displayed at Pilchuck Glass School.

4.2.1 Light effects

A 'tinkering' approach was used initially to explore the animation of the boat. I began to experiment with creating moving shadows by shining a light on or through the glass and playing with the effects. This built on my previous experience using moving lights and different materials to create movement, mood and storytelling in shadow theatre performances.

I programmed an Arduino Uno microcontroller with LEDs on long wires (See Appendix 2.2) using a sketch (blink_multiple_LEDs) to control them shining down onto the boat to turn on and off in a slightly erratic sequence to simulate a rolling sea effect in the shadow (Fig. 43). I intended for the LEDs to look like stars which the boat was following, however, I was not satisfied with the visual aesthetic. With support from the Sunderland Fablab manager, Alistair Macdonald, I started experimenting with programming moving lights on an LED

pixel strip[8]. (See code in Appendix 2.2). This created progressive lateral movement of the shadow which gave the illusion of the boat moving forward (Figs. 44 and 45).

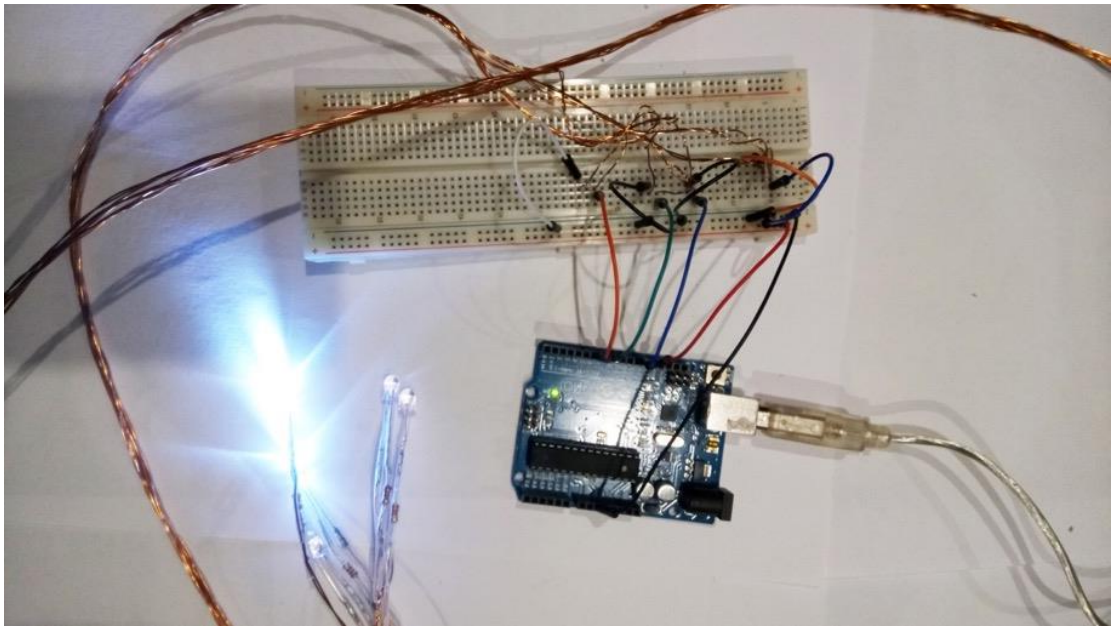

Figure 43 LEDs, resistors, copper speaker wire, breadboard and Arduino

Various positioning of the pixel strip and a cylindrical background screen were tried in order to produce caustic light effects from the glass in the shadows to simulate water. The lighting level had to be low to achieve a clear image of the repetitively moving shadow of the boat on the translucent screen, which could be viewed from both sides (Figs. 46 to 48). However, the darkness added to the narrative of a clandestine journey across the sea and the repeating progress of the boat across the screen emphasised the unrelenting number of migrants making such journeys. The boat was set on a sea of glass frits which sparkled in the light. These were then replaced with broken shards (of blown glass) to add a metaphorical dimension alluding to the danger of the journey and the broken asylum system (Fig.46). I made the title 'Stateless Vessel' in water jet cut glass sheet and placed it near the boat to form a moving shadow of the words on the screen (Fig.47).

[8] An LED pixel strip is flexible tape of RGB+W LEDs that can be individually programmed.

Figure 44 Shadows created by the LED pixel strip.

Figure 45 Progressing shadows cast by LEDs lighting up along the pixel strip.

4.3 Engagement

Referring to the categories that I identified in the previous chapter for qualities that engage viewers of interactive art (see Fig. 12), I explored liveliness, ambiguity, sensuousness of materials and captivation.

4.3.1 Animacy, ambiguity and enchantment

Stateless Vessel exploits the characteristic of 'animacy' that I previously used in the practice of puppetry to engage viewers. The innate human ability to perceive life in visual movement and how this is exploited in puppetry were discussed at length in Chapter 3.

Accordingly, *Stateless Vessel* demonstrates liveliness through the illusion of visual animation. This was realised by digitally programming the movement of an LED light source around the cylinder to cast sequential shadows of the glass boat and figures, sea and words. In a sense, the installation becomes an automated shadow puppetry scene. Viewers are able to watch both the boat with its occupants moving round the screen in shadow form and the static glass boat inside, experiencing a captivating perceptual ambiguity of liveness from an inert object.

Figure 46 Liz Waugh McManus, 2019, *Stateless Vessel* from above, showing shards of glass and pixel strip with three lit LEDs moving around the circle.

However, not only has incorporating electronics with glass animated the materials of the artwork, but has enabled the principal narrative of the artwork, the perilous boat journeys made by migrants and the lack of welcoming destinations for them, to be brought to life for the viewer.

4.3.2 Sensuous affect

As discussed in Chapter 3, 'sensation', or 'sensuous affect', relating to the sensuousness of materials contributes to engaging the viewer, used here for example, in the sleek glass boat contrasting with sharp shards of glass forming the sea. In *Stateless Vessel,* glass's capability to cast light, caustic refractions and ephemeral shadows was achieved with the microcontroller and pixel strip (Figs. 47 and 48). The light through the broken glass shards cast pale rising and falling shadows on the cylindrical screen creating the effect of waves moving on the surface of the sea. The blown glass vessel represented a visual pun for an inflatable boat. Mould-pressing in hot glass gave the passengers a watery indistinct quality where individual features were not easily distinguished, reflecting news media and politicians' portrayal of migrants and asylum seekers without their backstories. The shadow of the words 'stateless vessel' expands and diminishes as the light moves around the perimeter. This sign labelling both boat and its occupants prompts a viewer to reflect on its meaning. The smashed glass shards conjure for viewers the sensation of sharp edges, signalling the uncomfortable dangerous journey transporting the migrants, the broken asylum system and possibly their broken dreams.

Figure 47 Liz Waugh McManus, 2019*, Stateless Vessel,* W 64.5 cm, H 33 cm. Still of moving boat sequence.

Figure 48 Liz Waugh McManus, 2019, *Stateless Vessel.* Image showing watery caustic effects produced by light distortion through glass figures.

4.4 Analysis

The people who have seen the working installation, or videos, of *Stateless Vessel* have given feedback that they found it emotionally moving and appreciated the animation using glass.

The piece demonstrates an innovative blending of glass and electronics into an expressive artwork. *Stateless Vessel* communicates a complex narrative about a topical issue, the migrant crisis, provoking the viewer to reflect and hopefully respond with empathy. This is achieved visually, without verbal language apart from the title of the piece. I drew upon the

multifarious material and metaphorical qualities of glass to express layers of meaning. The orange blown glass vessel served to represent the inflatable rescue boat. Shattered glass dually evoked discomfort though visual tactility while producing the wave-like shadows that represented the sea; the cast glass figures refracted watery caustic effects; and the sharply cut-out letters in transparent sheet glass added words in a subtle way to prompt the viewer to dwell on the meaning. The meaning of the glass objects created by traditional blowing and pressing techniques was enhanced by the performative shadow and lighting effects produced by the moving light cast by the LEDs.

The addition of movement and lighting effects enabled by physical computing provided a new way of communicating not possible in my glass practice hitherto. It enabled me to incorporate techniques and sensibilities from my experience in puppetry. The digital element enhanced the capacity of glass to create ephemeral lighting effects of shadow and refractions, creating a sombre, clandestine and watery atmosphere. I was able to incorporate motion to serve the content of the piece, representing a circling journey going nowhere. Animacy through movement was also used to captivate the viewers' attention.

In *Stateless Vessel,* I treated the digital technology and electronic components as materials alongside glass and other materials. As in all projects in this study, different glass-forming methods were chosen to suit the ideas, prioritizing concept over craft specialism. The sensuous quality of the glass was appealing, but I found that the electronic components were less so, being designed for mass production and functionality rather than visual aesthetics (Fig. 49). Therefore, to avoid messiness, the circuit board and wires were hidden behind the base. This suggested that one focus for future work might be to develop more graceful ways of integrating glass and electronics in an artwork, for instance, combining glass with 3D-printed sculptural ceramic forms to house electronic components in an artwork. However, whether to hide electronic components is a conceptual as well as an aesthetic choice. The development and commodification of computational devices since the 1990s (resulting in technology hidden within 'black boxes') has led to even designers struggling to disentangle functionalities of complex artefacts (Penny, 2017, p. xxii). In contrast, some among the Maker Movement aim to demystify the way technologies function and increase digital literacy through physical computing, for example Kobakant (2023) in e-textiles. On one hand, hiding electronic components adds to the mystery about how the artworks are animated and could increase 'enchantment'. Alternatively, an open

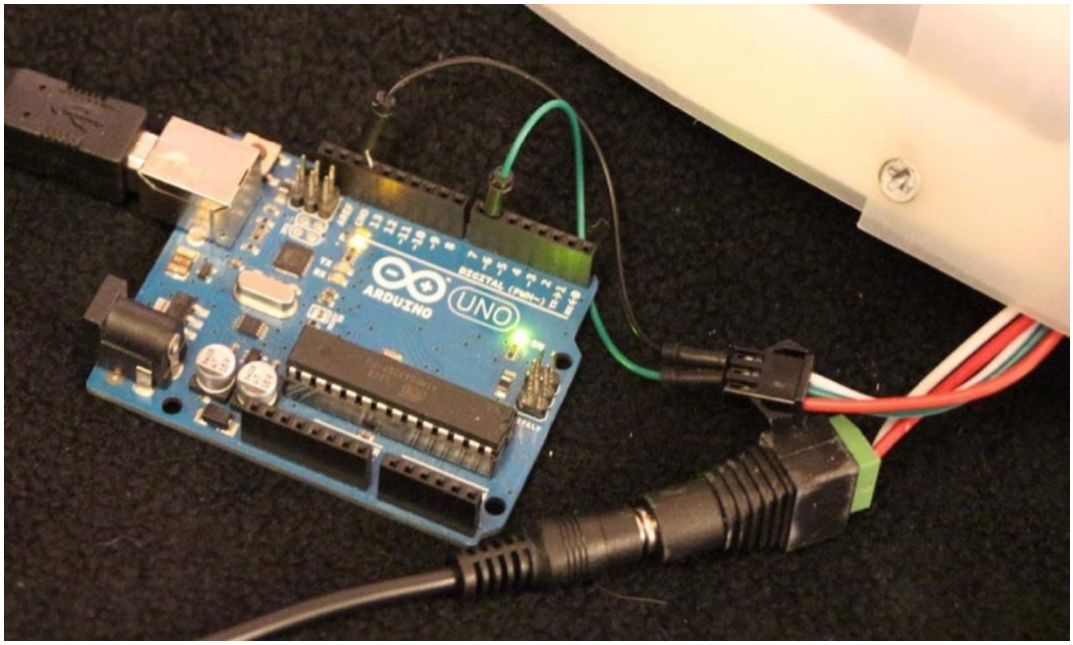

Figure 49 Arduino connected to the pixel strip at ground pin and pin 6 for data. The pixel strip is powered by 5V direct current.

approach would be to reveal how an effect is achieved while exploring aesthetic methods of displaying electronic circuitry with glass. This was the direction I explored in projects discussed in Chapters 6 and 7 where I build on previous research integrating conductive traces into glass by electroforming to create custom circuitry.

Stateless Vessel succeeded as a 'digitally communicating object' in its blend of glass and computational materials into an artwork that is meaningful for viewers. My next projects would expand on this goal to include digital interactivity, initially with data from the Internet and then through embodied audience interactivity.

5 Interactivity with real-time Internet data (*Jeopardy*)

Link to video clip of *Jeopardy* for reference:
https://www.lizwaughmcmanus.co.uk/jeopardy

5.1 Introduction to aims

My next project was to expand on blending glass with digital technologies and electronics begun in *Stateless Vessel* and add the element of interactivity. This chapter describes the artwork, *Jeopardy* (Figs. 50 – 56), a metaphorical piece about general human vulnerability and a prompt to consider those who live in regions with constant threat of earthquakes.

Jeopardy incorporates physical computing to connect to Internet data that triggers effects in the glass and mixed media artwork. A goal in developing *Jeopardy* was to create an artwork which responded to open seismic data from the web to trigger an effect on a glass form, however, it is not meant to act as a functional earthquake detector. Although the research concerned technological possibilities, this was at the service of artistic vision and the narrative about natural disasters and human vulnerability.

It is possible to trigger outputs from Internet data with a Raspberry Pi microcomputer. This study sought to demonstrate how Raspberry Pi can be linked to live USGS earthquake data that is being constantly uploaded from seismometers around the world and programmed to trigger video when an earthquake happens over a certain magnitude. It can also be connected to a circuit which will break a glass object when the data records an earthquake of a greater magnitude.

Building upon knowledge gained by making samples and experiments previously, my goal was to develop an artwork to learn ways a Raspberry Pi could be used for creative effect with inputs or actuators acting on crafted glass. There are potentially infinite ways this could be realised, however, the project was designed to address the research questions 2 ‘How may I use glass with embedded electronics to engage viewers?’ and 3 ‘How may blending glass with embedded electronics communicate content?’

5.2 Description of *Jeopardy*

My engagement with the issue of the threat of earthquakes on people was triggered by the personal experience of my daughter in India feeling tremors from the large Nepal

earthquake of 2015. The social media (YouTube) footage of birds fleeing at the onset of the quake in Kathmandu seemed to me a metaphor for the emotional anxiety and panic generated in human experience.

I took the imagery of startled birds fleeing from a tree to create a stop-frame animation which would be set off whenever a low to medium-level seismic tremor was detected somewhere in the world. I wanted a major earth tremor to trigger glass-breaking, using the metaphor of glass for its fragility and vulnerability.

Figure 50 Painted glass slides for stop-frame animation on a lightbox for the video of birds fleeing from a tree in *Jeopardy*

The animation was made by breaking a video of a flying bird into a sequence of still images as a source for twelve enamel paintings on 10cm glass squares (Fig. 50). These paintings were photographed sequentially on a lightbox with an animation software to create a video of one bird flying. This was duplicated and modified in postproduction software (Adobe After Effects) to create a video of multiple birds flying away from a tree (Fig. 51).

Figure 51 Liz Waugh McManus, 2019, *Jeopardy,* Glass, animation, mixed media, microcomputer, electronics. W 37.5 cm, H 74 cm, D 46.5 cm

In the past I have projected animation videos onto glass artworks, however wishing to avoid incorporating projection equipment, I decided to set an LCD monitor into the artwork for displaying the video. Although the screen cast light on the glass objects, it did not have the shimmering effect of projections on glass. In future works, captivating optical effects could be achieved by integrating kiln-formed textured glass in front of the screen.

5.2.1 Glass characteristics and techniques

Initially, I envisaged an abstract glass form, but eventually chose a representation of a glass house with glass dolls inside, exploiting the fragile nature of the material. The aim was to emotionally engage the audience to care about whether or not it would be destroyed. The audience would not be able to play with the dolls but could relate to doing so in their imaginations. The glass dolls signified the fragility of human beings in the context of an earthquake. I hoped the identification of dolls with living creatures would help to evoke empathetic engagement with the predicament of people living in earthquake zones.

There were various iterations of the house in an attempt to create a delicate form as a symbol of home and safety. Sheet glass was given texture by casting into moulds under kiln-heat and then water jet cut from a CAD design of wall and roof sections. The dolls were cast in glass using the lost wax method from components originally modelled in polymer clay.

Figure 52 Liz Waugh McManus, 2019, *Jeopardy,* Glass, animation, mixed media, microcomputer, electronics. Close-up view.

5.2.2 Internet connectivity

Regarding the computational technology and electronics used for connecting to the live data on the USGS earthquake website, I chose Raspberry Pi for its ability to respond to data and trigger action and, unlike Arduino-style microcontrollers which can sense and trigger, its ability to easily play video. I approached a computer programmer to assist in coding in Python 3 using GeoJson format for the Internet data and Omxplayer to play the animation video. The Raspberry Pi Foundation is still developing its products and I discovered when I updated the operating system on one occasion that the code stopped working, so the programmer had to update the code. (Please see Appendix 2.2). This is likely to be a recurring problem when working with new technologies, even when legacy versions of software remain available.

5.2.3 Response to real-time data

Figures 53 and 54 show a photograph and diagram of the electronics system devised with advice from the manager of Sunderland Fablab using a Raspberry Pi, 12V battery, MOSFET, and relay and fuse wire. A camera module is also connected to the Raspberry Pi.

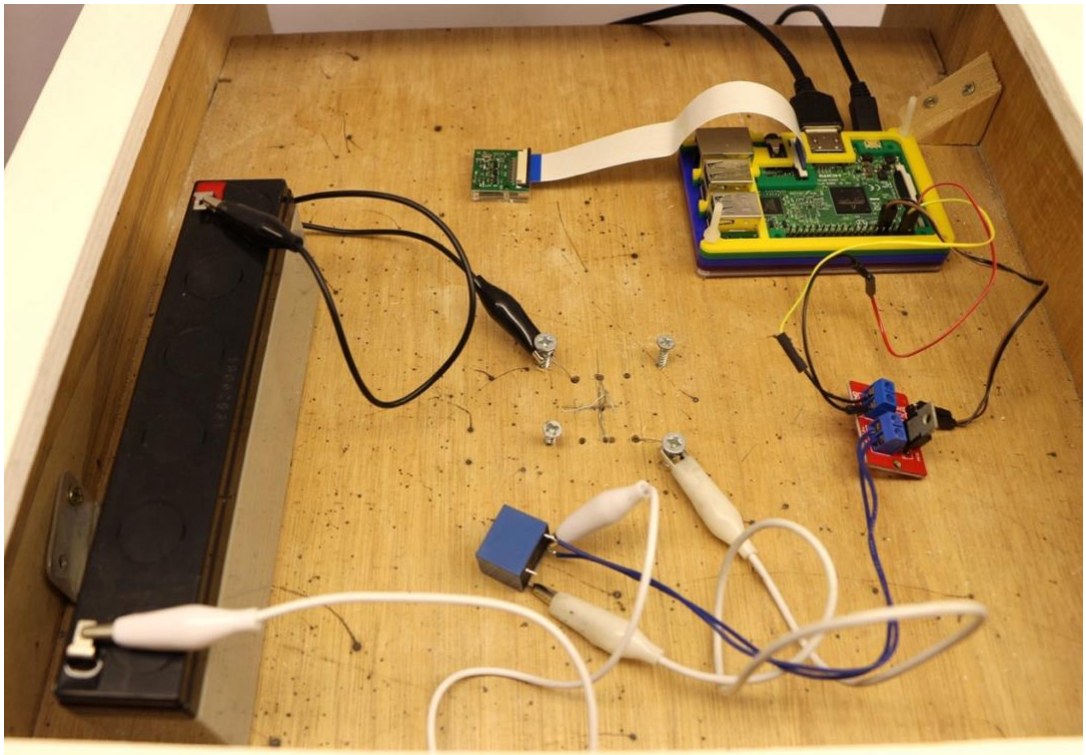

Figure 53 Electronic components in *Jeopardy*.

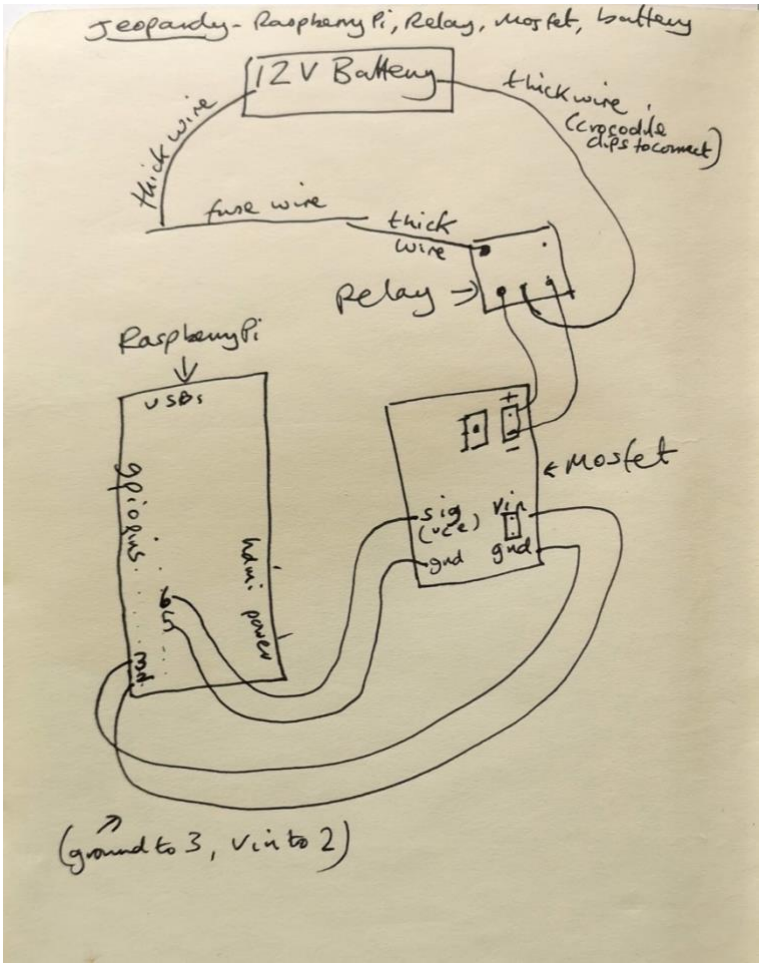

Figure 54 Diagram of electronics system from my notebook.

Various mechanisms for breaking glass, should the Pi sense an earthquake of sufficient magnitude, were considered, trialled and refined. Initially, thermally cracking glass through heating nichrome resistance wire fused inside was explored. Tests proved the effect was underwhelming - although the glass cracked, the break was barely visible. The use of electromagnets programmed to drop onto glass to smash it was considered, but rejected as this would rely on the artwork being always powered and risked breaking the artwork if there was a power cut. Using nichrome wire to melt a 3D-printed PLA hook holding a stone was tried. Although this worked it was felt to be a fire hazard to rely on code to switch off the current to the wire once it no longer needed to be hot. The penultimate solution was to hang a heavy stone (flint) from a two-part PLA component joined with fuse wire which a current would separate if triggered (Fig. 54). I received advice from the manager of Sunderland Fablab about the electronics to realise this. On testing this system, I discovered that when the fuse wire was triggered to heat up, it often melted the 3D-printed PLA components (Fig. 55) leaving the stone still suspended.

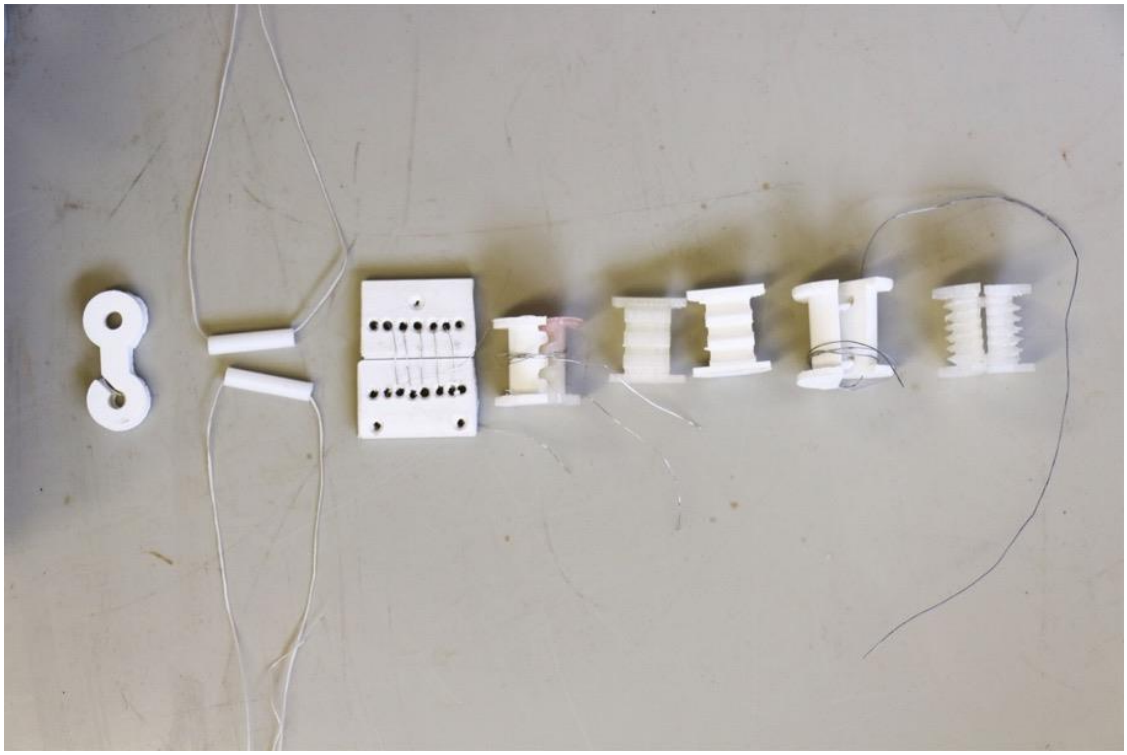

Figure 55 Iterations of 3D printed suspension components trialled for *Jeopardy*.

The final solution was to wrap the fuse wire multiple times directly around the wire from which the stone was suspended (Fig. 56). I added a camera to the artwork to add the possibility of livestreaming it when exhibited, allowing the largely dormant artwork to be remotely checked for activity by visitors in their own time and space.

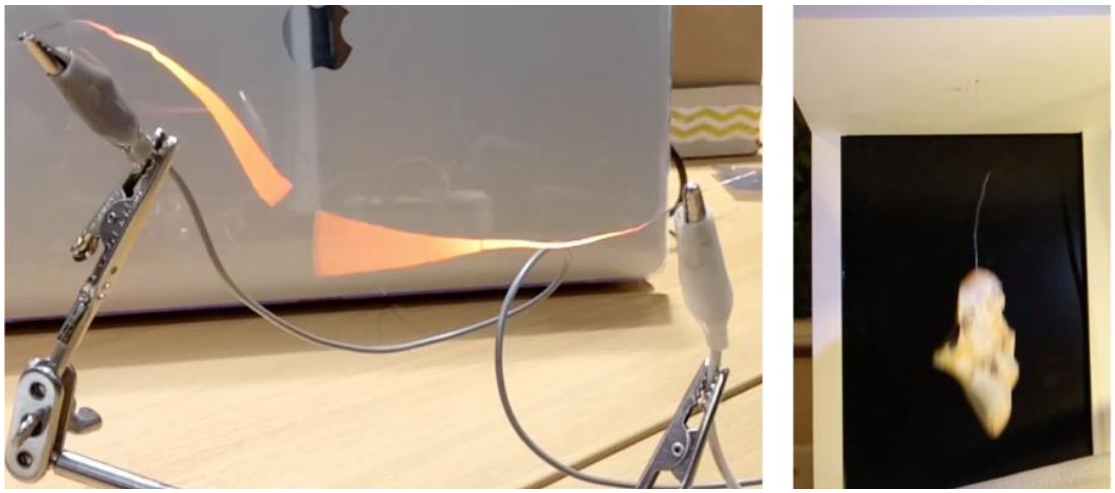

Figure 56 Tests of the system of electronics for breaking the fuse wire: (left) showing wire melting and (right) showing the flint dropping from the broken wire.

A flint was chosen for its visual appearance. This led to the reflection that flint (silica) was used throughout the work in processed silica form - a constituent of glass itself, of the moulds in which the glass figures were cast, and of the silicon chips in the computational

materials which processed the data. The glass house's vulnerability was made visually obvious by the rock suspended over it by a thin thread. This was a reference to the phrase 'Sword of Damocles' meaning a sense of foreboding engendered by a precarious situation, from the legend of the sword which was hung by King Dionysius by a horse's hair over the throne where Damocles sat, to give him a sense of the peril experienced by the king (Cooper, 1992, pp. 66-67).

5.3 Engagement

An objective of the research is to engage viewers. The qualities for engagement in Figure 12 that were explored in the development of *Jeopardy* were liveliness/agency/living presence, playfulness, ambivalence/paradox/ambiguity, sensuous affect, and enchantment. The other attribute identified in Chapter 3 that was relevant to this project for engaging viewers was telepresence. These are discussed below.

5.3.1 Liveliness and Agency

Liveliness is at the core of *Jeopardy* in the constant updating of live data which produces physical responses of movement or animation in the artwork. Both the animation of the birds and potentially the falling rock, capitalise on Glynn's 'irresistible perception of animacy in movement' discussed in Chapter 3, p. 62. The physical manifestations make visible real-time events and connections enabled by IoT in a playful way akin to the animated objects of Device Art.

Writing from the viewpoint of an anthropologist rather than an art practitioner, Gell (1998) discusses the agency of art in different cultures and the way it acts as a *living presence* on recipients (termed 'patients'). According to Gell, the agency of an artwork can be physical, psychological, spiritual, political as well as aesthetic. He states "the personhood of the artist, the prototype [what the artwork represents] or the recipient can fully invest the index [artwork] in artefactual form, so to all intents and purposes it becomes a person…" (p. 68). In Chapter 3, I discussed Gell's theory that an artwork captivates a recipient through its technical virtuosity - the recipient is confounded by the skill of the artist to bring it into being, sometimes attributed to divine inspiration or magic. Gell also explained how liveliness could be achieved in artwork through technical virtuosity, such as verisimilitude in representation or optical pattern effects producing the illusion of movement.

Jeopardy is an 'animated' artwork, not simply because it contains actual animation, an illusion of birds in motion, but because it responds to live data in real time. *Jeopardy* should act psychologically on a viewer who relates to the vulnerability of the glass house and dolls even when the artwork appears dormant. If there are no tremors around the world, the artwork appears static/dormant, yet it has a latent liveliness not visible to the audience, apart from the updating code on the top left of the screen. Only when seismic tremors occur above a certain level does the audience see something happening - the birds flying if registering 1 to 8.5 Magnitude, the flint dropping if above 8.5. It is also possible that to a viewer who did not understand the technology, any activity of the artwork would appear 'magic'. Revealing the technological functioning by displaying the terminal window showing the live data uploading increases understanding of the artwork's 'liveness' and makes the connection with earthquakes.

For exhibitions, *Jeopardy* would be accompanied by a short text explaining its interaction with earthquakes. I made the connection with live data visually obvious by placing, in the top left corner of the screen, the terminal window displaying the constantly updating code from the USGS website of seismic activity across the world.

5.3.2 Playfulness and ambivalence

Jeopardy is darkly 'playful' in concept and in the sense the viewer does not know if the artwork will show signs of life while they are present. This creates ambivalence in that the viewer would like to be present while it is animated, but this enjoyment would be paradoxical as it would mean that a disaster is playing out somewhere in the world. If the seismic activity is high enough, the artwork is also destroyed. This invites a dialogue about the value of an exhibited artwork compared to the incomparably higher value of the lives of humans affected by an earthquake.

5.3.3 Sensuous affect

Sensuous affect was another quality for audience engagement identified in Fig.12. I achieved this through the use of glass for the toy-like figures and house which exploited a viewer's embodied sensory knowledge of glass's fragility. The requirement for the house to look fragile informed my decision to create it in thin glass sheets, textured with moulded bricks and tiles, rather than as a solid cast glass object. The hand-drawn animated birds, bare treetops and plain sky contribute to a pared-down aesthetic.

5.3.4 Telepresence

As stated in the introduction, an objective of this project was connectivity with real-time data on the Internet. Presence and telepresence were explored through connecting the physical glass and mixed media artwork to live seismic data that had been uploaded to the USGS website from sensors around the world. The viewer is able to sense through *Jeopardy* events that are happening in real-time across the world.

5.3.5 Enchantment

Producing an opportunity for viewers to be captivated by the artwork was explored through the sum of the above characteristics of animacy, playfulness, ambivalence, sensuousness of materials and telepresence.

5.4 Analysis

Jeopardy transmits to the viewer a sense of anxiety, conveying tension visually through the rock suspended over the glass house. It has a potential for real disaster - the destruction of the glass house and its occupants. This is a metaphor for the destructive impact of a real earthquake which triggers the reaction in the artwork.

Through making glass figures in a glass house, I conveyed a socio-geological narrative of destructive seismic events in an embodied way. In answering my first research question, the main quality of glass I utilised in *Jeopardy* was fragility. Embodied haptic visuality discussed in chapter 3 (p. 66) enables the viewer to identify with the vulnerability of the childlike figures sheltered from the overhead rock by the brittle roof. Dickson (2015) discusses the phenomenology of glass in communicating artistic ideas through "capitalising on a viewer's material, cultural and social knowledge of glass through word play, imagery and cultural cues" (p. 159). *Jeopardy* draws on the viewers' experiential knowledge of the breakability of glass and potential dangers from stones, enshrined in the proverb, 'Don't throw stones in glass houses'.

I identified in Chapters 1 and 3 that animacy for captivating audience attention has been a key element throughout my practice and has been achieved through creating a sense of living presence through different means. Physical computing using a Raspberry Pi in *Jeopardy,* provided me with a new tool to animate art work. The project also demonstrated the creative possibilities of blending glass with digital technologies and electronics to

communicate content in an engaging way, beyond what would be possible using either glass or digital technology alone.

Jeopardy promotes awareness of human experience beyond the proximal and represents IoT 's capacity for enabling global interconnectivity. In *Jeopardy*, I have incorporated real time data in art work for the first time through the creative application of connecting with internet data. Connecting to live data enabled *Jeopardy* to be animated by a constant flow of content thus engaging the viewer in a playful way with the premise that the artwork changes as events happen concurrently in distant parts of the world. As discussed in Chapter 3, telepresence has been explored by artists, designers and engineers for decades, but rarely in the context of glass art. New IoT technologies allow telepresence with real time interaction mediated by the Internet, not only streaming information from distanced locations, but also offering the potential for making physical proximity unnecessary between the artworks and/or human recipients. This suggested for future development artworks with the ability to communicate with each other over distances, or enable viewers to do so. However, before distanced artworks, it was necessary to explore proximal audience interaction. This is investigated in the following two chapters.

The independent agency of IoT offers the potential, in addition to a glass art work acting on or responding to the viewer, of also creating a relationship between glass artworks, art work as 'person' digitally communicating with other 'persons' in the form of connected artwork(s). In the process towards "Developing 'an Internet of Glass Things' - glass artworks as digitally communicating objects", I have reflected on the relationship of IoT and Glynn's and Gell's analysis of the ways the agency of artworks is manifested and their subsequent 'personhood'. I am interested in imbuing artworks with the sense of a living presence. The animation of *Jeopardy* and the previous project *Stateless Vessel* may invest them with agency and 'personhood' for the viewer. This enables a sense of 'person to person' relationship, between the artwork as 'person' communicating to the audience as 'person'. However, communication in these artworks is one-way, in that a viewer can only interact mentally or emotionally. In my next projects I aimed to explore two-way communication by creating art work which responded to the audience's embodied actions.

6 Glass artworks and chemical, digital and embodied interactions (*She's Got the Wrong End of the Stick…*, *Hearing Instrument*, *Bin Bag Hug*)

Video clips of artworks for reference:

https://www.lizwaughmcmanus.co.uk/shes-got-the-wrong-end

(*She's Got the Wrong End of the Stick…* and *Hearing Instrument*)

https://vimeo.com/646082128

(*Bin Bag Hug*)

6.1 Introduction to aims

Having explored connectivity with real-time data via the Internet, the aim for my next project was to create artworks which responded to the presence of a viewer via touch and proximity sensors. The intention was to craft digital interfaces that enabled embodied human interactions.

I wanted to apply what I learnt from samples I had made with graphite and copper electroforming to integrate conductive traces and create sensors in artworks. I trialled various methods of applying graphite or carbon-based ink as a conductive trace with ink through painting, intaglio-etching or kiln-fusing between sheets of glass for connecting with microcontrollers. Researchers in Craft Futures workshops discussed in Chapter 1 experimented with the cold application of proprietary conductive paints that included metal particles, graphite or carbon black. I experimented with traditional media containing carbon and with Sumi-e ink which I discovered, from a presentation by calligrapher and academic Manny Ling, is composed of lamp soot. I tested the resistance of Sumi-e ink with a multimeter and discovered it could be used for conductive traces when applied thickly. My touch-interactive art projects leading towards the ones discussed in this chapter include *Lockdown Walks,* Sumi-e ink drawings on rice paper, and *Make Live* with school students using graphene ink produced researcher Robert Murray-Smith (2020). As mentioned in Chapter 3, I first explored copper electroforming as a means of integrated conductive traces in glass while on the Glass Electric class at Pilchuck.

The first resulting project discussed here is *She's Got the Wrong End of the Stick…* (Fig. 58) which uses touch or proximity sensing and electronics to trigger sound from crafted

capacitive-sensing artefacts made from copper electroformed flameworked glass, as does its related artwork, *Hearing Instrument* (Fig. 65). The artworks explored embodied multi-sensory participation for audience engagement in a system, with glass and copper elements, microcontroller, audio speaker, using Kluszczynski's *strategy of instrument* to enable viewers to create unique performances of the artwork. The second project*, Bin Bag Hug* (Fig. 69), used a novel application of graphene ink to an etched photographic image to create an interactive glass-audio artwork.

6.2 Description of *She's Got the Wrong End of the Stick …* and associated artwork

She's Got the Wrong End of the Stick … is based on sensory loss and compensation, frustrated and facilitated communication, translation and sensory intersections. It grew out of experience of my mother's deafness, her own and that of those around her. Otosclerosis caused tiny bones (ossicles)[9] in her middle ear to fuse. The project title comes from a saying of my father when frustrated by the regular miscommunications resulting from the deafness, "She's got the wrong end of the stick and won't let it go".

Although experiencing barriers to communication, my mother was very sociable and carried a notebook and pen for people to write their side of a conversation, encouraging

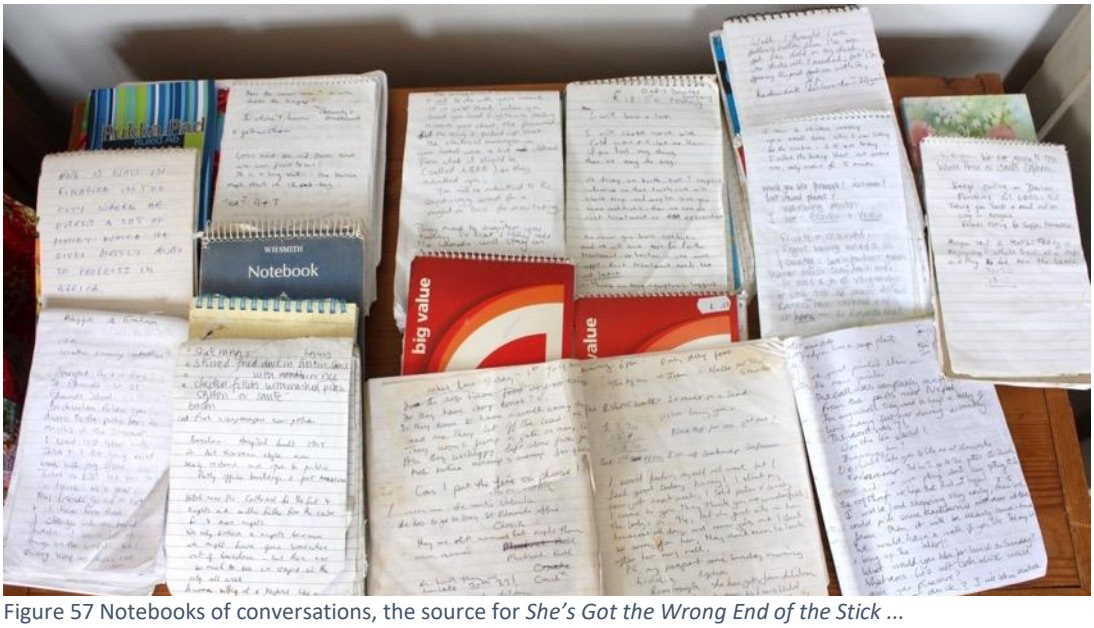

Figure 57 Notebooks of conversations, the source for *She's Got the Wrong End of the Stick …*

[9] Ossicles, known as the malleus (hammer), incus (anvil), and stapes (stirrup), normally transmit the tiny sound vibrations of the eardrum onto the cochlea, the inner ear structure responsible for encoding sounds as neural signals.

them to squeeze in as much as possible per page, (see Fig. 57). This resulted in wildly disparate dialogue and persons represented on every page with strange juxtapositions of mundane information, anecdotes, discussions and even theology. After death, she left a boxload of these notebooks spanning over a decade, referencing spatiotemporal contexts and forming a 'diary' of happenings, visits, journeys, holidays, family and friends. Gell (1998, p.222) discusses objects from which 'personhood' may be abducted, traces and effluvia testifying to a life even after biological death. As well as continuing after her death to attest to her presence as a person, the notebooks also highlight absence in that the conversations are one-sided, with no trace of the words spoken by her.

Figure 58 Liz Waugh McManus, 2021, *She's Got the Wrong End of the Stick...,* Flameworked glass cane, copper electroformed text, glass cyanotype photo-plate, conductive thread, microcontroller, speaker. Exhibited at *When We Touch Again* pop-up exhibition, the University of Sunderland.

Referencing issues of living without one sense, the artwork also alludes to synaesthesia or perceptual compensation where the lack of one sense is compensated for by increased sensitivity in another. Current thinking about sensory compensation is that there is greater plasticity in the areas of the brain dealing with processing cross-modality. Lacking one sense, these areas may become reorganized such that neurons that normally would serve the missing sense are recruited into serving a different sense, which can lead to differences in performance (Bavelier and Neville, 2002). There is also some evidence that even neurons in the primary sensory areas, areas which typically serve only one particular sense, may

also be recruited to serve a different sense (Bavelier and Neville, 2002). Studies of synaesthesia (Sagiv and Ward, 2006, p. 268) point to aspects of cross-modal integration in the brain being based on universal mechanisms of human cognition, evidenced in links between synaesthesia, language, metaphor and creativity. In *She's Got the Wrong End…*, vision is replaced with touch, and sight is replaced with sound, when touched sensors trigger audio excerpts from the notebooks[10], and in the associated work, *Hearing Instrument*, cello notes, both sounds my mother could not hear. (She gave up playing cello because hearing aids are adjusted for the human voice and distort musical sound).

6.2.1 Copper electroforming as a method to introduce circuitry and capacitance

My research goal to further explore copper electroforming as a means to integrate conductive traces in glass involved refreshing and learning new knowledge and skills in electroforming to craft the glass and copper capacitive sensors.

Figure 59 Flameworked borosilicate glass friggers with stencils prepared for sand-carving.

[10] Please refer to transcribed samples in Appendix 3.

With the assistance of Zoe Garner, I flameworked borosilicate glass canes as physical interfaces between audience and digitally reactive elements. These were inspired by ‘friggers’ (2023), glass walking sticks made by glassworkers in the past on view at the Museum of Sunderland. Cut vinyl stencils of text (designed in Adobe Illustrator), were used to sandblast the glass before painting with conductive paint (Fig. 59). Electrical wires were then connected along the text for electroforming.

I also made sensors by electroforming copper over silicone/acrylic ear moulds, spraying them with conductive silver paint and securing them in copper wire ‘cages’ attached (Fig. 60) to the electroforming cathode. I had an intimate connection with these ear moulds when attached to my mother’s hearing aids as she needed help daily to position them correctly.

Figure 60 Ear moulds prepared for electroforming.

Wires to the conductive paint were connected to the cathode in a copper electroforming system. (See Appendices 1 and 2 for the electroforming process). Copper was then deposited onto the conductive paint through the electrolyte from copper anodes (Fig.61 and 62). The copper and glass sticks were then wired to a microcontroller to become capacitive touch/proximity sensors.

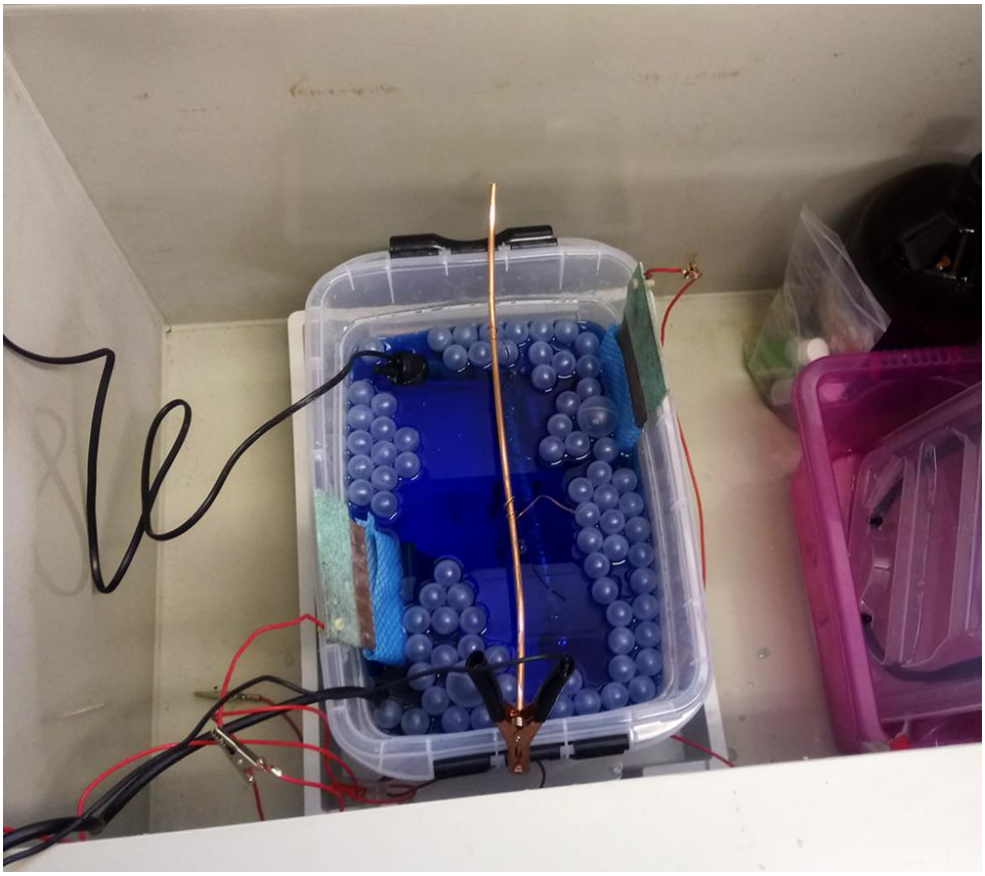

Figure 61 Copper electroforming tank used for *She's Got the Wrong End of the Stick...*

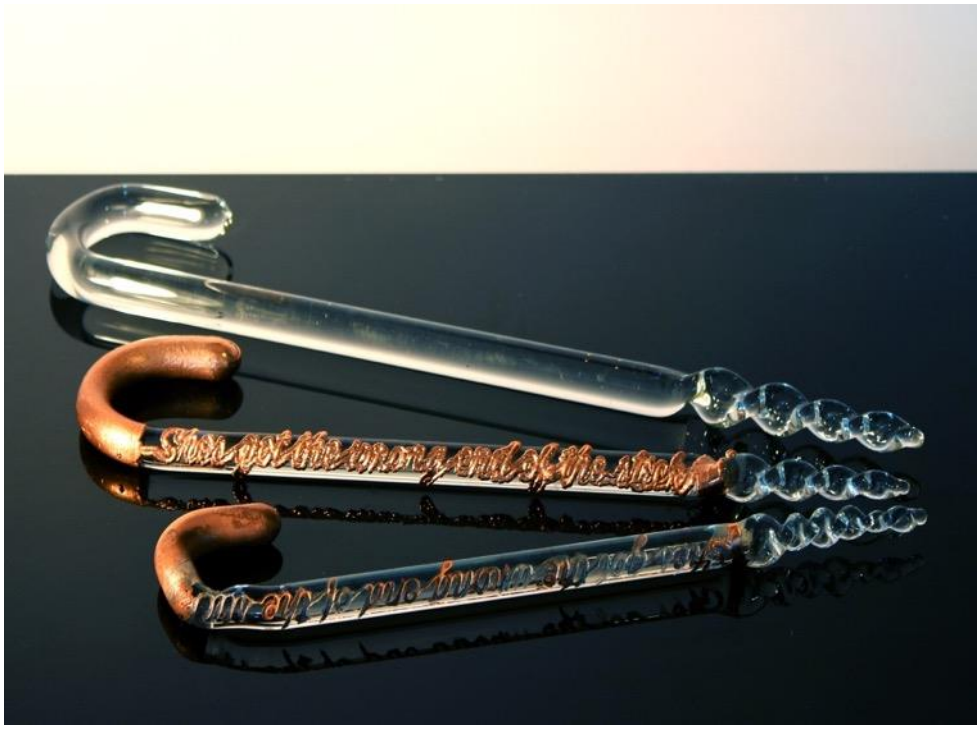

Figure 62 Flameworked borosilicate glass friggers with copper electroformed text.

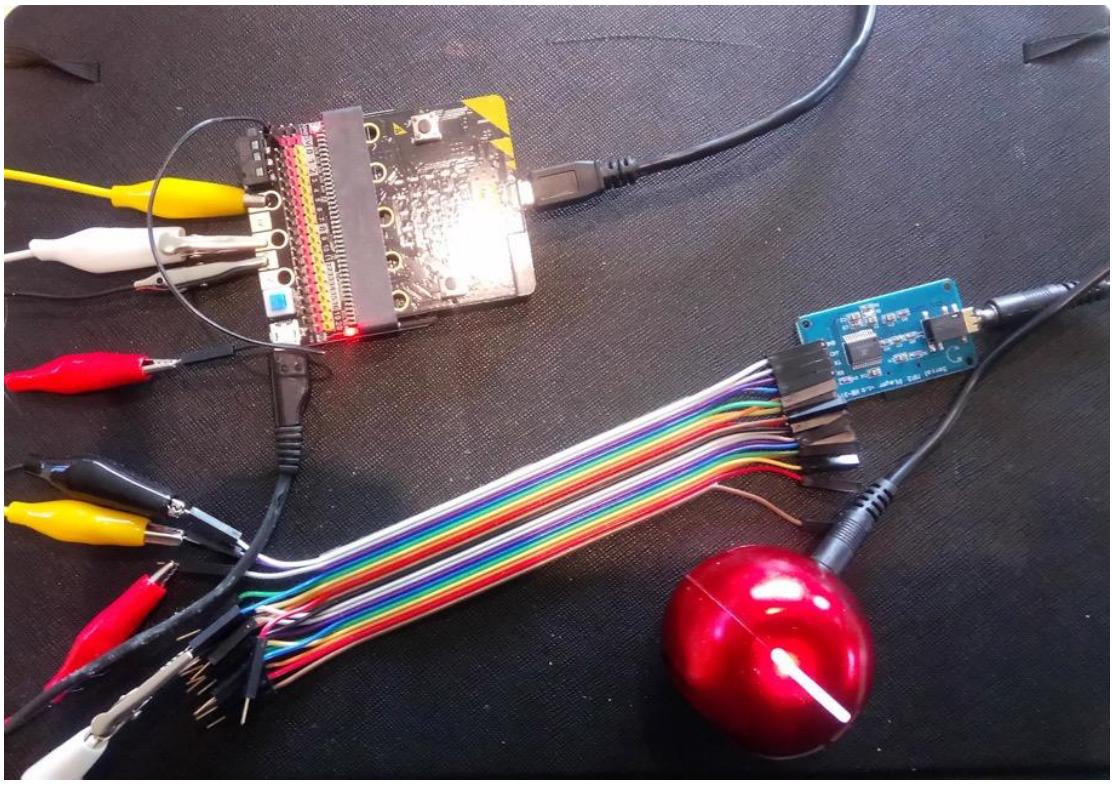

Figure 63 Early configuration of Micro:bit, expansion board, mp3 module and speaker for *She's Got the Wrong End of the Stick...*

6.2.2 Physical computing for interactivity

I experimented with several microcontrollers, the MPR121 Proximity Capacitive Touch Sensor Controller with both Micro:bit and Arduino Uno, before settling on the Bare Conductive Touch Board for this project. Initially, at the research workshops led by creative technologist Thomas Dylan, I experimented with BBC Micro:bits, using their radio communication and LED scrolling text facilities with touch sensing to generate random sentences from the notebooks. Preferring the sentences to be heard as speech, and not wanting to trigger audio on a computer, I investigated connecting a BBC Micro:bit via a MakerHawk expansion board to a YX5300 MP3 player module and speaker so that a sensor triggered audio recordings (see Appendix 2.2). This system had several advantages: it could be programmed with block-based code (visual programming) and could trigger audio from sensors without having to go through a computer, however, the wiring was messy and prone to coming apart (Fig. 63). I also experimented with using an Arduino Uno with the MP3 module and with generating sound from proximity sensing using Arduino theremin code (Fig. 64).

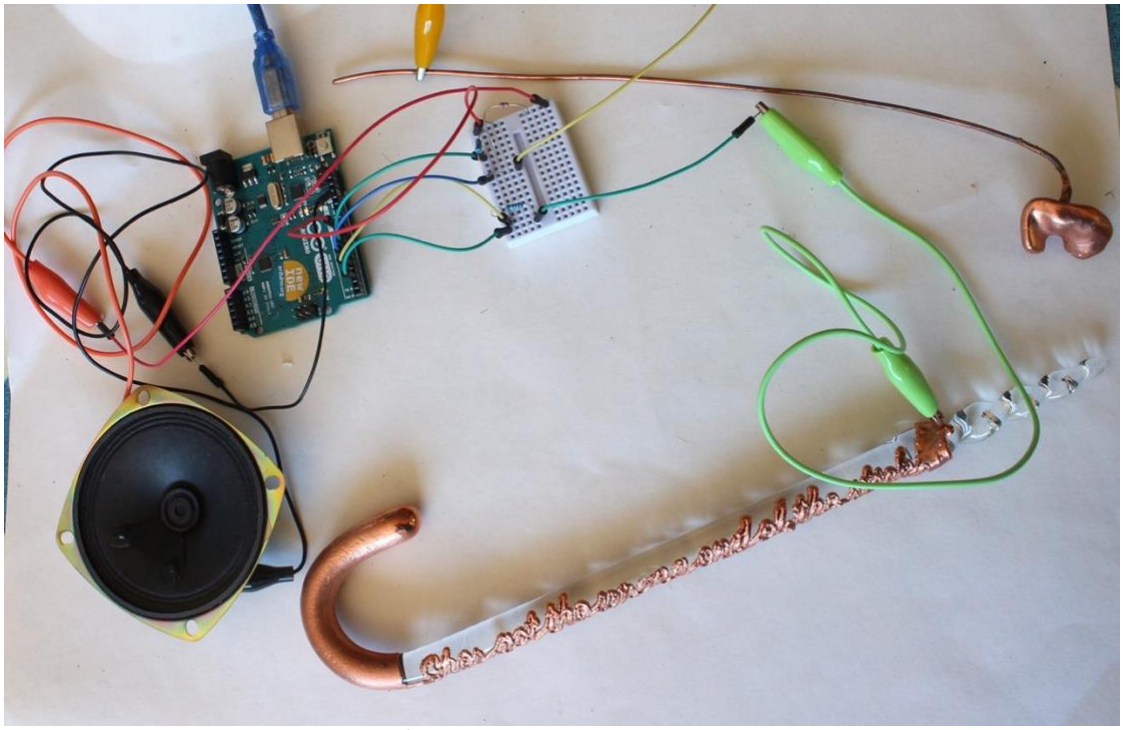

Figure 64 Arduino Uno, resistors, copper/ glass sensors, speaker set up to act like a theremin.

Ultimately, I decided to use the Bare Conductive Touch Board, as it incorporates an Arduino microcontroller (Leonardo) with a built-in MPR121 proximity touch sensor with 12 electrodes to which to attach sensors and a built-in MP3 player. As well as being compact and user-friendly, there were already Arduino sketches for several functions useful for this project which I could customize. I experimented with coding to trigger the audio from both capacitive touch and proximity sensing (the latter more useful during the coronavirus pandemic) and progressed from having one sensor electrode associated with one mp3 file to a single electrode being associated with many randomly played audio files, as less predictability is known to be more engaging for the audience. Programmer Craig James, with whom I connected through 'Touch Collaboration' discussed in Chapter 7, created a new sketch at my request, 'Random Proximity No Repeat', which enables someone to trigger the sound element by waving their hand over the sensor.

6.2.3 Audio

The concept was to translate the writing in my mother's notebooks into speech, excerpts of conversations which had never been heard aloud previously. I originally intended to record actors reading the handwriting and a musician playing the cello for the musical aspect.

However, it was not possible to do this during the COVID-19 lockdown. I chose several free online text-to-speech services, typing passages copied from the notebooks, though only a limited number of UK accents were available. I used one accent for all text on a page in the same handwriting. I felt computer-generated speech was appropriate for this project using technologies creatively. However, following audience feedback when the artwork was in a pop-up exhibition, I recorded humans voicing the texts. The sensor randomly activated snippets of speech, reflecting the random one-sided conversations in the notebooks. Listeners naturally wanted to make connections and sense of the speech and so had a similar experience to that of my mother when she tried to make sense of a partially-heard conversation and frequently 'grabbed the wrong end of the stick'. Written samples of the audio are available in Appendix 3.

For *Hearing Instrument* (Fig.65*)*, audio AIF files for bowed cello notes of A minor scale were downloaded from a website and converted into MP3s to be compatible with the Touch Board. Each note was assigned to a separate electrode connected to each copper hearing mould.

Figure 65 Liz Waugh McManus, 2020, *Hearing Instrument*, Copper hearing-aid ear moulds, wire, test tube rack, glass cyanotype, microcontroller, speaker.

6.2.4 Chemical interactions with cyanotype

During lockdown, another method of creating glass-mediated reactions, this time chemical ones using the cyanotype method, was explored. (See Appendix 1 for details of the cyanotype process). This alternative to working with electronics offered a more

spontaneous creative mindset and method. It enabled me to expand the visual narratives for *She's Got the Wrong End of the Stick...* using glass and copper artefacts created for prototyping sensors alongside other found objects related to the theme (e.g. acrylic and silicon ear moulds and tubing for hearing aids), unifying diverse materials through one medium. This method played with the refractive, reflective and shadow-producing properties of glass (Figs. 66 and 67).

A dynamic and gestural method of applying the chemicals on paper was used to create energy and contrast between positive and negative spaces in the composition, the reactive and inert surface of the paper corresponding to the conductive and insulating parts of the objects. Following the paper cyanotypes, I started to create cyanotypes on glass using gelatine, (McAllister, 2017), making one from a photograph of the notebooks as a base for the sensor. The final artwork including the cyanotype base is shown in the photograph in Fig. 68 taken when it was exhibited at the British Glass Biennale in 2022.

Figure 66 Cyanotypes with blown and water jet cut glass, copper and mixed media objects being exposed to sunlight.

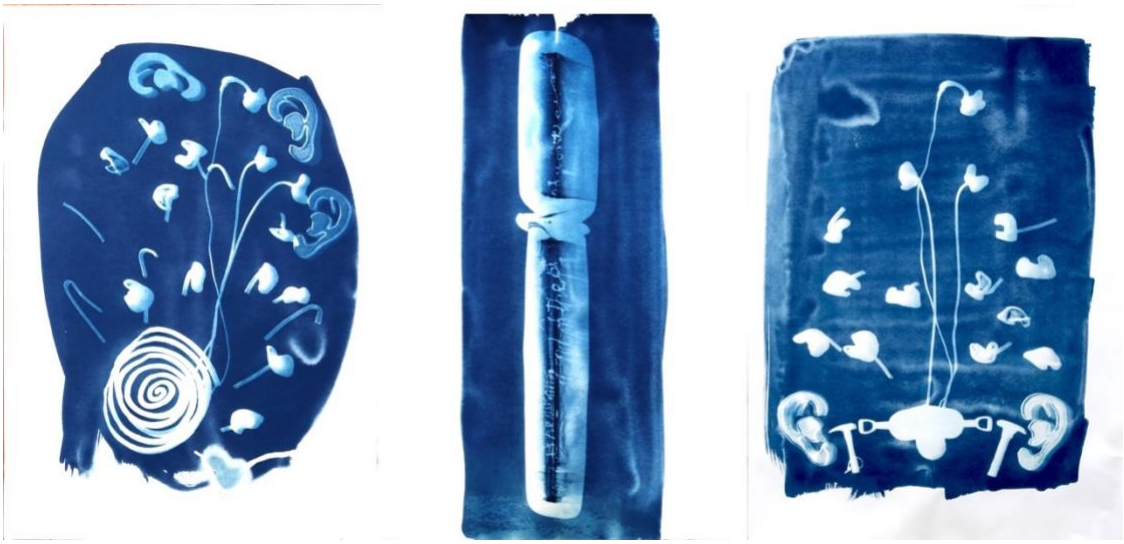

Figure 67 Liz Waugh McManus, 2020, A selection of the cyanotype prints on paper for *She's Got the Wrong End of the Stick...*

Figure 68 Liz Waugh McManus, 2021, *She's Got the Wrong End of the Stick...*, Flameworked glass cane, copper electroformed text, glass cyanotype photo-plate, conductive thread, microcontroller, speaker.

6.3 Description of *Bin Bag Hug*

Figure 69 Liz Waugh McManus, 2021*, Bin Bag Hug,* Glass, found photo frames, graphene ink and thread, microcontroller, speaker, mixed media. H25 cm D20cm W50 cm.

The image in Figure 69 shows *Bin Bag Hug*, the context of which is discussed in the next chapter in the section about *When We Touch Again*. However, it is included here in the discussion of methods for crafting conductive traces.

Bin Bag Hug was made for the *When We Touch Again* project and explored the effects of isolation, touch hunger and connecting across distance during the COVID-19 pandemic. It revolves around a hug with one of my daughters, on our first-time meeting in a garden after the lockdown restrictions eased in June 2020 where she wore a bin bag as PPE[11]. Photos and video taken at the time on a smartphone were emailed to me by her sister, who moved to Aotearoa-New Zealand the following October. Touching the pictures triggers audio extracted from the video and a conversation about the experience of being hugged, which was later recorded on Zoom, while we were 50 miles apart.

The graphene ink of the photographic image acts as a capacitive sensor to trigger the audio files stored on the Touch Board. I developed the method (see Appendix 2) for creating the conductive imagery, on the rear face of the glass, by experimenting with making a greyscale halftone bitmap file of the photograph, printing it on an acetate and using a

[11] Personal Protection Equipment.

photo-chemical process to make a stencil, through which I etched the glass with etching crème. I then applied graphene ink by a traditional method for inking up metal etching plates using scrim, tissue paper and my hand. The glass could have been etched deeper with a different type of stencil sheet and sandblasting, which would have allowed for thicker ink and greater conductivity, nevertheless, the method was sufficient for the images to act as sensors to trigger the audio. I played on the punk aesthetic of the bin bag garment by backing the dark photographic image with neon pink and cut-out printed letters to evoke a 1970s zine.

Figure 70 Visitor interacting with *Hearing Instrument*, pop-up exhibition, Glass and Ceramics Department, October 2021.

6.4 Engagement

The focus of this chapter has been to describe ways digital interfaces were crafted using copper or graphite to enable audience interaction. However, as in all the projects in this study, the development of the artworks was guided by categories for audience engagement identified in the contextual review. *She's Got the Wrong End of the Stick…, Hearing Instrument*, *Bin Bag Hug* (and the other artworks in the *When We Touch Again* project discussed in the next chapter) all investigate sensuousness of materials, animacy, playfulness, and embodiment. *Bin Bag Hug* also explored absence, presence and telepresence.

6.4.1 Sensuous affect

Sensuous affect was realised through contrasting materials and colours, such as the bright blue of the cyanotypes with the copper sheen of the electroformed metal and the smooth

transparent glass in *She's Got the Wrong End of the Stick…* and *Hearing Instrument* or the inky black with the bright fluorescent pink in *Bin Bag Hug*.

6.4.2 Telepresence

Bin Bag Hug, about face-to-face meeting after isolation during the pandemic also explored connecting across distances and used telepresent technology and methods in creating the sonic element by recording a video-conferenced conversation and extracting the audio from a video transferred by email of the face-to-face event.

6.4.3 Animacy, playfulness, embodiment

In all three artworks, animacy is achieved through the sound that is triggered by the embodied interaction of the viewer in moving to close proximity. Discovering a sonic reaction to their hand prompts the viewer to engage playfully to explore further sounds. With *Hearing Instrument,* they may be led to make up a tune, *Bin Bag Hug* to hear more of the story and *She's Got the Wrong End of the Stick…* to listen to more messages from the notebook. Additional to embodied audience interaction, *She's Got the Wrong End of the Stick's…* is inspired by embodied sensory relationships and synaesthetic cross-modal brain activity in its substitution of vision for touch and sight with sound.

I was able to observe audience interaction and responses with *She's Got the Wrong End of the Stick…*, *Hearing Instrument* and *Bin Bag Hug* when they were displayed in two pop-up exhibitions in the Glass and Ceramics Department in July and October 2021 as part of *When We Touch Again* project which is discussed in Chapter 7. At the private view (Figs. 70 and 71), visitors were observed to be absorbed in playing with the above artworks and others made by students using the same technology. They appeared excited by the touch-audio element, one commenting on the potential of artworks that spoke to you as you approached. People were curious about the technology and one visitor joked it was 'witchcraft'. One person fed back about *She's Got the Wrong End of the Stick…* was that it would be more engaging if the voices were less robotic. (This was later addressed). People appeared particularly to enjoy playing with *Hearing Instrument* as it offered the freedom to make up their own tunes. Several visitors were prompted to tell their own stories of isolation and touch hunger after interacting with *Bin Bag Hug*. The artworks both adhered to the aesthetic properties of interaction identified by Boden (2010) cited in (Candy and Edmonds, 2011) of predictability and control, attributability and speed of feedback, in that

they released the sounds quickly and consistently when a hand came within range. However, it became apparent that signage was important to help visitors engage with the artworks if there was not a person handy to demonstrate how they worked. When *She's Got the Wrong End of the Stick…* was exhibited in the British Glass Biennale 2022, a special label had to be made as the rest of the exhibits could be enjoyed on a purely visual level. Even then there were barriers to engagement due to the sign being small and the level of noise in the exhibition space high.

6.5 Analysis

She's Got the Wrong End of the Stick… could be described as a posthumous portrait, taking Gell's observation that personhood can be construed from traces someone leaves behind even after their death. The artwork brings to life an individual's past encounters and conversations recorded in their notebooks, documentation spanning different times and places. It celebrates their rich social life conducted despite their deafness. By voicing unheard conversations from the notebooks, it also highlights relations between deafness and communication as its subject. As a visitor tries to make sense of the random nature of the utterances, they experience a sense of confused and frustrated communication. Translation of text through different senses of sight, touch and hearing are a reminder that all figure in communication and one sense may be augmented to compensate for a lack in another or be connected synaesthetically.

My practice developed through the project both in skills and approach. I built on what I learnt about electroforming from Mark Hursty and jeweller Penny Akester. I used multiple creative methods to achieve the piece, also learning new techniques in glass-blowing, flameworking and cyanotype. This was also the first occasion I incorporated sound or interactive touch in a finished artwork.

The projects discussed in this chapter demonstrate new kinds of artwork that blend glass, interactive touch and sound. I described methods of crafting capacitive touch sensors for triggering audio, namely copper electroforming and intaglio etching with conductive ink. The methods enabled the combination of materials and media to convey subjects, such as an individual's experience of 'touch hunger' in *Bin Bag Hug*, that would be impossible in traditional glass art. The use of augmented glass objects combined audio narratives with the tactility and sensuousness of glass. Recognisable glass forms with historical, scientific or

domestic associations served to make the augmented objects relatable. The glass cane 'frigger' in *She's Got the Wrong End of the Stick...*, test tubes containing strange flower-like copper stems in *Hearing Instrument*, and picture frame juxtaposing unusual images in a domestic artefact in *Bin Bag Hug* served to trigger memories and curiosity of viewers. Physical properties of glass were captured in paper cyanotypes of the refractions and subtle shadows formed by sunlight through glass forms in *She's Got the Wrong End of the Stick...* The blending of sound with sculptural objects proved engaging for the visitors. The embodied mode of interacting with them using touch or proximity maintained their attention and enabled playful interchanges.

Having witnessed audience engagement through embodied interaction with the artwork and the capacity of sound to add layers of meaning to the glass, I decided to explore these aspects further in my next projects. The potential of interactions to generate audio carrying more complex narratives, storylines or sense of place is explored in installations in the following chapter.

7 What stories can be told? (*When We Touch Again*, *1.5 Degrees of Concern*, *After The Storm*)

Video and sound clips of the artwork for reference:

https://www.lizwaughmcmanus.co.uk/when-we-touch-again
(*When We Touch Again* project)

https://www.lizwaughmcmanus.co.uk/1point5-degrees-of-concern
(*1.5 Degrees of Concern* video clip)

https://www.lizwaughmcmanus.co.uk/19532020s-narratives
(*1.5 Degrees of Concern* audio clips)

https://www.lizwaughmcmanus.co.uk/after-the-storm
(*After the Storm*)

7.1 Introduction to aims

The projects discussed in this chapter were developed to explore the aim of engaging the audience with multiple layers of meaning. I planned to investigate in greater depth interactive touch in artworks with sound narratives, to convey more complex storytelling. Furthermore, my mode of working changed from sole working in the studio to exploring ways to make meanings in collaboration and through pedagogy. This offered a way of sharing and distributing knowledge between artist collaborators, students and audience. This chapter discusses the projects *When We Touch Again*, *1.5 Degrees of Concern* and *After the Storm.*

7.2 Description of *When We Touch Again*

When We Touch Again (2021) was a participatory art project starting May 2021, funded by a Mike Davis Innovation Scholarship, that responded to the COVID-19 pandemic, particularly isolation and the phenomenon of 'touch hunger'. At the time, there were reports that lack of physical touch was causing emotional stress for those shielding from physical human contact. Research early in the pandemic suggested, "that touch deprivation was more prevalent in individuals living alone and was negatively related to health practices scale scores and positively related to scores on scales measuring COVID-related stress, negative mood states including anxiety and depression, fatigue, sleep disturbances, and posttraumatic stress symptoms" (Field et al., 2020, p. 1).

Figure 71 *When We Touch Again* pop-up exhibition, October 2021, Glass and Ceramics Department, the University of Sunderland. Photo: D. Woods.

In March 2020 to slow the spread of COVID-19, the least vulnerable were instructed to keep a distance of two metres, later reduced, if unavoidable, to one metre plus, from other people not in their household or 'support bubble'. In England, for the first weeks, only contact with fellow householders was allowed. Subsequently, one could meet one other person for a socially-distanced walk, then in September 2020 a bubble of six people outdoors and one other household indoors, or a group of up to thirty outdoors. It was 'physical' distancing rather than 'social' distancing since social interaction carried on via video conferencing and social reach expanded, with many reporting old friends across the world re-establishing contact. Video conferencing may be psychologically better than telephone calls. Improvements in mental wellbeing of patients treated for depression in remote mental health care were found to be more sustained when treatment was via video conferencing versus telephone (Chen et al., 2022). However, there is general acknowledgement that social and physical isolation has a detrimental effect on mental wellbeing. As discussed in Chapter 3, studies have demonstrated how touch affects human emotions, social bonding and empathy. A post-COVID pandemic narrative literature review by Della Longa et al. (2022) on affective touch and loneliness cites many studies confirming interpersonal touch's role in social communication, establishing and maintaining bonds or physical and psychological wellbeing. Even when there is social interaction, people have reported that the lack of physical touch severely affects their mental wellbeing. This is unsurprising given the connection between physical sensation and our emotions. Proximity

and touch are linked deeply with human emotion, evidenced by our language, the word ‘touching’ meaning emotive or emotional. Similarly, ‘movement’ or ‘motion’ giving us emotion. ‘It was moving’ equals ‘it was touching’ equals ‘my emotions were affected by it’.

When We Touch Again promoted community and wellbeing by bringing University of Sunderland students together online to create interactive glass objects which generated audio stories when touched. It also expanded new post-COVID methods of working using video conferencing, which subsequently became ubiquitous, that I had been using in a participatory art project.

The project drew from experiences of *Make Live* (2020-2022), a pedagogical digital literacy art project I ran, external to this study, using the Touch Board system with 9- to 12-year-olds in schools (Fig. 72).

Figure 72 *Make Live*, 2021, interactive sound and glass painting project in a high school.

High school students taking part in Make Live developed creative responses to the natural environment, lockdowns and personal interests. During the later Make Live project in a primary school, students produced an interactive sound collage with ink drawings that released recordings they had made of creative writing, poetry and imaginative retelling of accounts by local fishermen and Scottish fisher lassies related to Lowestoft’s past fishing industry (Fig. 73).

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Figure 73 *Make Live*, 2022, interactive collage by primary school students about the historic local fishing industry displayed in a public library.

When We Touch Again project built on knowledge from artworks discussed in the last chapter and also my experience of adapting participatory practice to the COVID-19 pandemic by moving to online teaching. *When We Touch Again* became part of an international collaboration between myself and artists Kristine Diekman, Lisa Mansfield and Laura Nova working in the US, Mexico and Australia, facilitating international participants in story creation activities and crafting tangible interactive interfaces made from foraged glass, embroidered textiles, conductive paints and threads. It developed ideas and methods employed in *When We Touch*, a participatory storytelling project using interactive e-textiles by Kristine Diekman in Mexico, by creating glass rather than textile interfaces and using code developed by Diekman's programmer, Craig James (*When We Touch*, n.d.).

Invitations to participate in *When We Touch Again* were circulated through the Student Union, Global Friendship Group, Glass and Ceramic Society, International Officer, Volunteer Co-ordinator, Wellbeing Service and the Glass and Ceramics Department, advertising for people who felt isolated during the pandemic. International students were initially targeted as it was thought they might have felt most isolated, however, take up was from home students who appreciated the opportunity to meet and work together creatively while access to the University facilities was limited. I ran a series of five Zoom sessions in June, then two physical face-to-face days in July held in the Glass and Ceramics Department, culminating in three days in October putting on a pop-up exhibition in the foyer of the Glass and Ceramics Department.

Figure 74 Kit mailed to students comprising of a preprogrammed Touch Board microcontroller, glass cleaner, graphene ink, acrylic sealer, conductive thread, paintbrush and conductive paint

During the Zoom sessions, the theme of 'touch' in personal and cultural contexts and its role in communication, emotion and health were discussed. Following slide presentations about the theme and technology, participants recorded personal reflections on touch, using a story prompt, "These Hands". They went on to devise individual projects developing the brief around their interests, using crafted, scientific or 'foraged' glass objects as sensors for audio.

I mailed kits to each participant comprising a Touch Board microcontroller pre-programmed with a sketch of their choice, glass cleaner (isopropyl alcohol), graphene ink, acrylic sealer, conductive thread, paintbrush and tube of conductive paint (Fig. 74). Following a Zoom tutorial, participants used the materials to paint designs on their glass objects to create sensors which would play their narratives. Since students were working from home with no studio access, they chose ready-made glass objects suited to their creative themes. Over subsequent Zoom sessions, the participants were coached in technological aspects, i.e. installing Arduino and Touch Board software on their computers, good practice for recording audio on a smartphone, converting files to mp3, file-labelling and transfer to the microSD card, and text-to-mp3.

Figure 75 Student Penny Riley-Smith trouble-shooting her piece, *Reconnecting*, during a face-to-face session in the Glass and Ceramics Department

Once COVID-security restrictions eased sufficiently in July, we met offline for two days in the Glass and Ceramics Department at the NGC. The first was to troubleshoot problems, explain the *When We Touch* sketches ('recipes' of code created by programmer Craig James), and how to upload them onto the Touch Boards (Fig. 75). I also documented the projects on video. The second day was a pop-up exhibition in the foyer of the Glass and

Ceramics Department where the group shared their narratives through the interactive artworks with the few people in the building, enabling us to try out ways to display, test the technical systems of microcontroller, power and speaker and observe how 'audience members' responded to the artwork. This served as a prototype for the finale, a pop-up exhibition and private view in October (Figs. 70, 71 and 76). A consideration was how to encourage visitors to interact with the artworks in the absence of a steward to guide them. Labels with precise instructions were placed near the artworks, e.g.

"EACH FLASK IS LINKED TO FOUR SOUND RECORDINGS"
"TO LISTEN, PLACE HAND CLOSE TO A FLASK AND KEEP IN PLACE UNTIL RECORDING ENDS"
"IF THE RECORDING IS A REPEAT OF ONE ALREADY PLAYED, REMOVE HAND FOR A MOMENT AND RETRY"
"TO LISTEN TO EXPRESSIONS ILLUSTRATING THE CONCEPTS,
WAVE YOUR HAND VERY CLOSE TO (OR TOUCH) THE RIGHT-HAND PLATE"

The narratives of the exhibited artworks made during the project ranged from a joke, *Fee Fi Foo Fum*, to *The Gift,* (Fig. 77), about 'the web of inheritance and legacy stretching millions of years into the past to millions of years to come'; *The Many Meanings of Touch* which highlighted ways 'touch goes beyond the physical to embrace nebulous emotional ideas, the concept of agency and adjacency, drifting into things sinister and barely perceptible'; *Reconnecting,* recording some feelings of loss and reconnection among three generations of a family during the pandemic; and *Bin Bag Hug,* discussed in Chapter 6 that explored the effects of isolation, touch hunger and connecting across distance during the COVID-19 pandemic.

7.2.1 Engagement

Engagement took place at two levels, initially with the project participants who learnt to use the technology with glass to express narratives they developed and later, with the exhibitions' audiences who interacted with the resulting artworks. Telepresence was explored as initially face-to-face classes at university were prohibited by government Covid-19 guidelines, so students took part in the project over video conferencing with materials delivered by mail. The students selected glassware based on their sensory qualities or metaphorical significance to their individual projects. *The Gift,* which explored scientific and historical references, used laboratory flasks. For *The Many Meanings of Touch,* incised

patterns on cut-glass bowls carried the conductive ink traces. For *Reconnecting,* the student chose a brain-like glass form they had made in the past.

The October exhibition of *When We Touch Again* had a lively opening where visitors interacted with the artworks and chatted with the artists. I observed visitors absorbed in playing with and listening to the artworks. As discussed in 6.4.3, visitors were enchanted by the animacy of the artworks on display. The artworks prompted conversations about personal experiences of the lockdowns when people were separated from their friends and family and ways this had resulted in touch hunger. All the students said they benefitted socially from working in a group and meeting new people. The project demonstrated that *When We TouchAgain* facilitated the artists and audience to reflect on the emotional effects of the COVID-19 pandemic.

Figure 76 Visitor listening to *The Many Meanings of Touch* by student Kathleen James, *When We Touch Again,* October 2021, pop-up exhibition, Glass and Ceramics Department, University of Sunderland.

Below are some comments by students who took part in *When We Touch Again*:

- "It reminded me that I live in a relatively isolated life anyway. It's just me and my husband; we have cats, no kids. We didn't experience the intense loss of close contact in the same way many others did, or as keenly".

- “It made me think about the planet and the human effect on the planet with a ‘wide angle lens’ - nothing has ever, or in a long time - really affected humankind so simultaneously or made us consider our frailty and ubiquity”.
- “I had already been thinking about the effects on family life, and the project has given me the chance to think further on the effects on my family - and to share their feelings - We have talked a lot about the things we are grateful for”.
- “The theme got me looking into the concept of touch and the language around it. My artistic interests lie around words and lettering.
- “The project got me thinking on a large scale on aspects of touch through the lens of human touch on earth, and on touch through time”.
- “Much of my artwork is tactile, designed to be handled. It has been interesting designing a piece where proximity, not touch, is important. I have been thinking about my time in Sunderland, when touching materials I work with has replaced human touch”.

Figure 77 Frances Ross, 2021, *The Gift,* student artwork When We Touch Again project.

In summary, the students said that the project enabled them to reflect on the pandemic, *touch* and broader global effects. The creativity and opportunity to meet like-minded people benefitted them socially and contributed to their emotional wellbeing. They all considered incorporating sound or interactivity in future work as did several students visiting the exhibitions, with comments such as, "This is such a good idea. It really opens up

the possibilities of storytelling." This visitor was especially interested in having an artwork 'speak' as you approached it. All the participants said they appreciated the introduction to new technology, Touch Board microcontroller and Arduino.

While I acted as facilitator for the students' art and digital making, the learning and problem-solving were mutual as they tried out new ideas. For instance, one student was successful in using graphene ink with a calligraphy pen. When we were experimenting together with ideas in the architectural glass studio, I clipped a Touch Board to the lead in a stained-glass panel and experimented with it as a sensor, something students plan to use in future work. *When We Touch Again* also provided the stimulus to try out new techniques myself, such as the methodology adapted from etching for the project, *Bin Bag Hug.*

Figure 78 Liz Waugh McManus, Kristine Diekman and Lisa Mansfield, 2021, part of the *1.5 Degrees of Concern* installation, W250 cm H243 cm D 92 cm, at *1.5 Degrees* exhibition at Michigan State University Museum.

7.3 Description of *1.5 Degrees of Concern*

When We Touch Again was associated with an International artistic collaboration, *Touch Collaboration* with Kristine Diekman[12] in the United States and Lisa Mansfield[13] in Australia who I met at a poster presentation given by Kristine Diekman at the ISEA 2020 *Why Sentience?* virtual conference. We came together through an interest in interactive sound art and common use of Touch Board microcontrollers. Beginning in October 2020, we met between one and four times a month on Zoom to discuss and explore methods of making touch-interactive sound art. This has since informed our individual personal and pedagogic projects and led to a collaborative artwork for real-world exhibitions, *1.5 Degrees of Concern* (Fig.78), discussed in detail below.

During *Touch Collaboration*, we developed blended synchronous and asynchronous communication and methods of working together over three continents and time-zones using a combination of regular two to three-hour video conferencing meetings; email; an encrypted messaging app group (messaging and calls); and online Drive with documents, images, video clips and sound files. The subject content of the folders ranges from ideas, experiments, sound libraries, artists working in the field of sound/interactivity, funding proposals, and documentation on which we collaborated related to exhibitions (research and development, artworks, audio, didactics, designs for exhibition space, installation instructions). Physical artwork was made offline asynchronously in our respective locations, with progress shared via video conference meetings and messaging. Finished artwork was couriered to California from the UK and Australia and installed on-site by Diekman.

Our method for decision-making, Lisa noted, reflected the Antarctic convention 'approval for action' which enables countries with diverse interests and politics to co-operate, whereby instead of 'agreement', approval is signified by 'no objection'[14]. Whilst there was involvement of all in every aspect, we also shared our individual expertise, for instance, me in making and embedded electronics, Diekman in sound design and electronics and

[12] Kristine Diekman is a media artist and was then a Full Professor in the Art, Media and Design Department at California State University.
[13] Lisa Mansfield is an interdisciplinary artist and then Junior Time-Based Art Conservator at the Art Gallery of New South Wales.
[14] The Antarctic Treaty has enabled the Antarctic to be one of the few places on Earth where there has never been war, where the environment is fully protected, and where scientific research has priority.

Mansfield in exhibition design. For example, below are a few of the many potential design layouts produced by Mansfield for the joint artwork, *1.5 Degrees of Concern*, which were all discussed and the one on the right finally approved (Fig.79).

Figure 79 Lisa Mansfield's wall designs for suspending speakers in the *1.5 Degrees of Concern* installation.

In this project, I continued to explore embodied interaction and audience interactivity through artwork that generates sound through crafted tactile interfaces. In my contribution to *1.5 Degrees of Concern* (Fig. 78), I aimed for a more sustained and deeper level of audience engagement with a more complex audio narrative and layers of content than the former projects discussed above. *I.5 Degrees of Concern* built on and elaborated knowledge gained from previous artworks in the research journey which used touch or proximity to trigger audio, *She's Got the Wrong End of the Stick, Bin Bag Hug, When We Touch Again,* and *Make Live.* What I learnt from *When We Touch Again* about engaging viewers through narrative sound and the technicalities of interactive objects informed decisions in creating this new more elaborate installation.

1.5 Degrees of Concern was a collaborative project between Diekman, Mansfield and myself for a joint exhibit of interactive art and soundscapes applying ideas developed over a year in online *Touch Collaboration* discussions. Two physical exhibitions were held which included concepts, physical artwork and sound art produced by all three of us, firstly at *Rule 42 Stretched Language*, 6 November to 3 December 2021, at Bonita Museum and Cultural Center in California and the following year in *1.5 Degrees*, 6 September to 25 February 2023, at Michigan State University Museum (MSUM). Concerning the climate emergency, the piece presented imagined futures and present issues around water and historical flooding, through three stories spanning 200 years, beginning with the great North Sea flood disaster of 1953, to speculative narratives set in a drought-ridden Southern California of 2053 and ending in 2153 in an iced-over Australian desert.

The title *1.5 Degrees of Concern* refers to the limit to global warming scientists warned was necessary to avoid disastrous impacts on the planet. The Paris Agreement 2015, the international treaty on climate change adopted by 196 world leaders agreed to cut greenhouse gas emissions to keep global warming to under 2° Celsius and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels". To achieve this, greenhouse gas emissions must peak before 2025 at the latest and decline by 43% by 2030 (United Nations Climate Change, n.d.). The IPCC 6th Assessment Report (IPCC AR6 Working Group 1, 2021) warned that without such measures possible futures of global warming include, "increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost". The MSUM curatorial statement declared,

> **We are 0.4° away from catastrophe…. Thus, we must urgently consider the actions we need to take individually and collectively before it's too late. In this exhibition, we will be inviting the public to examine the scope of our impact on the planet and the way that our lives are deeply interconnected with the wellbeing of the environment. We hope that the public that comes will start to imagine new ways of addressing the social environmental issues connected to climate change and how we can build brighter, more sustainable futures** (MSUMuseum, 2022, 6:16).

MSUM curators selected, from an open call, innovative artworks demonstrating collaborations between art and science with the intention that visitors would create conversations around them (MSUMuseum, 2022). Curatorial team member Professor of Earth and Environmental Sciences, Julie Lebarkin stated that the thing that resonated with her was that while "the Earth and environmental sciences are retrodictive… some of the exhibits in this exhibition are about thinking about the past and some of them and some are about thinking about the future. So that past to present to future link was really exciting for me" (MSUMuseum, 2022, 11:30).

The tabletop exhibit in *1.5 Degrees of Concern* (Fig. 78) offered engagement through an array of natural, crafted and technological objects - feathers, molten glass and cyanotype plant specimens, driftwood and rocks which locate the stories geographically. Three modified books incorporated technology for the audio narratives. Visitors explored tactile interfaces which triggered the sounds through proximity. Touching, hovering over, listening and examining provided a multi-sensory experience that brought the audience into the

complex narrative, providing a mode of reflection with the intention they would ultimately be connected to the theme, the urgency of the climate crisis.

Books, cyanotypes and natural objects contained embedded conductive traces and electronics which operate as sensors for the audience to listen to archived voices of flood victims, letters and underground transmissions from drought-affected communities, and poetic invitations for environmental regeneration. The installation also had a background soundscape including water, ice, sand, cockatoos, sirens, fire, bells and voices that washed over the installation, emitted from wall-hung speakers hung configured as a graph delineating globally rising temperatures from 1953 into 2153.

My contribution to the installation related to the historical narratives about the 1953 North Sea flood disaster and the 2020 local flooding along the River Waveney. Research for the historical narratives was through archival oral history recordings and geographical papers about the 1953 North Sea storm surge and floods, some of which were used in the audio. I also examined the impact of climate change on the East Anglian coastline through AONB, Met Office and University of Cambridge geographical publications. This led to creative writing used in the audio and my understanding of saltmarsh habitat as a lens through which to view ecological responsibility and nature-based solutions to the climate emergency.

I created five soundscapes which included archival material, poetry and oral history. As well as sourcing memories about the 1953 flood, I recorded a couple about their experience of the River Waveney flooding in December 2020. I also contributed audio to the ambient soundscape which played in the background continuously moving from speaker to speaker on the graph on the rear wall (thunderstorm, tidal warning siren, church bell tolling, water lapping, underwater). I mixed ambient sounds from sound libraries with one recorded on location on the River Orwell. See Appendix 3 for Sound Scores.

We decided to use books as structures to house the microcontrollers and speakers, hacking old technology with new. I sourced books from second-hand shops to experiment with cutting, drilling and sanding pages. A local history of East Anglia with a map was selected for the final artwork. I cut holes in the spine and used pages to separate auxiliary and power cables from the Touch Board to minimise electrical interference. We used wired,

rather than blue-tooth connections for reliability. Subsequently, artistic and technical details of the installation including the use of Bare Conductive Touch Boards and Electric ink were disseminated on a public blog that I wrote for Bare Conductive (2022).

Figure 80 Liz Waugh McManus, 2021, *1.5 Degrees of Concern* detail. Hacked book with map of coastline after sea level rise, glass samphire, embedded speaker and microcontroller.

The modified book (Fig. 80) in which the Touch Board microcontroller and speaker were embedded, was open at a page with a map of East Anglia that I cut to represent the coastline in 2100 after a predicted sea level rise of 1.15 m if fossil fuel emissions remain high. The cutaway pages revealed text about the 1953 storm surge in Jaywick. Imagery of marsh plants was created on a glass plate using the photographic cyanotype process discussed in Chapter 6, p. 123.

To ensure the artwork functioned reliably over the months-long exhibitions, I used a single sensor which scrolled through five audio files without repeating, to prevent visitors from becoming bored by hearing the same one twice consecutively. I adapted parameters recommended by Bare Conductive (*Electric Paint Sensor Design Rules of Thumb*, n.d.) by edging the glass cyanotype plate with copper tape (Fig. 81), soldering a loop on the corner to which the microcontroller was connected by a crocodile clip lead, and creating a grid of conductive thread around it. This transformed the plate into a capacitive touch sensor. This design guaranteed good touch detection latency so that users would understand the sensor's responsiveness. To protect the gelatine from scratching, the glass was backed with

a book page, legible through the cyanotype, about birdlife and the environment. My collaborator Diekman created button-sized sensors which were activated by fingertips, or with copper-tipped 'wands'. The playfulness of the 'wands' made them popular with visitors, an element for my consideration in future projects. The others' books had several sensors and more conductive material and wires in them, which interfered with the microcontrollers so that they needed to be reset occasionally. This did not happen with my Touch Board which was programmed to trigger the five audio files randomly. This code sketch was similar to the 'Random Proximity' one I originally used for *She's Got the Wrong End of the Stick…,* however, I asked programmer Craig James to adapt it so no sound file would be repeated immediately after it played. See Appendix 2 for the code sketch, '10b_Random_Proximity_Norepeat_Adjustable_MP3'.

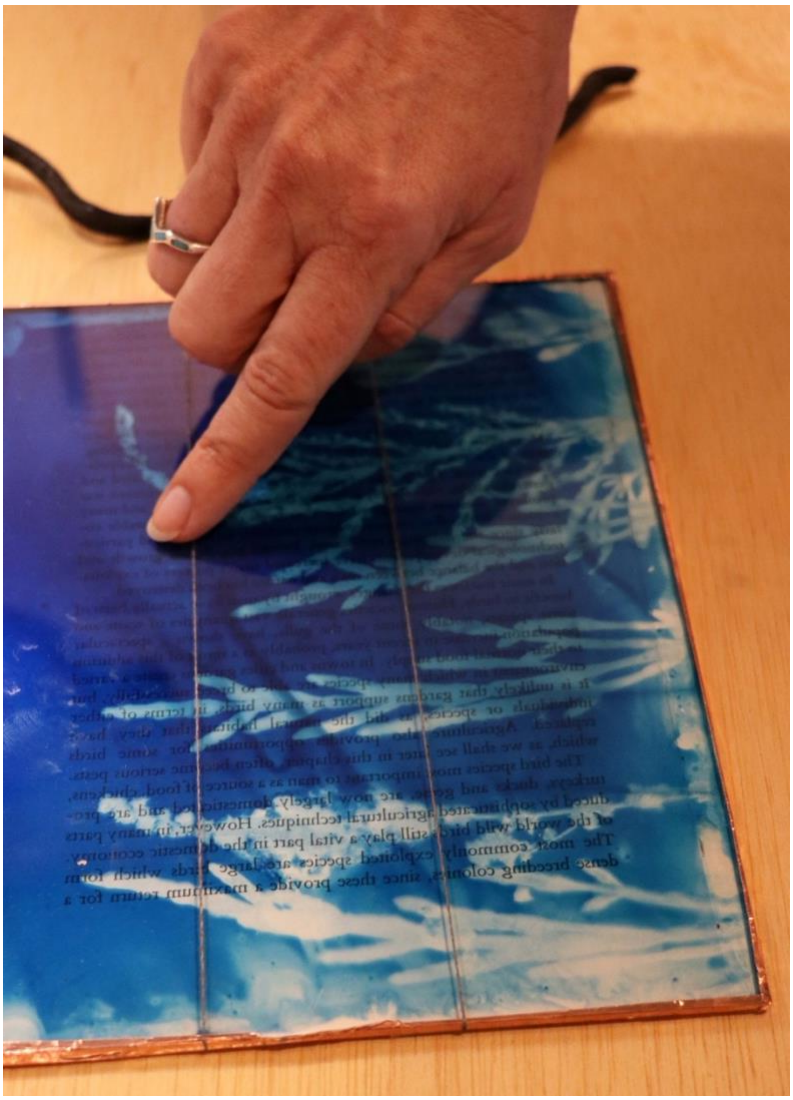

Figure 81 Liz Waugh McManus (2021), *1.5 Degrees of Concern* detail. Sensor consisting of glass cyanotype, conductive thread and copper tape.

I produced further glass cyanotypes of plant samples on microscope slides and specimen bottles and glass casts, 'crystallising' natural items collected from the saltmarsh on the Stour estuary, most of which were displayed on a lightbox (Fig. 82). I find the fossil-like effects achieved by casting from real objects or textures appealing and glass adds a gem-like quality. The use of specimens denoted specificity of place, connecting my narrative to the East Anglian coast, while Diekman and Mansfield contributed geological specimens, feathers and sticks, materials which located their ones in the USA and Australia. I captured purslane and samphire foraged from saltmarsh on the Stour estuary in cyanotype or in cast glass. (Samphire has a resonance for glass artists as it was a source of potash in historical glass-making). My research for the artwork revealed that restoration of saltmarsh is a strategy of Natural England to combat climate change because, as well as increasing biodiversity, it sequesters and stores carbon to a similar extent as peat (Gregg and Morecroft, 2021; *Natural Solutions to Climate Change: Saltmarshes, The Wildlife Trusts*, n.d.). Saltmarsh is also being restored to manage flooding (Baptist et al., 2021; Cambridge University, 2020; Steward and Whittle, 2023).

Figure 82 Liz Waugh McManus, 2021, *1.5 Degrees of Concern* detail. Glass specimens of saltmarsh plants and wasp nest made from natural objects collected on Stour estuary

The use of specimens and scientific glassware across the whole installation also reflected the scientific practice of sample collection to expand knowledge. The installation included collected natural history and geological specimens (marsh plants, bee hive, fern, rocks), measurement apparatus (microscope slides, beaker, test tubes, flasks and ruler), instruments for producing or making phenomena visible, (lightbox, fictitious recipe for

water) or representations such as maps or models (such as the temperature graph). In the second exhibition, a wall display was added with a pinboard (Fig. 83) of drawings by Diekman and notes relating to the natural objects on the tabletop, replacing the original information sheet for visitors. The concept was to invite the audience into the artists' ongoing research into climate change on our natural environments for human and nonhuman lives. The entire installation became an epistemic object by which knowledge and processes are studied and conveyed to the visitor to encourage dialogue about climate science, the environment and the effect of weather events on individuals and communities.

Figure 83 Kristine Diekman, 2021, *1.5 Degrees of Concern* detail showing drawings.

7.3.1 Engagement

Various strategies for engagement (including sensuous affect, animacy, playfulness, ambiguity and embodiment) and layers of interaction were employed:

- Ambient sound to draw people in
- Interesting natural and crafted objects for exploration
- Gamification
    - Trigger points to seek out
    - Special tools (the wands)
    - Riddle-like prompts written on the table in pencil
- Multisensory participation

- Audio connected to participant touch
- Short latency between touching a sensor and the responsive sound
- Storytelling – personal testimonies, interesting Foley, themes of contemporary interest

At the first exhibition at Bonita Museum and Art Center, 2021, total attendance was 965 people. Evidence of audience interaction was gleaned from several videos of visitors to the exhibit, a video-conferenced conversation with the Museum Studies Intern in charge of the exhibit, feedback from Diekman on her observations at the exhibition and her discussions with Wendy Wilson, the Director of the Bonita Museum and Cultural Center.

Observations by Heather, the Museum Studies Intern throughout the exhibition demonstrated that audience engagement with the exhibit progressed through stages: The ambient sound drew people into the space as it signalled something was happening; as they approached, the many attractive objects on the table sparked their curiosity; and they then read the didactic handout and messages pencilled on the table (e.g. "This glass speaks, hover your hand", "Trace the copper with your fingertips. It transmits the future", and "Dear friends, this book contains the 5 transmissions, the wands will find them. Touch. Contact. Listen") which encouraged them to start touching (or hovering their hand over) the objects which triggered sound. The two wands (sticks with black conductive paint and copper wire-bound ends) were very popular as tools for touching sensors. Some people touched a sensor, listened to a bit and went away, but many people were so engaged they spent a long time listening to the stories. One woman ran out of time but returned another day to listen to the rest. Someone returned with two pieces of coloured glass which they secretly added to the installation. Diekman noted that participants were visibly moved while listening to the stories. The riddle-like invitations for visitors to try out the sensors suited a poetic aesthetic more than the instructive labelling used for *When We Touch Again,* and contributed to gamifying the exhibit, as did the playfulness of the 'wands' provided to touch sensors.

Children and young people 5 to 18 years were very engaged, not simply for the novelty, but wanted to hear the whole stories. 120 eight- to nine-year-old schoolchildren and 30 college-level students interacted with the installation. The Museum Director and Intern reported that young people lined up to experience the artwork. They were quicker to explore the tactile surfaces than adults, who were perhaps more reticent because of

COVID-19. As a result of the success of the interactivity, Kristine was invited by the Museum Director to design an oral history project with local indigenous people that utilizes the same tactile technologies.

MSU Journalism students to the MSUM exhibition emailed that *1.5 Degrees of Concern's* storytelling ability struck them, with its use of distinct time periods and locations to talk about the changing world. They made particular mention of the interactive elements which they said helped them focus on the audio.

I.5 Degrees of Concern received international recognition for innovative use of art and technology addressing a global issue by being longlisted for the Lumen Prize 2022, in the Interactive category, from over 1500 entries across 50 different countries by the committee of curators (2022 Lumen Prize Longlist, 2023a.). *1.5 Degrees of Concern* was mentioned on the Lumen blog by Curator Anastasia Pineschi who identified climate crisis as one of the main themes of submitted artwork, "These works display a skilful deployment of technological tools, crafting artworks that span the spectrum from playful to pensive to passionate" (The Lumen Prize, 2022b).

7.3.2 Embodied engagement of the participant

In Chapter 3, I discussed Embodiment in relationship to interactive art. All art is interactive psychologically while 'interactive art' is also mediated by physical interactions. As with the previous projects (*She's Got the Wrong End of the Stick…, Hearing Instrument, Bin Bag Hug*), *I.5 Degrees of Concern* used the interactive art strategy of Instrument (Kluszczynski, 2010), where the realised artwork is in a sense performed like an instrument and exists in different iterations as viewer-cum-participants create their own rendition, using their bodies to trigger the audio in their own time and sequence. That an interactive artwork is only realised with the participation of the audience and consequently that there are an infinite number of possible renditions of interactive art is a fundamental characteristic which differentiates it from other visual artforms and allies it with the performing arts (Stern, 2013).

The audience becomes engaged through the playfulness of the installation as they use their agency to actively seek out the sensors and then gain a lively audio response when they discover them, prompting further exploration. Visitors could alter the volume of the sound

by the distance of their hand from the sensors. Glynn claims intuitive interactions in digital artworks responsive to hand gestures set up a social framework, “We wave towards the digital artefact and if we recognise a response, a social connection has been made. We may perceive life in these responsive behaviours and enter into extended gestural exchanges to explore these novel relationships” (2019, p. 188).

As discussed earlier in 7.3, I chose to eliminate possible interference between multiple sensors by making one sensor for all five audio files, activated by a full hand hovering over it. To keep the user from becoming bored, I designed my sensor to play the audio in a random sequence which would not repeat the same file immediately after it had played. There needed to be minimal latency between touching a sensor and the sound playing.

Feedback about the exhibit indicated that physical engagement with the artwork resulted in the viewer becoming more invested in listening to the narratives than they would if the sound element of the installation had been playing continuously. Kinaesthetic and tactile engagement prolonged listening time, which suggests participants became engrossed in the narratives and responded more deeply than otherwise. The touch responsiveness initially engaged the spectator-cum-participant and sparked their attention to the audio narratives; their agency in controlling the audio with their hand ‘held’ their attention and physically connected them to listening to the stories; then the narratives themselves carried their own momentum in engaging their interest. How engrossing an interactive artwork is, or amount of ‘flow’ experienced by the audience, is determined by both its content and the interactivity. Gilroy et al. (2009) in their study of the emotional and affective impact of interactive art through an AR artwork, *E-Tree,* state that, “Interactive art straddles these two concepts—the artistic narrative or metaphor remain in place as a first-class property, yet the experience itself is mediated by the physical interactions, interpreted by a computer system. Thus, flow stems from both the challenges of artistic interpretation and of discovering and mastering affordances of interaction”.

7.3.3 Intellectual and emotional engagement with the narratives

In *1.5 Degrees of Concern* I progressed from simple audio, such as the random voiced sentences from one side of conversations in *She’s Got the Wrong End of the Stick…,* which produced an absurd, surrealist effect, to introducing more complex storytelling and poetry to prompt the audience to think about real-life scenarios and the issue of climate change. This process drew on my experience in film-making and theatre as it necessitated mixing

soundtracks as one would for an audio documentary, combining ambient sound, voices taken from oral history recordings (accessed through county record offices) and my recordings of interviews and performances of texts.

With its characteristics of playfulness, experimentation, blurred boundaries between performance, sound and visual art forms and transformational intention, *1.5 Degrees of Concern* might be considered to offer a 'liminoid' experience, discussed in 3.2.2. On first impression for a visitor, the *1.5 Degrees of Concern* installation presents a confounding array of objects and ambient sound, then as they engage with the work they progress through different stages of experience. As viewer-cum-participant they may approach the artwork initially apprehensively and then choose to physically engage with it. At this point they leave their everyday life behind for the moment to begin to play with the artwork, discovering and listening, 'losing' themselves in the narratives. Listening to personal narratives gives an opportunity for empathy. When they move away from the artwork to return to 'real life', they may be changed by the experience, reflecting on the others' testimonies, perhaps moved by the stories to let go of their previous views and develop new ones.

Diekman (2013, p. 162) writes that when an artist creates, through physical computing installations, "sensorial, kinesthetic and immersive interfaces for the public to 'perform'", they "… can enter into a sensuous continuum with the artwork, oscillating between the representation of another's experience and reflection on their own, so as to reconstitute new subjectivities". Touch and empathy are closely associated, as discussed in Chapter 3. I discussed the way that even without physical touch, embodied spectatorship and haptic visuality produce empathetic responses (Marks, 2001; Ward et al., 2018). Stern states that, "interactive art frames moving-thinking-feeling *as* embodiment … Interactive installations amplify how the body's inscriptions, meanings, and matters enfold out, while the world's sensations, concepts and matters enfold in" (Stern, 2013, p. 4). Diekman believes the sense of touch, which offers living beings a way of knowing and connecting, enables deeper listening to the voices that relate their stories. Drawing on psychological studies of trauma recovery through intersubjective exchange and citing audience feedback from her exhibition, *United and Severed,* (about somatic experiences of living with traumatic bodily injury) she claims "Performing the artwork through appropriate kinesthetic explorations gives the audience the reflexive experience of sensing oneself at close proximity to and

within the artwork. This can move the audience through symbolic understanding to an integrated somatic/affective response and ultimately, empathy" (Diekman, 2013, p. 163). Certainly, scientific research cited in Chapter 3 indicated links between touch, empathy and social bonding. Experiments showed holding hands with a loved one enabled a partner to gauge their level of pain and produced synchronicity of breath and heartbeats (Goldstein et al., 2017). In a case such as *1.5 Degrees of Concern* which includes harrowing oral testimony, could it be possible that listening via touch sensors increases engagement through empathy?

Global warming is a vast and overwhelming subject for people to comprehend, however, environmental artists and 'craftivists' are re-contextualising climate crisis issues as a way of disseminating knowledge and offering perspectives that prompt viewers' intellectual and emotional engagement. Embodied interaction as in *1.5 Degrees of Concern* adds a further way of connecting the viewer with the content. *1.5 Degrees of Concern* applies research into crafted interfaces, embodied interaction and physical computing to engage its audience in a relatable way with the intention of bringing deep awareness to the public about the impact of climate crises on individual and community lives. Such storytelling has the power to offer a way that engages audiences' imagination and bring them to a new understanding of crucial issues involving them in the process of understanding and empathy.

7.3.4 Online workshopping and collaboration.

The *1.5 Degrees of Concern* project evolved a new tele/present method of working, now commonplace but rare before COVID-19, using a combination of multiple online networking platforms and offline asynchronous practice. The advent of the COVID-19 pandemic meant that one of my methodologies, group workshopping events (or hacks), was curtailed. Artists and researchers began circumventing the lack of opportunity to meet in the same physical space for workshopping/hacks by developing the practice online (FutureEverything, 2020; Pearlman, 2020). While the COVID-19 pandemic closed down physical face-to-face local workshopping opportunities, new global online possibilities and interactions opened up. *Touch Collaboration* became a vehicle which enabled me to explore the applications of interactive technologies to crafted artwork and narrative in the absence of the Craft Futures series of workshops with researchers from Northumbria and Sunderland Universities. This online workshopping has advanced my research and practice

on several fronts: finding new ways interactive artwork may communicate narratives; learning new skills in sound art, such as creative writing and editing sound recordings in Adobe Audition; and prototyping and documenting an interactive art and sound installation for exhibition. It enabled connection and feedback in a time of isolation caused by the pandemic, and the opportunity to share our various expertise (making, electronics, sound art, exhibition design) and that of Diekman's programmer, Craig James. *The 1.5 Degrees of Concern* project has prototyped a new method of working using a combination of multiple online networking platforms and offline asynchronous practice. It has provided evidence of a successful model for geographically-distributed artists to collaborate towards real-world outcomes. It was a way to begin to explore key research themes presence/telepresence, which I may expand in the future, e.g. in telepresent performance with distributed performers or networked geographically-distanced interactive glass artworks.

7.4 Description of *After the Storm*

After the Storm (Figs. 84, 89) was a collaborative artwork created over a project begun in May 2021 which was curated by glass artists and academics Max Stewart and Vanessa Cutler for an exhibition at Wolverhampton Art Gallery entitled *Collaborations* (23 August to 23 October 2022) to coincide with the International Festival of Glass and the United Nations' designated Year of Glass. Ten pairs of established UK glass artists with national and international profiles took part. As another dimension of collaboration, the curators arranged three monthly online meetings to discuss the progress we were making in our pairs and to give the feel of a "collective of artists". At the first online meeting, the curators stated their ambition for the project was that the collaboration would push the boundaries of glassmaking and explore glass as a 'fine art' material. Page (2022) wrote that Collaborations embraced, "…pioneering methods and exploring wide-ranging contemporary themes and issues. … Collaborations broadens narratives of glassmaking traditionally centred on notions of craft and industry…"

The collaboration with Thwaites aimed to build on our individual interests, strengths and expertise to create something bigger and different from what we would do by ourselves. We began with a series of discussions on walks or via video conferencing (four meetings between July and December 2021) about themes, methods, and common interests in traditional craft methods and new digital technologies for glass-making and expanded glass practice. We sifted through many ideas, many of which had to be discarded until they

coalesced into the decision to create *After the Storm*, a mixed-media sculpture referencing the effects of climate change on the local East Anglian coastal landscape familiar to us both. I am Suffolk-based and Thwaites has lived in Essex. The East Anglian coast and marshlands are environments vulnerable to climatic change in terms of erosion and destruction of wildlife habitat, whilst also offering hope for nature-based solutions to climate emergency through carbon capture and storage by its flora and sediments. They are liminoid terra-aqueous spaces that change daily with the tides.

Figure 84 Liz Waugh McManus and Angela Thwaites, 2022, *After the Storm,* Glass, mixed media, microcontroller, speaker. W 112 cm H 180cm D 70 cm Exhibited at Wolverhampton Art Gallery.

Wishing to start working together practically before we could meet again in person, as part of the collaborative methodology we started a distanced game of Exquisite Corpse. (Exquisite Corpse was invented by the Surrealists based on the traditional parlour game of Consequences, which we had played as children). We used the online 3D modelling software TinkerCAD , intending to generate digital forms for 3D printing, moulding, glass casting and assemblage. This game offered the opportunity to work together during a

COVID-19 lockdown and increase our skills by collaborative digital modelling both separately and together while distanced through sharing in a video conferencing app. However, in the end, once we could work together in person, we decided to leave 3D scanning and print for another project. Nevertheless, we kept the notion of Exquisite Corpse as a method of responding to each other's suggestions regarding materials, places to visit and approaches to making.

Figure 85 Photos from onsite research at Abbott's Hall nature reserve, Covehithe Beach and Benacre Lagoon, 2022.

Our first site visit together was to Abbott's Hall, an Essex Wildlife Trust reserve where we made audio recordings of playing with huge mysterious heaps of shells we found and used alginate to mould the matted fragments of reed, flotsam and jetsam left by the tide. At every site, I took photographs and videos (including drone footage at Covehithe with Toby McManus). I conducted research visits to Covehithe Beach and Benacre Lagoon, a designated AONB in Suffolk and shared my videos and photos with my collaborator before we were able to visit the location together. I did more field audio recording there and we foraged natural objects (fragments of sandstone, seaweed, and branches) and human-made debris washed up on the beach, to either use directly in our installation or to mould (Fig. 85). The fallen trees and buildings at the foot of the eroding cliffs and entanglements deposited by the sea or blown by the wind during stormy weather both informed the visual, material and textural qualities of *After the Storm* and served as a metaphor for climate emergency, the COVID-19 pandemic and other intersecting crises, such as those described poetically by Malcolm Ferdinand:

> **An angry red covers the sky, the waves are rough, the water is rising and the birds are panicking. Swirling winds wrap around the destruction of the Earth's ecosystems, the enslavement of non-humans, as well as wars, social inequality, racial discrimination and the domination of women. The sixth mass extinction of species is underway, chemical pollution is percolating into aquifers and umbilical cords, climate change is accelerating and global injustice remains iniquitous** (Ferdinand and Davis, 2022).

We translated some natural finds into glass and other media, through analogue and digital processes including mould-making, casting and water jet cutting. *After the Storm* included interactively triggered sound, three compositions made from the field recordings with breaking waves, wind and thunder which we hoped would help transport people in their imagination to the coast. The wealth of material in the artwork, sonic, natural and crafted, represented our interpretation of the landscape as artists, formed from our memories of sensory experiences of the places and their associations. It should in turn awaken memories and associations for the audience and perhaps offer new insights. We intended the liveliness brought to the sculpture by the interactive soundscapes and the creative mutations from one material to another would speak of regeneration, survival and resilience.

7.4.1 The making process.

We planned *After the Storm* to have a raw, unrefined aesthetic, quite a different quality to studio glass art where technique and refinement are highly valued. The making process (Fig. 86) nevertheless included very precise planning, measurements and techniques (CAD, water jet, mould-making, casting with glass, concrete and silicone, glass polishing, metalwork and patination, copper electroforming onto glass, sound design and electronics). For instance, a silicone and plaster mother-mould was made from the alginate-mould of reed wrack taken at Abbot's Hall marsh. From this were made open cast moulds, for a solid glass version representing the marsh when covered with water and hollow pate-de-verre casts representing it when the tide had receded. The solid glass cast had to fit precisely into glass sheets, so we cut contours first in cardboard, which I drew on graph paper and photographed. This was traced in Rhino with the assistance of Colin Rennie for water jet cutting. The waterjet cut glass was layered and UV-glued to resemble the contours left by the sea in the sand and on the sandstone. Precise measurements were worked out for the concrete supports to accommodate the unevenness of the undersurface. I copper-electroformed some of the smaller cast or pate-de-verre elements to become capacitive touch sensors.

Given the theme of climate emergency, we chose to use recycled materials where possible, so, in addition to the beach finds, we used salvaged glass sheets, copper wire, rope and metal bars, glass waste from silo enamelling and offcuts from glass reservoirs and casts. Concrete pillars were cast to resemble the texture of eroded cliffs into salvaged cardboard and polypropylene tubes. Their silicone caps supporting the glass sheet were cast into salvaged plastic packaging. The scale and contours of the sculpture were decided through making a 1:1 version in recycled corrugated cardboard and then a 280mm high scale model constructed before work started on the actual piece (Fig. 87). Improvising structures with scrap materials was a method I used when devising costumes or puppets during research and development sessions with actors and directors. Angela Thwaites used similar 'ad hoc' methods on a smaller scale to create models for jewellery (Thwaites, 2018, p. 193).

Figure 86 Some stages in making *After the Storm*, 2022.

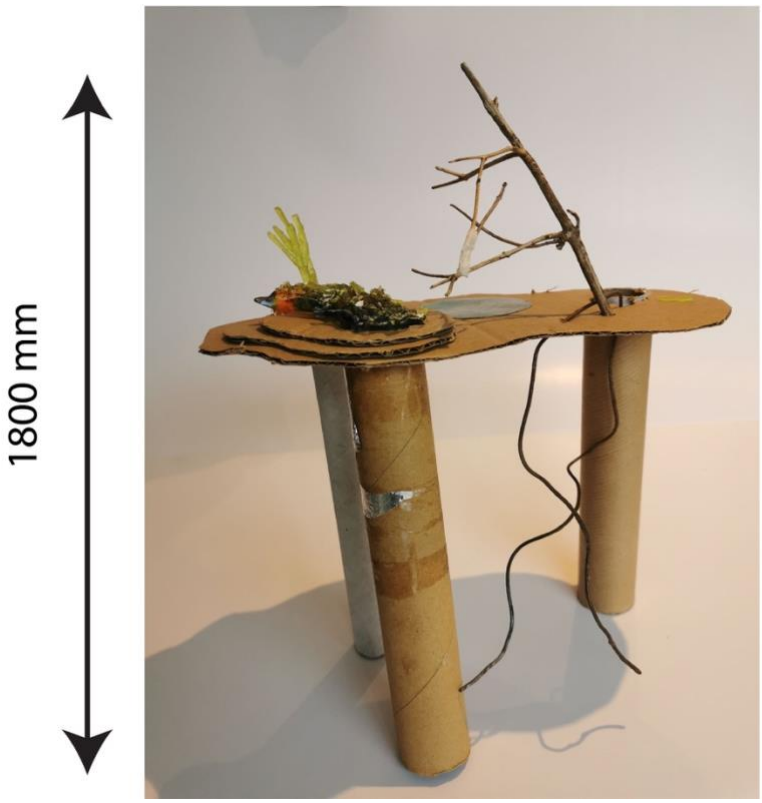

Figure 87 Maquette for *After the Storm,* 280mm high.

'Play with intention', tinkering, ad hoc-ism, assemblage and improvisation were methods we chose early on in our collaborative process. Improvisation, where a practitioner has freedom to play and experiment once they have mastery of techniques and understanding of form, is a method common to both our creative practices (Thwaites, 2018, p. 34). It allowed us to embrace the unexpected in the making process and to build positively on each other's suggestions.

Reflecting on the collaborative process, we felt sufficiently secure with each other to present half-formed ideas, offering patience to tease out how these might grow. We were also both resilient and willing to sacrifice our own ideas or compromise when necessary. We continued to adapt our ideas during the process, e.g. I suggested that the electronic hardware for the interactive sound, Touch Board and speaker, should be treated as integral materials and suspended as part of the entanglement under the glass surface rather than hidden inside a niche in one of the concrete columns as we originally agreed.

7.4.2 Engagement

After the Storm differed from the other exhibits at the *Collaborations* exhibition which, apart from Carrie Fertig's performance video *Unbind* and Kirsty Brooks and Max Jacquard's video projection onto cast glass, comprised beautiful refined glass objects mounted on plinths (Fig. 88). I believe *After the Storm* met the curators' intention more fully to push the boundaries of glass art than most. Arguably in its narrative content and media, it crossed a boundary from glass art into fine art, the focus being more on communicating a concept than demonstrating virtuosity in glass-making.

Figure 88 Exhibits adjacent to *After the Storm* in the *Collaborations* exhibition, 2022, at Wolverhampton Art Gallery.

Audience engagement in *After The Storm* was realised through playful sensors for embodied interactions and stimulating the senses through a rich combination of materials, textures and sounds. Alongside our artists' statement, the curators installed a panel with photos of the three copper and glass sensors with instructions for visitors to hover their hands over them to listen. I visited the exhibition twice during the International Festival of Glass and observed visitors interacting with and responding to *After the Storm* and witnessed reactions of curiosity, joy and amazement. Often, they approached it intrigued and when they activated the sound, there was an 'Oh I see!' moment and look of pleasure, indicating enchantment.

The sound was quite subtle and built up in volume the closer a hand was held near a sensor. A couple visited the exhibition with their son who had ASD and I was curious to see how he responded as people with autism can be particularly sensitive to sensory stimulation. He enjoyed listening to the sounds and held his hand over each sensor until the track had finished. *After The Storm* was the artwork most referred to specifically in the visitors' book receiving more than 10% of comments, with many positive remarks about its interactive sound.

As with *1.5 Degrees of Concern,* there was an array of items to explore with the eyes, in this case, natural and glass objects (Fig. 89). There were also three sensors activating sound, though in this case rather than narrative storytelling, the sound was more atmospheric and evocative of location. One visitor confided that the sound recordings of sea and shingle etc. made the installation alive and gave opportunity to consider our coastal regions.

Figure 89 Details of *After the Storm*, 2022, at Wolverhampton Art Gallery. (Top right) Visitor touching one of the sensors.

The combination of sensuous and haptic qualities of the crafted and natural materials was an appealing element, particularly the demonstration of glass's versatility in representing different forms and textures of the landscape and changing tidal levels. Solid clear or blue-

grey glass casts captured effects of textures, snail shell and bird footprint seen through pools of water. Delicate green and brown pate de verre casts represented clumps of marsh wrack the left when the tide receded. As previously mentioned, sheet glass was cut in wavy outlines to evoke the contours left in the sand by the tide.

7.5 Analysis

The projects described in this chapter progressed my research and practice in finding new ways interactive artwork may communicate narratives to develop more complex storytelling and, in the process, to learn new skills in sound art, creative writing and editing sound recordings. I also explored new ways of collaborating, developing distant and proximal methods to collaborate nationally and internationally on artworks and exhibitions.

How stories may be told within an 'Internet of Glass Things' was discussed in this chapter, in the sense of communication with the audience through embodied and emotional/intellectual engagement. The artworks were exhibited in a variety of contexts including an academic department, a cultural centre, a public art gallery, a glass biennale and a museum, which gave opportunities for observation, feedback and conversation with visitors. Comments about *1.5 Degrees of Concern,* at the Bonita Museum and Arts Center and MSU Museum, and about *After the Storm*, at Wolverhampton Art Gallery, confirmed that the viewers enjoyed the playful element of physically interacting with the crafted glass and copper sensors to listen to the sound, indicating the interactive element was an attraction to spend time with the artwork. There was a dialogic dynamic to the viewer's experience of the responsive artwork. Viewer reactions to the artwork demonstrated that the elements of playfulness and viewer agency contribute to how the stories are received. Visitors' agency in discovering and exploring content, controlling volume and sequence of audio for themselves through activating sensors piqued curiosity and was more engaging than merely listening to a soundtrack playing. Releasing the sounds through touch or proximity necessitated the visitors' physical engagement with the artwork and stimulated their attention.

The projects discussed in this chapter and Chapter 6 demonstrate that incorporating interactivity and the additional medium of sound with glass artwork expands the possible layers of meaning, which thus increases capacity for intellectual and emotional engagement. *1.5 Degrees of Concern* demonstrates how interactive sound may incorporate

oral history and storytelling to engage people in conversation about climate crisis. Sound may reinforce and add narrative detail in representational artworks such as *Bin Bag Hug,* where audio relates directly to the image. In the case of the less figurative *After the Storm*, while the visual, textural and aural elements act harmoniously to refer to the coast, seashore and crumbling cliffs, they are more abstract and deconstructed. The sound compositions, which include shells, shingle, waves, wind and thunderstorm, evoke atmosphere, embodied experience and a sense of place. *After the Storm*, referring to coastal erosion of a particular place, also summons the narrative of climate change, the source of more frequent storms, and, beyond that, metaphorically to other storms the world faces such as the destruction of ecosystems and pollution, war, pandemics, racial, sexual and gender discrimination, social inequality and the extinction of species.

After the Storm, designed to be brought to life sonically by visitor interaction, personifies the eroding, deconstructed natural landscape. Standing on its three leg-like pillars supporting an entanglement of fragmentary natural, crafted and on-view electronic elements, the sculpture appears part-creature and part-landscape. The sculpture's semblance of sentience is reinforced when a visitor touched elements which release soundscapes evocative of the coastal landscape punctuated by lively scuttering sounds. Comments by visitors to the Collaborations exhibition confirmed that the sound brought *After the Storm* alive for them. It also transported them in imagination to the coast. Whilst the audio element (sea, shells, shingle etc.) reinforced the sculpture's visual coastal references, the unanticipated element of sound in sculpture contradicted the normal expectations of a viewer, attracted them to explore the exhibit further and, from comments, enhanced their experience.

Glass, with its unique capacity to evoke ideas or things through its diverse physical qualities and metaphorical associations, was a vital element in conveying all the narratives. In I.*5 Degrees of Concern* and *After the Storm*, it captured and preserved the natural specimens foraged at the coast and beckoned the viewers' attention through the precious jewel-like quality of coloured glass. A historical photographic process using glass, cyanotype, was also used to capture images of marsh flora in *1.5 Degrees of Concern.* The versatility of glass to create hollow pate-de-verre, solid core-cast transparent forms or flat sheets in stepped layers enabled the representation of beach textures submerged or above water, eliciting the effects of the changing tide. Laboratory glassware associated with scientific research

was featured in *The Gift, Hearing Instrument* and *1.5 Degrees of Concern*, acting as epistemic objects indicating the artists' research and production of knowledge.

What stories can be told with an Internet of Glass Things? Multiple, often entangled, narratives for the artworks were revealed through background research conducted through a combination of creative practice and academic literature from different disciplines (geography, psychology, health and social sciences). *1.5 Degrees of Concern* and *After the Storm* immersed me in the subjects of historical weather events, current and future local and global climate change and the natural environment, while *When We Touch Again* focussed on impact of the COVID-19 on wellbeing and touch hunger. These narratives were embodied in the combination of sound and interactive three-dimensional elements.

Projects in earlier chapters focused on animacy or liveliness in artworks through the perception of movement rather than sound. However, on reflection, I realise that movement is implicit in all the artworks. It is present in the movement of electrons in the interactive technology and the gestures of the participants interacting with the sensors. The interactions form reciprocal movements, the participant moves a hand close to a crafted sensor which triggers audio, and then the feedback loop triggers the participant to gesture to a sensor again. Furthermore, movement features in the themes and narratives of all the artworks in this enquiry: The circling boat in *Stateless Vessel,* evoking both the mobility of migrants and their immobility in being unable to gain refuge in their destination countries; *Jeopardy* features geological movement in seismic activity, highlighting the vulnerability of inhabitants of earthquake zones who may have to flee; *Jeopardy* represents movement of data to the artwork via the Internet from distant lands experiencing seismic activity; *When We Touch Again* focusses on the touch hunger that occurred during the limit on population mobility during the COVID-19 lockdowns; *1.5 Degrees of Concern* encompasses temporal movement with stories spanning two centuries and includes a speculative narrative of migration due to climate change across an iced over Australian desert in 2253; *She's Got the Wrong End of the Stick…* has at its core the immobility of the fused inner ear ossicles that caused deafness and the mobility of alternative communication that resulted; and *After the Storm* and *1.5 Degrees of Concern* reference the geographical movement of East Anglia's coast inland due to sea level rise and erosion of cliffs by weather events. Sheller and Urry (2016) on the new transdisciplinary 'Mobilities

paradigm'[15], refer to a wide range of "different modes of mobilities and their complex combinations: corporeal travel of people; physical movement of objects; virtual travel often in real-time transcending distance; communicative travel through person-to-person messages; and imaginative travel" (2016, p. 11). This study has shown that the Internet of Glass Things is suited to tell such stories of interconnected systems which provide diverse data for creative researchers. Barry et al., (2023) advocate for creative practice mobilities research, arguing art practice-based research offers mobility studies [and other transdisciplinary projects], strengths where pure academic research may be weaker, such as sensory research, co-production or participation, making invisible things visible, engagement with the environment/landscape and a practical understanding of materiality (*'Setting an Agenda for Creative Practice in Mobilities Research'*, 2023).

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[15] The new mobilities paradigm was originally formulated in 2006 by Mimi Sheller and John Urry at the University of Lancaster (Sheller and Urry, 2006).

8 Conclusions and Impact

8.1 Summary of the trajectory of the research and impact on practice

This PhD research has taken me into new territory, both metaphorically and physically. In my practice, it has introduced me to new techniques, brought new understandings and enabled new discoveries. Later projects such as *1.5 Degrees of Concern* and *After the Storm*, discussed in Chapter 7, took me into previously unexplored natural environments along the coast of East Anglia, where I am based, such as the estuarine tidal marshes.

A saltmarsh is a porous interface between land and sea marked by meandering channels

Figure 90 Saltmarsh on River Deben at Waldringfield, Suffolk

(Fig. 90). The tidal flow constantly changes the landscape eroding edges and aggradating silt into new islands in the creeks on which new plant life starts to grow. Geography shaped by the ebb and flow became a symbolic reference or metaphor for my research process. The hard landscape represents my practice before the PhD (artworks, exhibitions, socially-engaged projects, theatre productions, theoretical positions). The incoming sea is formed of the theories, practices and training encountered during the PhD, with the wider ocean representing as yet unexplored fields of knowledge. The shifting creeks and channels of the marshland represent the different threads explored during the research which bring the 'wrack' of new ideas and ways of practice during the research. These are absorbed through

reflective working to modify my practice as the marsh reeds are churned and broken down by the tidal ebb and flow moving between land and sea, original practice and new ideas or techniques.

As the marshy landscape changes with the tides as islands are formed of sediment in the creeks from the eroded land mixed with the organic particles into a rich fertile silt for new flora, the morphology of my practice has changed as I have absorbed new theories, understandings or techniques. The tide flows in two directions, not only introducing flora and fauna to the marsh, but also taking them out to sea, an analogy for my new work being disseminated and making impacts in the world.

I discovered land artist Robert Smithson expressed a similarly geological understanding of the cognitive journey in 'A Sedimentation of the Mind: Earth Projects', (Smithson, 1968, p. 82), "One's mind and the earth are in a constant state of erosion. Mental rivers wear away abstract banks, brain waves undermine cliffs of thought, ideas decompose into stones of unknowing, and conceptual crystallizations break apart into deposits of gritty reason".

The landscape of my practice has changed over the course of the research, in themes and practices: modes of working, materials and techniques. The research began with experiments in methods for introducing conductive traces into glass and connecting these to different microcontrollers that were programmed to achieve various effects. I adapted practices from other electronic crafts to glass-making, such as the use of copper tape or conductive ink in 'paper circuits' or conductive thread in 'e-textiles', making discoveries along the way (such as that traditional sumi-e ink could be used to make capacitive sensors owing to the conductivity of the carbon of the soot from which it is made). I then progressed to the development of finished interactive artworks that blended electronics, mixed media and glass, exploiting its physical or metaphorical/associative properties. I have explored ways to engage viewers, from ambiguity, playfulness, enchantment, embodiment and animacy to multimodal methods, including touch and sound. I reflected on the roles 'animacy' and 'interactivity' have played as guiding element throughout my practice through different art forms. Over the PhD blending glass artwork and DIY electronics was investigated to enable different layers of interaction: with internet data, with proximal audiences via environmental sensors and with the potential of connecting distanced audiences through networked communication. At the start of my research journey, I

realised my desire to ‘bring things to life’ in puppetry had started to be expressed in my glass practice through projecting animation onto cast forms. By the end, I had integrated electronics with glass and mixed media as new ways to create animacy. I had started to experiment with copper and glass capacitive sensors to ‘puppeteer’ colour and shapes on a screen as in the image in Fig. 93.

I explored research methodologies and methods new to me, building on my existing studio art practice. In the introductory chapter, I discussed concepts of reflective practice, repertoire and appreciative system originating with Schon and how these are expanded through research (Scrivener, 2002). My overarching methodology has been bricolage, applied to both my theory and practice. Bricolage was considered to be the most appropriate as it allowed me to draw on and expand research tools and methods from my diverse practice. It enabled me to use methods ranging from a hybrid digital-physical studio practice to research workshops in electronics and glass and to employ perspectives from different disciplines to analyse and interpret viewers’ engagement with the artwork. The methodology encouraged synthesis between my experiences of puppetry, theatre, collaborative artistic practices, improvisation, multisensory audience engagement and animation techniques. The creative practice in this study has included reflection in and on action, tinkering, artistic prototyping, collaboration (artistic, exploratory workshopping or pedagogic), and evaluation through observation and questioning. I drew on interpretive paradigms and analyses from the disciplines of art, performance, media, film studies, anthropology, geography and psychology. I added microcontrollers, electronics, coding, CAD, photogrammetry and sound design to my previous repertoire of creative tools and used them in accordance with my aesthetic sensibilities. New glass techniques added to my repertoire include waterjet cutting, blowing, flamework, stencil-making, copper electroforming, casting from 3D print, and screen-printing. Answering my research questions demanded that I adopt methods new to me to use alongside my existing studio practices. Tinkering and prototyping enabled me to develop an understanding of microcontrollers and electronics and ways they could be blended with materials, textiles, paper and glass. Tinkering was extended beyond electronics to sculptural and sonic materials. Prototyping artworks resulted in instantiations of physical computing with glass. However, the artworks are not intended solely as technical examples, but stand in their own right artistically as communicating objects which evoke memories, associations and hopefully insights for the spectator. The result has been that my practice changed

significantly through the research from the starting point described in Chapter 1. My creative identity has shifted ontologically from being a glass artist using multimedia to a multi-mixed-media artist using glass. Not only has my practice expanded in terms of materials and methods or audience engagement through interactivity, but through successive projects and collaborations, the landscape of my artistic concerns shifted from personal narratives to climate change, the natural environment and mobilities.

8.2 Reflections on research questions

Q1 How may qualities of glass and glass-forming processes lend themselves to blending with digital technology or embedded electronics?

My research sits within a growing body of artworks and literature that explores blending traditional crafts and tools with computational materials to create interactive objects. This augmentation of physical materials in everyday use may be used for computational design outcomes or, as in the case of my study, for artistic expression. In addressing my first question, I explored fabrication techniques used by glass artists and adapted them for the purpose of creating conductive traces to connect with microcontrollers. I formed a palette of methods, listed below, from initial experiments making samples inspired by existing research into blending conductive materials, electronics and traditional crafts e.g. conducted by MIT Media Lab research groups, Universities of Sunderland and Northumbria's Craft Futures workshops and Pilchuck Glass School's Glass Electric class. I then explored selected techniques further to create finished artworks.

Material processes for introducing conductive traces into glass that I have discussed include:

- electroforming copper onto glass (Chapter 6, *She's Got the Wrong End of the Stick …* and Chapter 7, After the Storm)
- using glass techniques of fusing, casting, glass-blowing hand or water jet cutting to integrate copper or nichrome into glass (Chapter 1, *Craft futures workshops*)
- incorporating graphite by fusing or kiln-casting inclusions (Chapter 1, Appendix 2, *Craft Futures workshops*)
- sandblasting glass and filling with electroconductive paint (Chapter 1, Appendix 2, *Craft Futures workshops*)
- acid etching stencilled images or text on glass and using intaglio technique with graphene ink (Chapter 6, Appendix 2, *Bin Bag Hug*)

- application of copper tape (Chapter 7, Appendix 2*, 1.5 Degrees of Concern*)
- application of electroconductive paint to the surface of glass (*When We Touch Again)*

Glass has many properties that make it a rich material for digital augmentation. Characteristics of glass (physical, metaphorical or utilitarian forms) were utilised in diverse ways through the research projects, e.g.:

- As an interactive surface for video projection in experiments with Makey Makey, Arduino or Touch Board, conductive ink and sandblasted glass sheet (Chapter 1, Fig. 10, Chapter 8, *Deben Matters*)
- In *Jeopardy* for its fragility and transparency to portray the vulnerability of the house and occupants (Chapter 5)
- In *Stateless Vessel* for its inflatability for the boat, its capacity to create shadows and caustic light effects through the boat, glass people and shards and its sharpness in its shattered form for the sea under the boat, metaphorically representing the dangerous context (Chapter 4)
- *She's Got the Wrong End of the Stick* referenced historical 'friggers' made by glass workers and *Bin Bag Hug* used the form of picture frames (Chapter 6)
- *Hearing Instrument* and *1.5 Degrees of Concern* referenced glass epistemological instruments (Chapter 7)
- *1.5 Degrees of Concern* and *After the Storm* used the capacity of cast glass to mimic natural textures and forms (Chapter 7)
- *I.5 Degrees of Concern* employed the protective utility of glass for the samphire specimens
- *Bin Bag Hug* and *She's Got the Wrong End of the Stick…* contained glass as a substrate for photographic processes/imagery

Q2 How may glass be used with embedded electronics to create interactions that engage viewers?

In answering this question, I researched the topic of Interactivity in art and identified embodiment, playfulness, enchantment, animacy, ambiguity, agency, presence and telepresence as elements key to this research and relevant to my art practice. These characteristics enabled me to develop strategies for engagement to engage audiences on

many layers, embodied, intellectual and emotional. Please refer to Fig. 91 identifying the key qualities for engagement explored in each artwork.

Through incorporating microcontrollers, I explored novel approaches to integrating the viewer's body and mind with interactive glass artworks, so that the artwork is animated, enlivened or actualised when a person engages with it. The Internet of Glass Things is the manifestation of crafted objects of glass with interactive technology and other materials that enable audience engagement through haptic[16], somatic[17] and ludic[18] means. I created artworks that were responsive to gesture (Kluszczynski's strategy of instrument), using proximity to trigger audio for a body-centred, rather than solely visual engagement. This enabled viewers to interact playfully with the artworks. It was observed that the playfulness and use of touch meant visitors spent longer engaging with the artworks and some reported that it helped them to pay more attention to the audio. Even where there was no physical engagement, playfulness was used for engagement in *Jeopardy*, where the onlooker was left to wonder whether an earthquake somewhere in the world would trigger the destruction of the glass house in the artwork.

Incorporating new technologies and electronics with glass enabled animacy as a method to engage the viewer, demonstrated in the animation of birds in *Jeopardy*, the moving shadows in *Stateless Vessel* and interactive beach sounds in *After the Storm*. In the first two examples, visual animacy was achieved in the artworks through the impression of liveliness in responsiveness or real / perceived motion. I have integrated ideas from my former practice of puppetry through discussion of neo-animism, ontological paradox or perceptual oscillation whereby the viewer is 'enchanted' through perceiving something as being both ambiguously alive and an object. Soundscapes and aural histories were also used as a means to attract and engage audiences. In an often-quiet glass exhibition environment the novelty of the presence of sound attracted curiosity, prompting visitors to investigate an installation more closely. I produced novel methods for the interactive interplay of sound with sculptural artworks that activated the audience's imagination to create a sense of liveness to inanimate structures. I discovered that introducing digital media through

[16] Sculptural forms, materials and textures.
[17] Bodily gestures to trigger media and multi-sensory modes of reception.
[18] The playful experience of each viewer's rendition of an artwork.

electronics to glass art would not only expand possibilities for expressing narrative content, but may enable a viewer to have a liminoid, even transformative, experience[19] .

[19] Evidenced by audience feedback of being moved by *1.5 Degrees of Concern*.

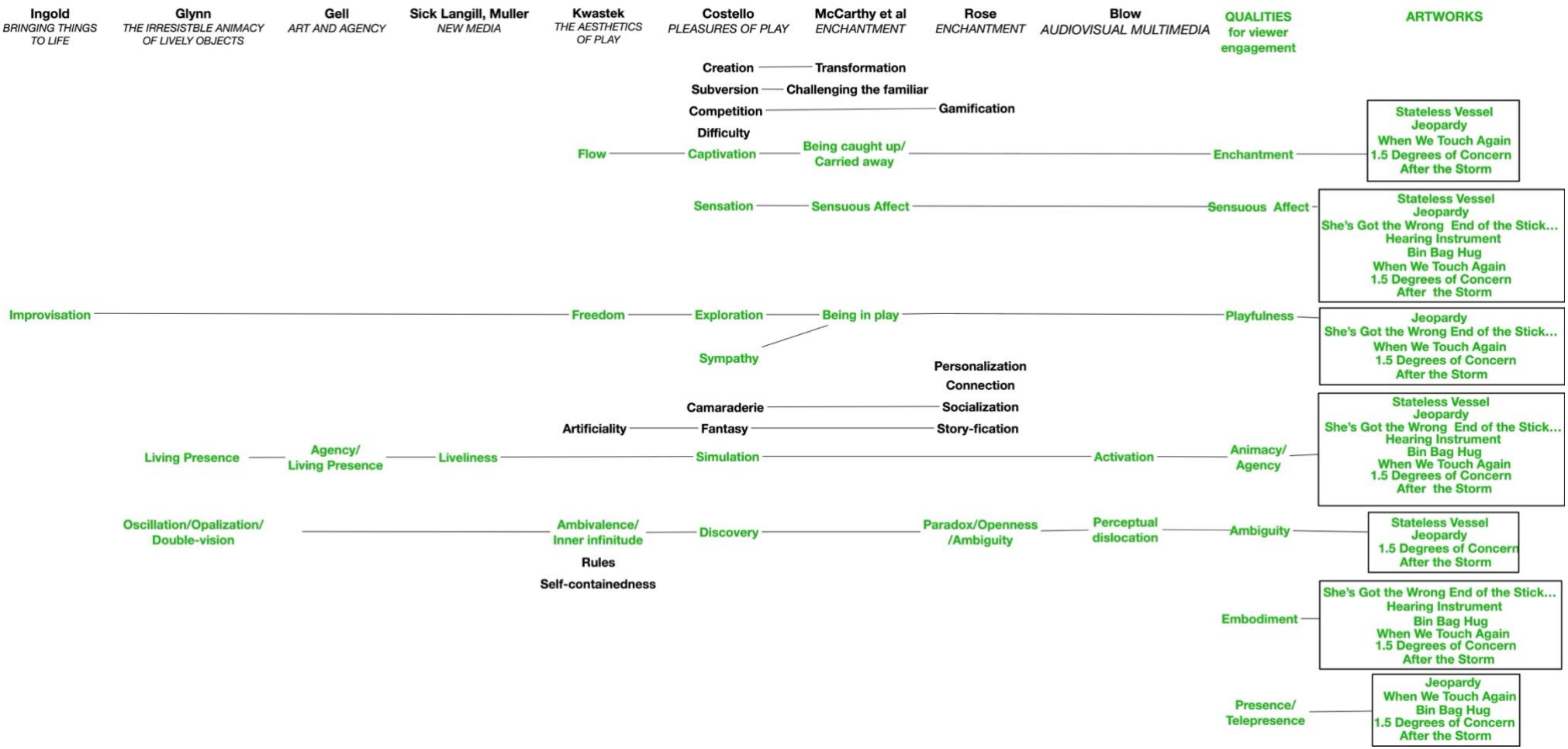

Figure 91 Artworks (in boxes on the right) created following key qualities for engaging viewers (in green text) identified from literature review (Blow, 2014; Costello and Edmonds, 2007; Gell, 1998; Glynn, 2019; Kwastek, 2015; McCarthy et al., 2006; Rose, 2014; Seck Langill and Muller, 2016).

Q3 How may blending glass with embedded electronics communicate narrative content through various media?

Projects undertaken during this study have shown that blending glass with other media extends the expressive potential of glass art. Coniglio in his essay "Materials versus Content in Digitally-mediated Performance" distinguishes two traditions in the arts, one that exhaustively explores the attributes of materials in a work and the other content-driven, where all materials are related to the idea or narrative theme of a work (Coniglio, 2006). In formulating my third question and in subsequent development of the artworks, this study has been driven as much by an exploration of narrative content as by a focus on technologies and materials for their own sake. The precarity of migrants or people living in earthquake zones was communicated through lighting, video and physical reactions enabled by electronics embedded in *Stateless Vessel* and *Jeopardy*. Crafted conductive traces acting as sensors embedded in glass that trigger sonic compositions enabled narratives as diverse as frustrated/facilitated communication in *She's Got the Wrong End of the Stick…* and *Hearing Instrument*, touch hunger in *Bin Bag Hug* and *When We Touch Again,* and climate change/coastal erosion in *1.5 Degrees of Concern* and *After the Storm*. In answering this question, I have enabled glass artists to create work that acts as a bridge between people, local history, the environment and scientific research, engaging audiences and communities directly with these issues.

This question stimulated me to find ways to use electronics to incorporate socially and globally important narratives through video, sound and web data into glass artwork, expanding the nature of the content (Coniglio, 2006). Prior to the research project, my artistic focus was predominantly on personal, historical and literary narratives, however during this study, the research expanded its scope to global issues of human migration, natural disasters, disability and climate change.

In the face of a global pandemic and unprecedented restrictions on human contact, I responded with an initiative to sustain and enhance wellbeing through interactive art projects. I further developed glass artworks which incorporated novel approaches to integrating audience presence and proximity into interactive audio narratives. *She's Got the Wrong End of the Stick* (Chapter 6) was the first example where a single glass and copper

object triggers random spoken sentences taken from a deaf person's notebook evoking frustrated and facilitated communication. When the pandemic restrictions were enforced, notions of distancing, lack of touch and proximity were further developed. *Bin Bag Hug* (Chapter 6), consisted of two framed pictures activated, by proximity but not actual touching, recorded voices telling and discussing the story of the effects of enforced isolation and non-contact during the pandemic. This was first exhibited alongside student artwork in the results of *When We Touch Again* project about 'touch hunger' during the COVID-19 lockdowns. In *Touch Collaboration*, I developed methods for a sustained and deep collaborative practice online which produced real-world results in the exhibitions of *1.5 Degrees of Concern.* Complexity of narrative was elaborated in *1.5 Degrees of Concern,* (Chapter 7) which introduced more layered and resolved audio content to artwork with a complex narrative (multiple soundtracks and layered sound design with scripted stories, poems and curated archival voices) in a complex table-top installation for the audience to engage with. Simple interactive audio compositions in *After the Storm* (Chapter 7) brought liveliness to a sculpture and evoked a sense of place and mood.

In *Stateless Vessel* (Chapter 4) a combination of a glass boat and figures with a programmed LED pixel strip casting moving shadows evoked a narrative of an unending migrant journey. *Jeopardy*, (Chapter 5) explored telepresence, communicating the effects of earthquakes around the world through using a microcomputer to connect with live data on the USGS website and produce visual effects in the artwork. Learning from the research was also applied in school STEAM projects which explored a range of content including local heritage (history of the fishing industry in Lowestoft).

I have developed, demonstrated and documented methods to blend the qualities of glass with the capabilities of electronics for creating interactions and incorporating media, to make new kinds of artwork. Whilst my study focus was on content rather than solely exploring material or technological attributes of glass or digital interactions, glass as a medium was crucial to the telling of these stories which would have a very different audience impact if conveyed in purely screen-based interactive art. Glass with its sensory, associated metaphorical and representational qualities has been used in multiple ways to communicate the narratives in this study, as discussed in the Engagement and Analysis sections of each project in Chapters 4 to 6 and enumerated in this section under Q1. It has enabled the embodiment of objects and ideas to stimulate and captivate the audience. The

multiform multimodal artworks communicated a wider range of themes and contemporary issues beyond what would have been possible through a single artform.

8.3 Summary of contribution to knowledge

My research method of bricolage manifested an eclectic interest and background in glass art, puppetry, theatre and multimedia and therefore the contribution to knowledge is multifarious. The novel use of interactive technologies to connect glass art objects with digital media has the potential to communicate diverse environmental, political or personal narratives, experiences, scientific data and visual, aural or verbal storytelling modes. The hybrid physical-digital medium of an Internet of Glass Things offers an artist multiple interconnected layers to communicate narrative. Multi-modal storytelling may include physical objects with specific haptic and metaphorical qualities and ephemeral content-bearing media of data, sound, or video. The digital and physical in an Internet of Glass Things are embedded together and connected by interactivity.

My research is embodied both in this written thesis and the actual artworks described. Scrivener (2000) explores the role of the artefact and new knowledge in design/technology or creative-production projects in doctoral research. Technological or design projects are focussed on researching solutions to a defined problem and the artefact is less important than the transferrable knowledge that it embodies. My research aims to present new technical knowledge, for instance in that it explores innovative techniques for embedding conductive traces in glass for digital interactivity. However, the ultimate goal of my research is not so much technical innovation for its own sake, but in the ways it contributes to art practice, specifically, engaging spectators by conveying new narratives through the addition of interactively-activated media. I propose that my contribution to knowledge is aligned with Scrivener's distinction between problem-solving design/technology PhD projects and creative-production projects of PhD researchers who are artists seeking to advance their practice, where he notes that in the latter case, the artefact is important in its own right. He asserts that the artefact, not being imitative or derivative and by embodying issues, concerns and interests of the PhD researcher that reflect cultural preoccupations, ultimately makes a contribution to human experience.

The study addresses a gap in academic research and documentation about physical computing using glass. 'Internet of Glass Things' is a new term I coined to describe hybrid

artworks that combine glass with computational materials for the purpose of interaction. It addresses that I have not found terms equivalent in the glass field to expressions such as ‘e-textiles’ or ‘paper circuits’. An Internet of Glass Things identifies and highlights the importance of emergent art and research into embedding conductive traces into glass and connecting them to microcontrollers to create digital interactions. My first public use of the term Internet of Glass Things was 22 May 2020 in a poster presentation for the Glass Art Society conference. As the conference was virtual, the presentation was pre-recorded and the video made publicly available on the GAS website until the 2021 conference and is currently available on my online video channel (Waugh McManus, 2020). As a speaker for the Contemporary Glass Society’s ‘Glass Discovery Day’, 20 April 2024 at the University of Sunderland, I took the opportunity to explain the meaning of the Internet of Glass Things to an audience of glass artists and students. I also reference the Internet of Glass Things on my website and have started to raise awareness of the term Internet of Glass Things by creating three new social media pages and encouraging artists who create glass artwork blended with electronics to post using the hashtags #internetofglassthings. This will enable me to find relevant work by other artists to discuss on a future blog about the Internet of Glass Things.

The glass artworks and mixed media installations produced for the study themselves contribute to knowledge as they expand artistic practice into new territory that has not been explored in much depth to date. The works represent instantiations of digitally-interactive glass artworks with embedded microcontrollers and computational materials that connect with Internet data or proximity sensing with sonic, video or lighting outputs. The study contributes to new knowledge in the glass field by providing methods and examples of ways the characteristics of glass may be used with digital augmentation for narrative purposes. I responded uniquely to the social conditions and challenges presented by the COVID-19 pandemic in finding solutions to touch hunger by promoting human interaction through the Internet of Glass Things. The works and thesis contribute to human experience through interactive installations that communicate diverse and timely narratives of human vulnerability, natural disasters, conflict and economic migration, touch hunger, isolation sensory loss and compensation, and climate change.

8.4 Areas for future research

The title *Towards* an Internet of Glass Things captures that the research worked towards the creation of interactive artworks that sensed and responded through embedded electronics. However, the use of 'towards' acknowledges that the research embodied in this thesis and the artworks has only touched upon what an Internet of Glass Things might become. I conceive multiple ways to build on this research into glass and embedded electronics in future practical projects, tackling a variety of issues. Furthermore, researchers with different skills and interests will propose different avenues to advance embedding computational materials in glass.

8.4.1 Multi-layered interactivity

My research journey changed course as a result of the COVID-19 pandemic, which closed certain doors, such as physical access to the Fablab and creative technologists, and opened others, e.g. international artistic collaboration. My original plan was for my final hybrid glass and computational technology project to explore the combination of Web-connected real-time data driving a video visualization that could be altered by proximal audience interaction. Instead, I drilled into the storytelling capacities of blending glass art with interactive sound. Recently, I have begun experiments for a project, *Deben Matters,* an interactive glass artwork connected to real-time Internet data and proximity sensors. This will comprise a glass projection surface with a relief map of Deben River saltmarsh onto which video compositions will be projected (Fig. 92). The projections including TouchDesigner compositions and video sourced on-site will respond to River Deben tidal data and viewers via touch sensors. Please see Fig. 93 for an experiment conducted with video designer Toby McManus in controlling an animation with glass and copper capacitive sensors using a Touch Board microcontroller and MIDI with TouchDesigner.

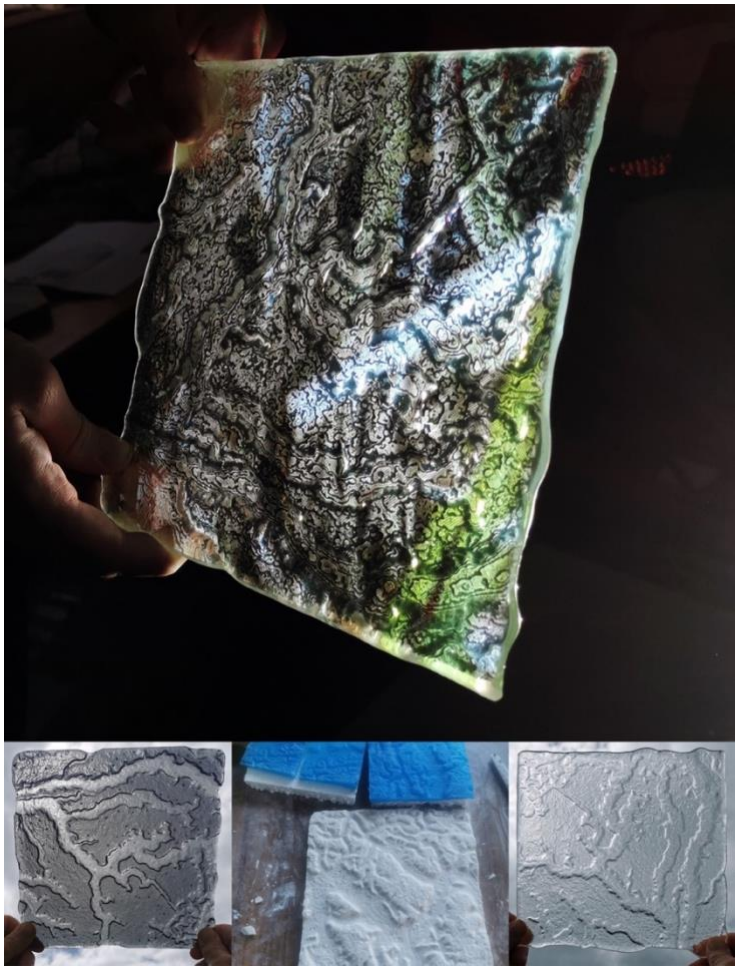

Figure 92 Liz Waugh McManus, 2023, *Deben Matters* WIP Cast glass samples and moulds made from a process of photogrammetry and 3D print from drone footage of Deben saltmarsh. The large image shows testing a sample as a projection surface.

8.4.2 Pedagogical applications

Another area for future research is the application of the research to pedagogical contexts in STEAM rather than STEM education. *When We Touch Again* project was conducted with university BA and MA students and *Make Live* with Year 5 to 7 primary and high school students. I also ran several out-of-school projects that disseminated the research with 7 to 15-year-olds.

Feedback from the *Make Live* project from primary schoolteacher Martin McGuiness indicated that interactive art was a successful way of increasing digital literacy and connecting different curriculum areas:

> The use of technology within the artwork itself was a first for us and is something we will look to continue in the future…. I also think the art aspect of the project did encourage those who are typically less interested in STEM. The group of students that took part had a mix of genders and

> academic ability and from my experience they were all very interested and engaged across the board. I think the project exceeded expectations simply because the technology used was so impressive, and the final piece of completed artwork was similarly impressive and unique.

Researchers interested in pedagogical practice may wish to build on the application of my research in educational contexts to measure how similar digital-analogue projects may be used to increase mental wellbeing, digital literacy, or to engage students in different curriculum areas through interactive storytelling.

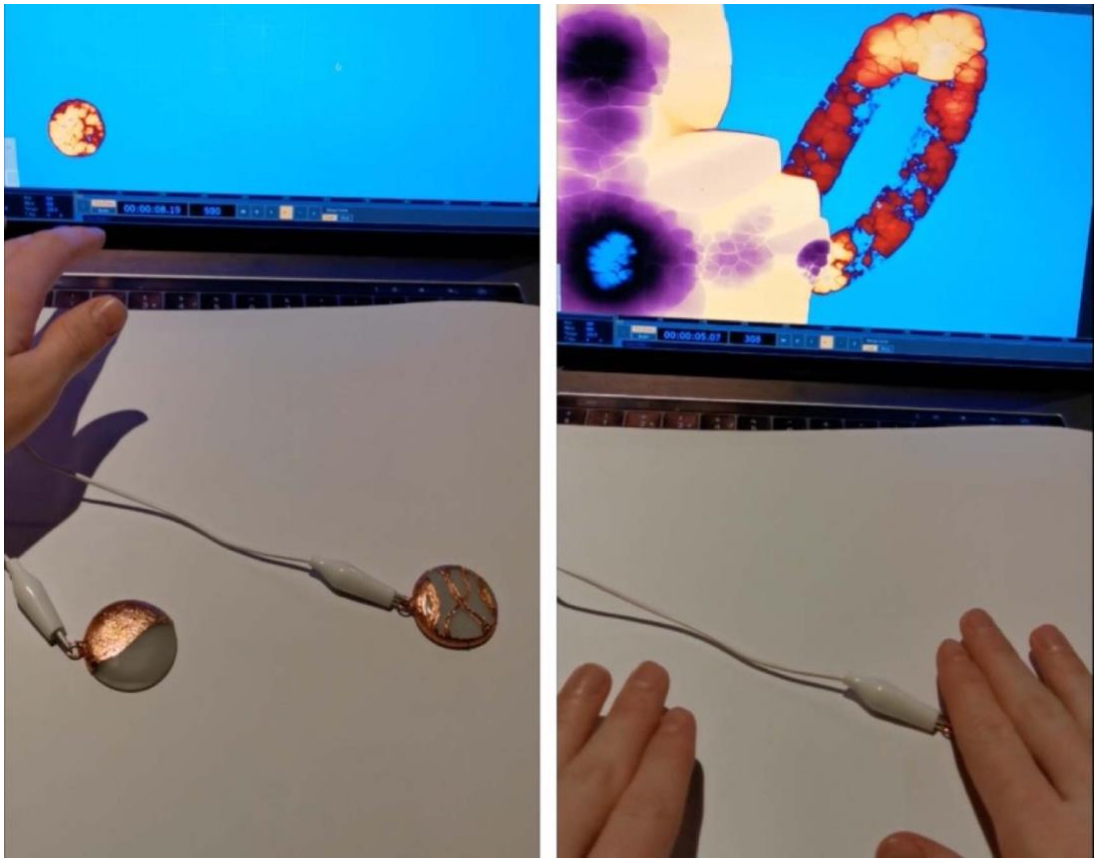

Figure 93 Liz Waugh McManus and Toby McManus, 2021, experiment controlling a composition in TouchDesigner using copper and glass buttons attached to a Touch Board.

8.4.3 Evaluation of audience engagement

A third area for future research is to evaluate in greater depth audience responses to Internet of Glass Things artworks. As discussed in 2.5, the COVID-19 pandemic changed the course of my research in several ways, preventing a planned local exhibition of interactive artworks where I proposed evaluating audience response through interviewing viewers with video-recall as a prompt. Having explored ‘how’ glass may be used with embedded electronics to create interactions that engage viewers, the next stage would be to answer the questions 'How does blending glass with embedded electronics engage viewers’? This

could be achieved through the evaluation methodology called video-cued recall used by Creative and Cognition Studios (C.C.S.) of the University of Technology, Sydney, (Costello and Edmunds, 2007, p. 82) whereby a viewer is video-ed while engaging with an interactive artwork and then questioned about their experience and thoughts while watching the replay. This allows comparison between the artist's intentions for how an artwork should be received and the way a viewer actually responds. This evaluation can both confirm what works and generate ideas for improvement in audience interaction.

8.4.4 Future contexts for an Internet of Glass Things

The contexts for an Internet of Glass Things are an area for future research. The exhibition and collection of such artworks which are both object-based and immaterial, time-based and interactive requires particular considerations beyond those for static artworks. An Internet of Glass Things will face similar challenges and solutions to documentation, archive, collection, conservation, production and exhibition as those for media art explored by Graham (2017) and her other contributors. The British Digital Art 2022 research group aims to map digital art production and collection in Britain, explore digital-physical collaboration and widen curatorial engagement with art and technology (*British Digital Art*, 2023). From my perspective, the way my art practice has developed through the research may have closed doors to more traditional galleries exhibiting studio glass, but has opened up new contexts such as residencies with art and technology organisations and socially-engaged art practice or participatory projects with communities, schools and exhibitions in museums.

Rapidly evolving digital technology poses a challenge for the maintenance of computational artworks. Hardware and software used by an artist may fail or go out of date, e.g. the problem encountered with *Jeopardy* when the original Python code script no longer worked with Raspberry Pi updates (see 5.2.2). Graham and Cook (2010, pp. 197-210) highlight the need for standardized approaches to document and conserve new media art in museums. These range from training staff in different computational systems to capturing from artists the intentions behind artworks and characteristics crucial to preserve should 'reinterpretation' be necessary through alternative software or interface options (p. 208). As new technologies evolve, future research is therefore needed to help both artists and museum curators, for instance in methods an artist may choose to aid conservation of

their work and in ways to document their methods and intentions so their artwork may be reproduced (Edmonds, 2023; Laurenson, 2017).

This study developed blended and networked methods of working: offline practice and networked communication between geographically-distributed people. This suggests the potential for networked or blended ways of exhibiting finished work for proximal, distributed or blended audiences. This could, for example, be developed through online performance platforms streaming physical exhibitions of interactive art. Since the COVID-19 pandemic, there have been multiple developments for blended telepresent and proximal performance (*Mission*, n.d.; *Telepresence Stage,* n.d.; 'UpStage - the Online Venue for Live Performances,' n.d.). What roles could a distributed 'Internet of Glass Things' artworks play with networked collaborators, performers and audience? Following the example of Tingley's *anyWare*, (p. 73) and Lozano-Hemmer's *Remote Pulse* (p. 70), there could be networked interactive glass artworks distributed at different geographical locations which respond to local people and communicate changes in the distant artworks.

I have concentrated on contexts related to my visual arts practice, however for designers, I suggest there can be a place for an Internet of Glass Things within design and architecture, for example in the area of Human Computer Interaction in developments in computationally-augmented 'smart' everyday objects or in sentient computing which connects computing systems to smart objects at physical locations in the home or work environment. Designers may augment glass, which is already a ubiquitous material used in many domestic, architectural and industrial situations.

Recent rapid expansion of Artificial Intelligence may also offer new applications for an Internet of Glass Things. Computer scientists are investigating using machine learning to process and respond to data from IoT networked communication between things and humans to improve performance. The result would lead to an 'Internet of Everything' whereby Intelligent Cyber Things are added to the ecology of humans and things connected by the Internet. Furthermore, the opening up of coding by natural language fed through AI would be a way to allow non-programmers to use the methods in this study without having to learn code.

8.5 Closing Remark

As expressed above, conducting this research has impacted my creative practice in many ways, both in new materials, technical methods and tools and in research methods, ideas, fields of inquiry and theoretical discourses. I have accessed, adapted and built on research from many different disciplines. I hope that this thesis presents ideas, methods and information which will be of value to future artists, researchers and curators.

Please refer to Appendix 2 for details of glass and electronics methods used in this study.

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Links to video and audio clips of artworks that are part of the PhD study

Video and audio clips of the interactive artworks discussed in this thesis are available for reference on a memory drive with the printed edition. The video and audio clips of interactive artworks are also available at the time of writing on the following weblinks which are also located in the chapters where they are discussed:

Stateless Vessel:
https://www.lizwaughmcmanus.co.uk/stateless-vessel

Jeopardy:
https://www.lizwaughmcmanus.co.uk/jeopardy

She's Got the Wrong End of the Stick… and *Hearing Instrument:*
https://www.lizwaughmcmanus.co.uk/shes-got-the-wrong-end

Bin Bag Hug:
https://vimeo.com/646082128

When We Touch Again project:
https://www.lizwaughmcmanus.co.uk/when-we-touch-again

1.5 Degrees of Concern:
https://www.lizwaughmcmanus.co.uk/1point5-degrees-of-concern

1.5 Degrees of Concern audio narratives:
https://www.lizwaughmcmanus.co.uk/19532020s-narratives

After the Storm:
https://www.lizwaughmcmanus.co.uk/after-the-storm

APPENDICES

1 Glossary of terms

1.1 Electronics

1.1.1 Microcontroller

Microcontrollers are small programmable circuit boards used to make devices that sense digital or analogue inputs and control outputs. There are many microcontrollers on the market with a vast array of compatible electronic components for sensing, such as IR sensors, accelerometers, thermistors to detect movement to heat, and outputs such as LEDs, motors or speakers and so on.

1.1.2 Microcomputer

A Raspberry Pi is a mini computer with a processor, memory devices, graphics driver and ports to attach external hardware such as keyboard, monitor or camera.

1.1.3 Coding

Various coding languages and editors may be used to programme microcontrollers or microcomputers, e.g. Python (Python, 2023), Arduino IDE (Arduino, 2023), Make Code, (Microsoft MakeCode, n.d.) or Scratch (Scratch, n.d.).

1.1.4 Physical computing

Physical computing refers to tangible, embedded interactive systems using microcontrollers or microcomputers to sense the world around them and/or control outputs e.g. lights, audio or motors.

1.1.5 Capacitive sensing

In capacitive sensing, the electrode on a microcontroller registers the proximity of a human body's small electrical field. The sensing electrode does this by measuring how much energy is routinely charged (stored) and discharged and notes the longer discharge time resulting from a proximal electrical field (Braun et al., 2015).

1.1.6 Pixel strip

A pixel strip is a flexible circuit board tape with RGB+W LEDs that can be individually programmed with a microcontroller. Strips can be cut or soldered together to form different lengths.

1.1.7 MOSFET

A MOSFET, short for 'metal-oxide-semiconductor field-effect transistor', is a type of transistor used to act as a switch to control higher voltage from low input signal. A MOSFET was used in the *Jeopardy* project to switch Direct Current on or off.

1.1.8 Relay

A relay is an electrically operated mechanical switch with input and output contact terminals. It is controlled by a low-power electrical signal through an electromagnet.

1.2 Electroforming

Electroforming is a system used in this study for coating surfaces with copper to make them conductive. It is a method for forming metal onto an object through 'electrodeposition', which transfers metal ions electrochemically from an anode to the object connected to a cathode through an electrolyte. The electrical circuit is powered and regulated by a bench power supply unit or rheostat.

1.3 Cyanotype

Cyanotype is an alternative lens-less form of photography using a UV light-sensitive chemicals. Potassium Ferricyanide (an iron salt) and Ferric Ammonium Citrate, (a light-sensitive iron salt) are mixed in a darkroom and used to coat paper. A photographic negative, or objects for a photogram, are placed on the prepared paper and exposed under sunlight or a UV lamp. The image is fixed by washing with water. For glass cyanotypes, chemicals are mixed with gelatine and floated onto a glass plate in the dark room prior to exposure.

1.4 Maker Community

The Maker community are people who participate in designing and producing DIY projects extending old technologies, such as carpentry, metalwork or textiles, with new ones, such as 3D printing, laser cutting, CNC and electronics.

2 Information for artists and educators

2.1 Details of some technical processes used in PhD projects: cold application methods for making a crafted capacitive sensor

Described below are some methods of applying conductive traces to glass. A touch or proximity sensor can be made by connecting the conductive trace to a microcontroller (e.g. Arduino, Touch Board or Micro:bit) programmed with code for capacitive sensing.

1.5 Degrees of Concern

The capacitive sensor in *1.5 Degrees of Concern* was made by applying self-adhesive copper tape around the edge of the glass sheet with the cyanotype print. A copper ring was soldered to the tape for attaching a crocodile clip lead that connected the sensor to an electrode on the Touch Board.

Bin Bag Hug

Below is the method for *Bin Bag Hug* that uses etching cream, does not require a kiln and adapts a method of inking-up used in print-making.

1. Prepare a black and white bitmap image with strong contrast for a stencil in Photoshop.

   This depends on the source image and needs experimentation. The resulting image needs to be dense enough and not have gaps to be a successful capacitive sensor.

   For the coloured source images in *Bin Bag Hug*, the process after importing was:

   - Increase contrast, Image>Adjustment>Brightness/Contrast,
     or, for more control use, Image>Adjustments>Black and White (adjust)
   - Image>Mode>Greyscale
   - Image>Adjustments>Posturize (select between 4 to 12)
   - Image>Mode>Bitmap (600 pixels per inch, halftone screen>35 lines per inch, angle 45 degrees, round shape)

The result was printed onto transparent/translucent paper (e.g. Folex Inkjet Printing Film A4).

.

2. Use the print of the image to expose photosensitive film in a UV exposure unit. Develop and prepare stencil following manufacturer's instructions.

3. Follow manufacturer's instructions for positioning the wet stencil on the glass sheet.

   For Bin Bag Hug, this involved:

   - Positioning wet stencil then drying the edges of the glass
   - Using plastic parcel tape to hold the stencil in position and mask off the sides and rear of the glass from the acid
   - Sticking the stencil to the glass using stencil liquid and pressing the edges down
   - Drying the stencil with a hairdryer

4. Apply etching cream following manufacturer's instructions
   - Put on thick. Press through the stencil with a Q-tip
   - Squeegee several times – at least once in each direction
   - Leave cream on for 2 to 4 minutes. The etch needs to be deeper than recommended by manufacturer.
   - Scrape off etching cream and replace in bottle for re-use. Make sure it is all off before removing the tape and stencil.
   - Rinse and dry thoroughly

5. Apply conductive ink to glass using a traditional printmaking method for intaglio.

   I used Robert Murray-Smith's FWG Conductive Ink with graphene for *Bin Bag Hug,* available at the time from his online shop.
   - Use scrim to press ink into the etched glass
   - Use paper towel to remove ink from non-etched areas before the ink dries
   - Use tissue paper flat to clean and polish non-etched areas
   - Repeat the three stages above until there is a sufficient build-up of ink
   - Use conductive paint to attach conductive thread to the edge of the image and connect to the electrode of the microcontroller.

She's Got the Wrong End of the Stick…, After the Storm, and Hearing Instrument

The capacitive sensors were made through Copper Electroforming onto artefacts of, respectively, torchworked glass, cast glass and silicone hearing aid moulds. Please refer to Appendix 1 for more information about Electroforming.

For the projects in this study, I used a small plastic tank with 8 litres electrolyte. The solution was circulated and aerated by a fish tank pump. A fish tank heater kept the electrolyte at around 20°C. Anodes were copper plates, wrapped in cloths, and the cathode was a thick copper rod from which the objects to be electroformed hung into the tank from wires.

Preparation:

- A vinyl-cut stencil of text was prepared for *She's Got the Wrong End of the Stick…* (as described and illustrated in the body of the thesis). The writing, designed on Adobe Illustrator, was joined up with no gaps so that the copper would be a continuous copper trace. It was exported as a .svg file for cutting on the vinyl plotter.
- The vinyl stencil was adhered to the glass cane and uncovered glass masked with electrical tape. The text was sandblasted through the stencil to a depth of 1mm and then painted with silver-coated copper conductive paint.
- The handle and the silicone hearing moulds (glued onto copper wires) were sprayed with silver conductive paint which results in a smoother finish than painting with a brush. The areas to be electroformed on the *After the Storm* sensors were sandblasted to provide a key for silver-coated copper conductive paint.
- Vinyl stencils were removed and glass cleaned and degreased before painting.
- Some smaller cast glass artefacts for *After the Storm* were joined together with copper wire and epoxy glue. Copper jump rings were glued to the glass sensors as attachment sites for wires connected to the microcontroller.
- The copper wires attached to the hearing moulds were masked with liquid latex to prevent them being copper electroformed (which would have made them thicker and inflexible.

Wiring up to connect conductive areas to the electrical current:

- Copper wire was wound loosely to form a 'cage' round the hearing moulds and convex glass forms, then the other end was wound round the copper cathode rod in the electroforming tank. It was important to make connection points on each artefact without being so tight that the cage would be fused onto the object. (Method taught by jeweller Penny Akaster).

- For the concave surfaces of the text on the glass cane, it was necessary to use a more complex wiring system (taught by Mark Hursty on the Glass Electric course). Multi-strand telephone cable was used with the metal at ends of the wires exposed. They were positioned into the sandblasted text that had been painted with conductive paint and held in place by gluing the plastic wire coating to the glass about 12mm from the end. The other end of the telephone wires was wound round a copper hook, which was hung form the copper cathode rod (Fig.94).

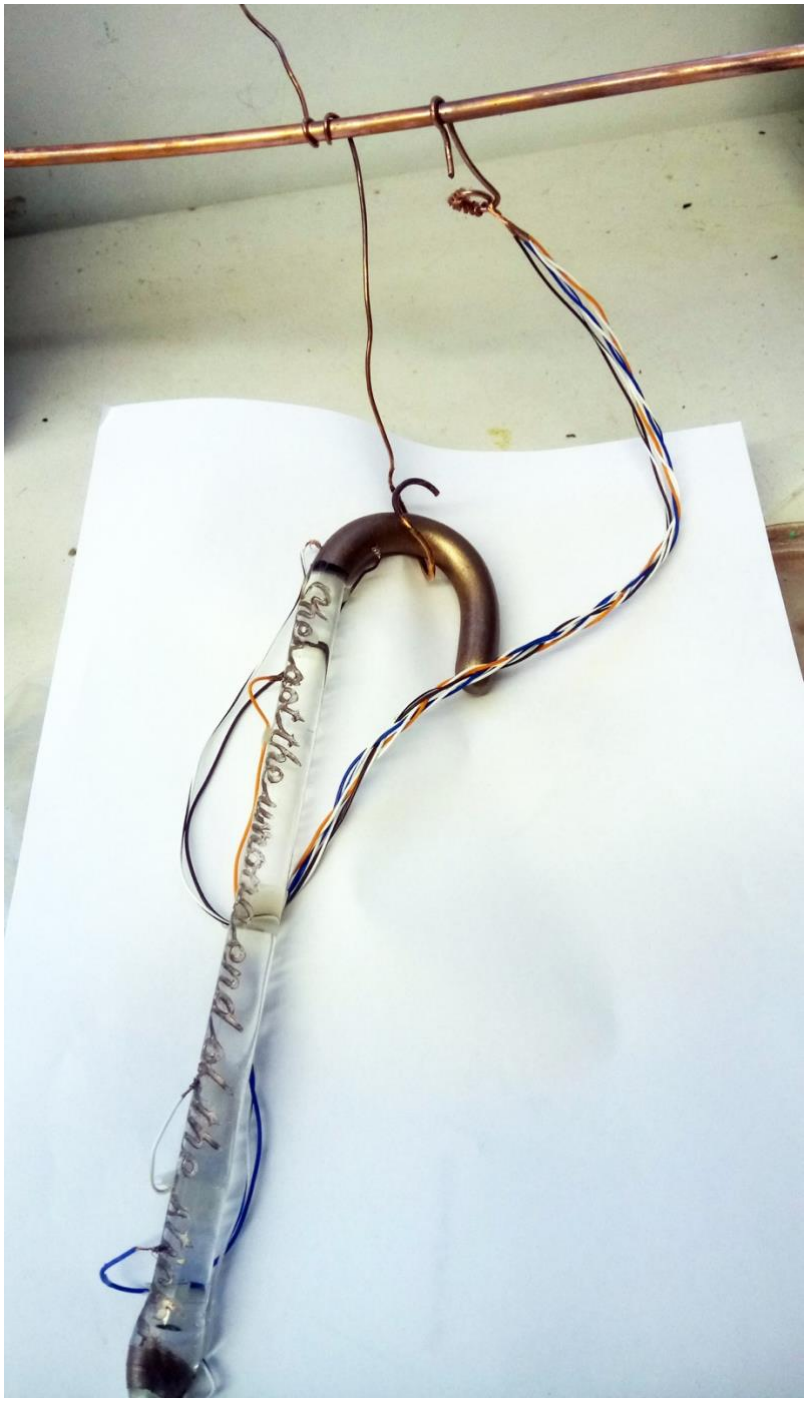

Figure 94 Photograph showing attachment of wires to the text and the cathode rod before immersion the electroforming tank.

Electroforming*:

- Objects were immersed in an electroforming tank in a system as described in Appendix I. The tank contained 8 litres of electrolyte consisting of consisting of 6.52 litres distilled water, 1.2 kg pure copper sulphate crystals, 172 ml pure sulphuric acid and 15 ml of brightener solution.
- Electroforming the objects above took 24 to 36 hours @ 0.5 – 0.75V in the tank, depending on surface area, number of pieces in the tank and arrangement of the anodes.
- The system is checked on regularly to make sure the system is working correctly. Also jiggle objects inside copper wire cages occasionally so they do not become fused.
- The current was turned down to about 0.2V for a few hours over night
- Once copper electroforming is complete, the objects are rinsed in distilled water and baking soda to neutralise any residual acid.

*This uses dangerous chemicals and relevant Health and Safety procedures must be followed.

When We Touch Again

Conductive ink (either FWG Conductive Ink with graphene or Bare Conductive Electric Ink) was painted onto glass surfaces. Conductive thread was attached to the paint prior to sealing the ink with acrylic sealer, being careful not to smudge it. The thread was then connected to the electrode on the microcontroller either directly or with a crocodile lead.

Alternative methods of turning imagery or text on glass into sensors were developed during the Craft Futures workshops between the Universities of Sunderland and Northumbria. For example, making a stencil, sand-blasting through the stencil into the glass sheet then filling the etched areas with conductive paint (e.g. carbon, silver or copper).

2.2 Examples of code used in PhD projects

Stateless Vessel

Lighting experiment

Long insulated copper wires were attached to an Arduino Uno via a breadboard at one end and soldered to an LED at the other. A 330 ohm resistor was soldered to one leg of the LED to stop it burning out. The Arduino sketch below (blink_multiple_LEDs) was used control the blinking of the LEDs.

Blink

Turns an LED on for one second, then off for one second, repeatedly.

Most Arduinos have an on-board LED you can control. On the UNO, MEGA and ZERO
it is attached to digital pin 13, on MKR1000 on pin 6. LED_BUILTIN is set to
the correct LED pin independent of which board is used.
If you want to know what pin the on-board LED is connected to on your Arduino
model, check the Technical Specs of your board at:
https://www.arduino.cc/en/Main/Products

modified 8 May 2014
by Scott Fitzgerald
modified 2 Sep 2016
by Arturo Guadalupi
modified 8 Sep 2016
by Colby Newman

```
/* Blink Multiple LEDs without Delay
*
* Turns on and off several light emitting diode(LED) connected to a digital
* pin, without using the delay() function. This means that other code
* can run at the same time without being interrupted by the LED code.
*/
int led1 = 13;       // LED connected to digital pin 13
int led2 = 12;
int led3 = 8;
int led4= 7;

int value1 = LOW;       // previous value of the LED
int value2 = LOW; // previous value of the LED
int value3 = LOW;
int value4 = LOW;

long time1 = millis();
long time2 = millis();
long time3 = millis();
long time4 = millis();

long interval1 = 1000;      // interval at which to blink (milliseconds)
long interval2 = 500;
long interval3 = 800;
long interval4 = 2000;
```

```
void setup()
{
 pinMode(led1, OUTPUT);   // sets the digital pin as output
 pinMode(led2, OUTPUT);
 pinMode(led3, OUTPUT);
 pinMode(led4, OUTPUT);
}

void loop()
{
 unsigned long m = millis();

 if (m - time1 > interval1){
  time1 = m;

  if (value1 == LOW)
   value1 = HIGH;
  else
   value1 = LOW;

  digitalWrite(led1, value1);
 }

 if (m - time2 > interval2){
  time2 = m;

  if (value2 == LOW)
   value2 = HIGH;
  else
   value2 = LOW;

  digitalWrite(led2, value2);
 }
 if (m - time3 > interval3){
  time3 = m;

  if (value3 == LOW)
   value3 = HIGH;
  else
   value3 = LOW;
```

```
 digitalWrite(led3, value3);
}
if (m - time4 > interval4){
 time4 = m;

 if (value4 == LOW)
  value4 = HIGH;
 else
  value4 = LOW;

 digitalWrite(led4, value4);
}
}
```

Final project

Code for Arduino Uno connected to a NeoPixelStrip powered by a 5V 2A power supply; adapted for the project by Alistair McFarlane from the Adafruit Neopixel RGBW_strandtest Arduino sketch.

```
#include <Adafruit_NeoPixel.h>
#ifdef __AVR__
 #include <avr/power.h>
#endif

#define PIN 6

// Parameter 1 = number of pixels in strip
// Parameter 2 = Arduino pin number (most are valid)
// Parameter 3 = pixel type flags, add together as needed:
//  NEO_KHZ800 800 KHz bitstream (most NeoPixel products w/WS2812 LEDs)
//  NEO_KHZ400 400 KHz (classic 'v1' (not v2) FLORA pixels, WS2811 drivers)
//  NEO_GRB   Pixels are wired for GRB bitstream (most NeoPixel products)
//  NEO_RGB   Pixels are wired for RGB bitstream (v1 FLORA pixels, not v2)
//  NEO_RGBW  Pixels are wired for RGBW bitstream (NeoPixel RGBW products)
Adafruit_NeoPixel strip = Adafruit_NeoPixel(288, PIN, NEO_GRBW + NEO_KHZ800);

// IMPORTANT: To reduce NeoPixel burnout risk, add 1000 uF capacitor across
// pixel power leads, add 300 - 500 Ohm resistor on first pixel's data input
// and minimize distance between Arduino and first pixel. Avoid connecting
// on a live circuit...if you must, connect GND first.
```

```
void setup() {

 strip.begin();
 strip.show(); // Initialize all pixels to 'off'
}

void loop() {

 // Loop through all the LEDs
 for(uint16_t l=0; l<strip.numPixels(); l++) {

  // Reset all the LEDs to off
  for(uint16_t i=0; i<strip.numPixels(); i++) {
   strip.setPixelColor(i, strip.Color(0, 0, 0));
  }

  // Fade from las to is LED
  int steps = 40; //for 650mm diameter. int steps = 26; // for 1000mm diameter.
  for(uint16_t j=0; j<steps; j++) {
   int inten = (float) j/steps*255;
   if (l-1<288) {
    strip.setPixelColor(l-1, strip.Color((255-inten)*0.8, 255-inten, 255-inten, 255-inten));
   }
   else {
    strip.setPixelColor(l-1, strip.Color(255-inten, 255-inten, 255-inten, 255-inten));
   }

   if (l<288) {
    strip.setPixelColor(l, strip.Color(inten*0.8, inten, inten, inten));
   }
   else {
    strip.setPixelColor(l, strip.Color(inten, inten, inten, inten));
   }
   strip.show();
  }
 }
}
```

Jeopardy

OMX player was installed on the Raspberry pi 3 model B. An .mp4 file of the bird animation was imported into the Video folder.

Python code (by programmer Andy Card with additions by Alistair McDonald) for Raspberry Pi parsing data from USGS website and triggering either the animation to play or the fuse wire to heat, depending on seismic activity. In July 2023, Andy Card altered the code originally written in 2019 after it stopped working following an update and upgrade of the Raspberry Pi.

```
import requests
import json
import datetime
from time import sleep
from subprocess import run

videoPath = "/home/pi/Videos/Corvids_3.mp4";

run(["gpio","mode","0","output"]);

while True:

 print("loading API");

 time = datetime.datetime.now() - datetime.timedelta(seconds=10);
 print("Timespan: {0}".format(time));

 response =
requests.get("https://earthquake.usgs.gov/fdsnws/event/1/query?format=geojson&starttime={0}".format(time
)).text;

 print("parsing data");
 data = json.loads(response);

 numberOffeatures = len(data['features']);
 print("Outputting features ({0})".format(numberOffeatures));

 if numberOffeatures > 0:
  for feature in data['features']:
   print(feature['properties']['type']);
   print(feature['properties']['mag']);
   magnitude = feature['properties']['mag'];
   if magnitude > 8:
```

```
    print ("redalert");
    run(["gpio","write","0","1"]);
    sleep(20);
    run(["gpio","write","0","0"]);
   elif magnitude > 1:
    omx = run(["omxplayer",videoPath]);
    print ("play video");
   else:
    print ("tremors");

sleep(10);
```

She's Got the Wrong End of the Stick …

Cap sense Theremin experiment

A tutorial is available at https://www.youtube.com/watch?v=REGhsgB4NyE
that uses an Arduino Uno, breadboard, speaker, jump wires, crocodile leads and two 210M resistors. I used 1M resistors and substituted crafted sensors for the pieces of tinfoil in the tutorial. Speaker wires were connected to pin 8 and GND with a 100k resistor. The capacitive sensors and resistors to pins 4 and 2 and 7 and 5.
The Arduino sketch below is called sketch_Daniels_theremin:

```
#include <CapacitiveSensor.h>
CapacitiveSensor capSensor1 = CapacitiveSensor(4,2);
CapacitiveSensor capSensor2 = CapacitiveSensor(7,5);

void setup() {
 Serial.begin(9600); // put your setup code here, to run once:

}

void loop() {
 long sensorValue1 = capSensor1.capacitiveSensor(30);
  long sensorValue2 = capSensor2.capacitiveSensor(30);

  Serial.print("Sensor1: ");
  Serial.print(sensorValue1);
  Serial.print("Sensor2: ");
  Serial.println(sensorValue2);

  int val1 = map(sensorValue1, 0, 5000, 50, 4000);
  int val2 = map(sensorValue2, 0, 10000, 10, 1000);

  tone(8,val1,20);
  noTone;
  delay(val2); // put your main code here, to run repeatedly:

}
```

She's Got the Wrong End of the Stick …

Experiment using Micro:bit/Makerhawk expansion board/Mp3 module

A Micro:bit microcontroller was used with a Makerhawk expansion board connected to a YX5300 Mp3 module and a small speaker with minijack. The Mp3 module has an SD card formatted as FAT16 or FAT 32 on which Folders are named 01, 02 etc., with .mp3 files inside (or .wav) labelled 001xxx.mp3, 002xxx.mp3 etc.

Wiring:

Micro:bit Makerhawk Expansion Board		YX5300 Mp3 module
P0	———	RX
P1	———	TX
GND	———	GND
5V	———	VCC

The visual block code editor Microsoft MakeCode was used to programme the Micro:bit. Makecode has code for connecting an Mp3 device and a 'Makerbit' extension which worked with the Makerhawk expansion board. The code is first downloaded onto the Micro:bit via USB. The USB lead is then removed and inserted in the USB 5V power port of the expansion board.

Here is the Javascript for the MakeCode blocks shown in the image below.

```
function readPin () {
 readings += pins.analogReadPin(AnalogPin.P2)
 pins.digitalWritePin(DigitalPin.P2, 1)
}
function sense () {
 readings = 0
 for (let index = 0; index <= samples; index++) {
  basic.pause(1)
  readPin()
 }
 buttonState = Math.idiv(readings, samples) > callibrationValue + threshold
}
function callibration () {
 readings = 0
 for (let index = 0; index <= samples; index++) {
  readPin()
  basic.pause(1)
 }
 callibrationValue = Math.idiv(readings, samples)
```

```
}
let readings = 0
let callibrationValue = 0
let buttonState = false
let samples = 0
let threshold = 0
serial.redirectToUSB()
threshold = 25
pins.setPull(DigitalPin.P2, PinPullMode.PullNone)
samples = 8
buttonState = false
callibrationValue = 0
callibration()
makerbit.connectSerialMp3(DigitalPin.P0, DigitalPin.P1)
makerbit.setMp3Volume(30)
basic.showNumber(callibrationValue)
basic.forever(function () {
 sense()
 if (buttonState == true) {
  basic.showIcon(IconNames.Skull)
  serial.writeLine("")
  basic.pause(500)
  basic.clearScreen()
  makerbit.playMp3Track(1, 1)
 }
})
```

Figure 95 Image of MakeCode blocks for Micro:bit/MakerHawk/MP3 code above

She's Got the Wrong End of the Stick ….* and *1.5 Degrees of Concern

Final sketch for programming Touch Board in Arduino IDE

10b_Random_Proximity_Norepeat_Adjustable_MP3

(A modification by programmer Craig James of 'Bare Conductive Random Touch MP3 player' by by Jim Lindblom, Stefan Dzisiewski-Smith and Peter Krige.

****

Random_Touch_MP3.ino - touch triggered MP3 playback taken randomly from microSD

You need twelve folders named E0 to E11 in the root of the microSD card. Each of these folders can have as many MP3 files in as you like, named however you like (as long as they have a .mp3 file extension).

When you touch electrode E0, a random file from the E0 folder will play. When you touch electrode E1, a random file from the E1 folder will play, and so on.
You should note that this is not the same file structure as for Touch_MP3.

```
SD card
|
├──E0
|  some_mp3.mp3
|  another_mp3.mp3
|
├──E1
|  dog-barking-1.mp3
|  dog-barking-2.mp3
|  dog-growling.mp3
|  dog-howling.mp3
|
├──E2
|  1.mp3
|  2.mp3
|  3.mp3
|  4.mp3
|  5.mp3
|  6.mp3
|
└──...and so on for other electrodes
```

Based on code by Jim Lindblom and plenty of inspiration from the Freescale Semiconductor datasheets and application notes.

Bare Conductive code written by Stefan Dzisiewski-Smith and Peter Krige.

**********/

```
// compiler error handling
#include "Compiler_Errors.h"

// touch includes
#include <MPR121.h>
#include <Wire.h>
#define MPR121_ADDR 0x5C
#define MPR121_INT 4

// mp3 includes
#include <SPI.h>
#include <SdFat.h>
#include <FreeStack.h>
```

```
#include <SFEMP3Shield.h>

// mp3 variables
SFEMP3Shield MP3player;
byte result;
int lastPlayed = -1;
int lastFilePlayed = -1;

// sd card instantiation
SdFat sd;
SdFile file;

// define LED_BUILTIN for older versions of Arduino
#ifndef LED_BUILTIN
#define LED_BUILTIN 13
#endif

void setup(){
 Serial.begin(57600);

 pinMode(LED_BUILTIN, OUTPUT);

 //while (!Serial) ; {} //uncomment when using the serial monitor
 Serial.println("Bare Conductive Random Touch MP3 player");

 // initialise the Arduino pseudo-random number generator with
 // a bit of noise for extra randomness - this is good general practice
 randomSeed(analogRead(0));

 if(!sd.begin(SD_SEL, SPI_HALF_SPEED)) sd.initErrorHalt();

 if(!MPR121.begin(MPR121_ADDR)) Serial.println("error setting up MPR121");
 MPR121.setInterruptPin(MPR121_INT);
 MPR121.setTouchThreshold(20);
 MPR121.setReleaseThreshold(10);

 result = MP3player.begin();
 MP3player.setVolume(10,10);

 if(result != 0) {
  Serial.print("Error code: ");
  Serial.print(result);
```

```
 Serial.println(" when trying to start MP3 player");
 }

}

void loop(){
 if(MPR121.touchStatusChanged()){

 MPR121.updateTouchData();

 // only make an action if we have one or fewer pins touched
 // ignore multiple touches

 if(MPR121.getNumTouches()<=1){
  for (int i=0; i < 12; i++){ // Check which electrodes were pressed
   if(MPR121.isNewTouch(i)){
    Serial.print("pin ");
    Serial.print(i);
    Serial.println(" was just touched");
    digitalWrite(LED_BUILTIN, HIGH);

    if(MP3player.isPlaying()){
     MP3player.stopTrack();
     Serial.print("stopping track ");
     Serial.println(lastPlayed);
    }
    if (i == lastPlayed) {
     // If this is the same pin, avoid replaying the same track (lastFilePlayed)
     lastFilePlayed = playRandomTrack(i, lastFilePlayed);
    } else {
     // Different pin touched, select file purely randomly
     lastFilePlayed = playRandomTrack(i, -1);
    }
    lastPlayed = i;
   } else {
    if(MPR121.isNewRelease(i)){
     Serial.print("pin ");
     Serial.print(i);
     Serial.println(" is no longer being touched");
     digitalWrite(LED_BUILTIN, LOW);
    }
   }
```

```
  }
 }
}
}

int playRandomTrack(int electrode, int lastFilePlayed) {

 // build our directory name from the electrode
 char thisFilename[255]; // 255 is the longest possible file name size
 // start with "E00" as a placeholder
 char thisDirname[] = "E00";

 if(electrode<10){
  // if <10, replace first digit...
  thisDirname[1] = electrode + '0';
  // ...and add a null terminating character
  thisDirname[2] = 0;
 } else {
  // otherwise replace both digits and use the null
  // implicitly created in the original declaration
  thisDirname[1] = (electrode/10) + '0';
  thisDirname[2] = (electrode%10) + '0';
 }

 sd.chdir(); // set working directory back to root (in case we were anywhere else)
 if(!sd.chdir(thisDirname)){ // select our directory
  Serial.print("error selecting directory: "); // error message if reqd.
  Serial.println(thisDirname);
 }

 size_t filenameLen;
 char* matchPtr1;
 char* matchPtr2;
 unsigned int numMP3files = 0;

 // we're going to look for and count
 // the MP3 files in our target directory
 while (file.openNext(sd.vwd(), O_READ)) {
  file.getName(thisFilename, sizeof(thisFilename));
  file.close();

  filenameLen = strlen(thisFilename);
```

```
 matchPtr1 = strstr(thisFilename, ".mp3");
 matchPtr2 = strstr(thisFilename, "._");
 // basically, if the filename ends in .MP3, we increment our MP3 count
 if(matchPtr1-thisFilename==filenameLen-4 andand matchPtr2-thisFilename!=0) numMP3files++;
}

// Generate a random number, representing the file we will play. But
// try not to repeat the same track we just played.
unsigned int chosenFile;
int tries = 0;
while (tries < 30) {
 chosenFile = random(numMP3files);
 if (chosenFile != lastFilePlayed) {
  break;
 }
 tries++;
}

// loop through files again - it's repetitive, but saves
// the RAM we would need to save all the filenames for subsequent access
unsigned int fileCtr = 0;

sd.chdir(); // set working directory back to root (to reset the file crawler below)
if(!sd.chdir(thisDirname)){ // select our directory (again)
 Serial.println("error selecting directory"); // error message if reqd.
}

while (file.openNext(sd.vwd(), O_READ)) {
 file.getName(thisFilename, sizeof(thisFilename));
 file.close();

 filenameLen = strlen(thisFilename);
 matchPtr1 = strstr(thisFilename, ".mp3");
 matchPtr2 = strstr(thisFilename, "._");
 // this time, if we find an MP3 file...
 if (matchPtr1-thisFilename==filenameLen-4 andand matchPtr2-thisFilename!=0) {
  // ...we check if it's the one we want, and if so play it...
  if(fileCtr==chosenFile){
   // this only works because we're in the correct directory
   // (via sd.chdir() and only because sd is shared with the MP3 player)
   Serial.print("playing directory ");
   Serial.print(thisDirname);
```

```
   Serial.print(", track ");
   Serial.print(lastFilePlayed);
   Serial.print(", ");
   Serial.println(thisFilename); // should update this for long file names
   MP3player.playMP3(thisFilename);
   return fileCtr;
  } else {
   // ...otherwise we increment our counter
   fileCtr++;
  }
 }
}
}
```

Bin Bag Hug and ***After the Storm***

A sketch for Touch Board developed by Craig James including the library he developed, BTUtils, was used:
9_Proximity/Volume_ResumeSingleTrack

```
 //Proximity changes volume (the closer the hand, the louder it gets); the track resumes in place.
//If you get near another sensor on the same board, it will start playing new track from beginning.
//No time out on any sound file. Best with unshielded cable.
//Using a shielded cable you have to get closer or touch it before getting a response.
//setProximitySensingMode - Controls how far or how close the hand to fade in and out, and also how loud it gets at different proximities.
//The higher the number the further the hand can be to trigger it and the sooner it will full volume.

#include "BtUtils.h"                          "
#include <MPR121.h>
#include <Wire.h>
#include <SPI.h>
#include <SdFat.h>
#include <FreeStack.h>
#include <SFEMP3Shield.h>

SdFat sd;
SFEMP3Shield MP3player;

BtUtils *bt;

void setup() {
 bt = BtUtils::setup(andsd, andMP3player);
```

```
 // Set up the TouchBoard for proximity sensing. This changes the sensitivity
 // of the board and changes its filtering characteristics so that slow hand
 // movements are detected correctly.

 bt->setProximitySensingMode();

 // Change the proximity sensitivity. The default (if you don't set this at all)
 // is 1.3. If you increase it (say by setting it to 2.0), the volume will
 // increase more rapidly as your hand gets near the sensor. If you
 // decrease it (say to 0.5), the volume will increase more
 // slowly. Additionally, values lower than 1.3 will limit the total
 // volume. A value of one means the maximum volume is around 70%. A value
 // of 0.8 will lower the maximum volume to about 50%.

 bt->setProximityMultiplier(1.5);


 // Set the volume to zero initially so that nothing sounds until
 // your hand gets near the proximity pin (pin zero that we set above).

 bt->setVolume(0);


}

void loop() {


 int highestProximity = 0;
 int highestProximityPin = -1;


 // Find the pin with the highest proximity reading.
 for (int pin = FIRST_PIN; pin <= LAST_PIN; pin++) {
  int proximity = bt->getProximityPercent(pin);
  if (proximity > highestProximity) {
   highestProximity = proximity;
   highestProximityPin = pin;
  }
 }

 // What's currently going on? (IS_PLAYING, IS_PAUSED, or IS_STOPPED)
```

```
int playerStatus = bt->getPlayerStatus();

// Which track was last played?
int lastTrack = bt->getLastTrackPlayed();

// If nothing is near (proximity is zero) and a track is playing, pause it.
if (highestProximity == 0) {
 if (playerStatus == IS_PLAYING) {
  BtUtils::log_action("pause: ", lastTrack);
  bt->pauseTrack();
 }
 bt->setVolume(0);
 bt->turnLedOff();
}

// else -- proximity was detected
else {

 // Set the volume. The proximity is in percentage 0-100, and the volume is
 // also 0-100, so we can just set the volume to the proximity number.
 bt->setVolume(highestProximity);
 BtUtils::log_action("setVolume: ", highestProximity);

 // If it's already playing but this is a different pin, switch tracks.
 // If it's the same pin, we don't have to do anything.
 if (playerStatus == IS_PLAYING) {
  if (highestProximityPin != lastTrack) {
   bt->startTrack(highestProximityPin);
  }
 }

 else if (playerStatus == IS_PAUSED) {

  // If it's paused and this is the same track, resume playing
  if (highestProximityPin == lastTrack) {
   bt->resumeTrack();
  }

  // If it's paused and this is a different track, switch to the new track
  else {
   bt->startTrack(highestProximityPin);
  }
```

```
 }

 // If it's currently stopped, start this track
 else if (playerStatus == IS_STOPPED) {
  bt->startTrack(highestProximityPin);
 }

 bt->turnLedOn();
}
}
```

When We Touch Again

Student chose from examples of Craig James's Touch Board sketches as well as the library he developed, BTUtils. He has shared them on the open source site at https://github.com/craig-james-author/btutils/tree/master/Arduino%20Sketches_When%20We%20Touch%202019 and https://github.com/craig-james-author/btutils

3 Samples of sound scores

1.5 Degrees of Concern: The Past (1953 and 2020), composed by Liz Waugh McManus.

AUDIO COMPOSITION 1a (2 min 43 sec)

- A mix of archival recordings and sound FX

(Sound of fierce wind blowing)

MAN'S VOICE 1

1953 BROADCASTER: During the night of January 31st, many of the lower lying districts of Eastern England were overwhelmed by a devastating flood. A strong north-westerly gale had been blowing for some days creating a tidal surge which swept down the coast to increase an already high spring tide.

WOMAN'S VOICE:

I put my hand down, woke up in the night, put my hand down the side of the bed and felt water.

MAN'S VOICE 1

1953 BROADCAST: A strong north-westerly gale had been blowing for some days creating a tidal surge which swept down the coast to increase an already high spring tide.

(Sound of a dog persistently barking, fading to background)

MAN'S VOICE 2 I was woken up from around about one o'clock in the morning by our dog barking and raising alarm in a very

: agitated manner and my arm sort of fell out of bed and it was a shock of cold water

(Howling wind)

MAN'S VOICE 1

1953 BROADCAST: Great gaps were scarred through the sea defences.

(Howling wind in the background)

WOMAN'S VOICE: …and told her and she said, "Oh God, the wall's gone".
It was right over the bed, you know, coming over the bed, and the clothes were floating then

MAN'S VOICE 2 We didn't have night clothes so we were sort of sitting there with very little on, on the rafters. I was cold.

WOMAN'S VOICE: Freezing! Cos that was the worst thing – it was so cold.
My uncle was in the other room and he got up and he carried us on to the kitchen table. We stayed there all night.

(Footsteps wading through water)

(Wind howling)

MAN'S VOICE 3 The bed was soaking wet and as I stepped out I was up to the thighs in water and it was climbing and we sort of rushed round to the living area and our father was scrabbling on top of this table trying to rip the ceiling down.

(Splashes and muffled underwater sounds)

And he pummelled a hole in the asbestos roof above his head and then he decided he would pass the children up one at a time.

(Background sound of water flowing)

For them to sit across the rafters that spanned the living room.

MAN'S VOICE 2 If you fell asleep you were gonna die. You were going to fall off and you were going to die. There was no doubt about that at all. So you hung on for grim death.

(Sudden loud splash)

(Muffled underwater sounds)

MAN'S VOICE 3 I realised I had been standing in cold water for something like ten hours, holding my younger brother.

(Water gurgling)

MAN'S VOICE 2 I remember my mother saying to my father, "The children have stopped crying. I think they must … I think they might be dead". And my father saying "No they ain't. They're probably just asleep".

(Wind howling)

MAN'S VOICE 1

1953 BROADCAST: Unfortunately, many people had no time to escape the rising waters.

Some were drowned, some died of exposure in the bitterly cold wind.

(Wind howling)

END.

<u>AUDIO COMPOSITION 1b</u> (2 min 44 sec)

- A mix of archival recordings and sound FX

(Sound of fierce wind blowing)

MAN'S VOICE

1953 BROADCASTER: During the night of January 31st, many of the lower lying districts of Eastern England were overwhelmed by a devastating flood. A strong north-westerly gale had been blowing for some days creating a tidal surge which swept down the coast to increase an already high spring tide.

WOMAN'S VOICE 1:

I put my hand down, woke up in the night, put my hand down the side of the bed and felt water.

MAN'S VOICE

1953 BROADCAST: A strong north-westerly gale had been blowing for some days creating a tidal surge which swept down the coast to increase an already high spring tide.

(Sound of a dog persistently barking, fading to background)

WOMAN'S VOICE 2 I shook my husband and said we were flooded or something and he just grabbed hold of the baby and me and we all sort of tried to swim out of the house and water was coming up and up all the time.

(Howling wind)

MAN'S VOICE 1

1953 BROADCAST: Great gaps were scarred through the sea defences.

(Howling wind in the background)

WOMAN'S VOICE 1: …and told her and she said, "Oh God, the wall's gone".
It was right over the bed, you know, coming over the bed, and the clothes were floating then

WOMAN'S VOICE 2 We got out into the garden. So he put me on the chicken … on the shed, with the baby.

WOMAN'S VOICE 1: Freezing! Cos that was the worst thing – it was so cold.
My uncle was in the other room and he got up and he carried us on to the kitchen table. We stayed there all night.

(Footsteps wading through water)

(Wind howling)

(Splashes and muffled underwater sounds)

(Background sound of water flowing)

WOMAN'S VOICE 2 His mum was calling for help…dragged her along to the chicken shed. She couldn't get on it because she was twenty-two stone. So she just stood there in the water and I stood there holding the baby and holding her hand.
Some neighbours were up in the loft just at the back of us, so he said I'll go up, try to get up there and see if I can get a blanket. To cover the baby up, 'cos we had no clothes on at the time we struggled out of the house, with all the furniture floating about. She didn't give us a blanket. And he came back again and he couldn't speak any more – he had lockjaw.

All of a sudden I heard a terrible …

(Sudden loud splash)

(Muffled underwater sounds)

WOMAN'S VOICE 2 Me mother-in-law went first.
She let go of me hand and she was gone. Floated away like.

(Water gurgling)

Then I heard a terrible scream and when I looked round me husband was gone.

(Sounds of water lapping)

We went to Rochford hospital.
I didn't know at the time but my baby died as got in the gate. But I didn't know. They didn't tell me that till afterwards.

(Wind howling)

MAN'S VOICE 1

1953 BROADCAST: Unfortunately, many people had no time to escape the rising waters.

Some were drowned, some died of exposure in the bitterly cold wind.

(Wind howling)

END.

<u>AUDIO COMPOSITION 2</u> (I minute 7 seconds)

- A mix of archival recordings, report-based re-enactment and sound FX

(Background sound of sea)

GEOGRAPHER'S VOICE: (in style of 1953 recording)

I surveyed the damage. By nine o'clock the Sunday morning the thirty-foot high cliff near Lowestoft had been cut back thirty feet. At another point where the cliff is seven feet high, it had been cut back by eighty-six feet.
The beaches were stripped of their sand, and in a few cases, the material was thrown inland.

We heard later, 160 thousand acres of agricultural land flooded. It will take years to recover from the inundation of salty water.

(Church bell starts to toll solemnly)

It was unprecedented. Over one thousand two hundred breaches of sea defences, thirty-two thousand people were evacuated, twenty-four thousand properties were damaged, forty-six thousand lifestock were killed and three hundred and seven people had lost their lives.

(Church bell continues to toll)

MAN'S VOICE 1

1953 BROADCASTER: Even though the waters had now returned to the sea, much still remains to be done and many months are needed to ensure that a similar catastrophe shall not occur again.

(Church tolls and fades to silence)

END

<u>AUDIO COMPOSITION 3</u> (2 mins 9 seconds)

A mix of oral history recording and sound FX

(Sound of streaming water in background)

WOMAN'S VOICE:

My first experience of any flood, quite honestly, any serious flood was Mike waking my up in absolute, sheer panic, saying "There's a problem, there's a problem".

It was totally dark outside. You couldn't see anything. We weren't aware … it felt like we were … completely isolated.

MAN'S VOICE: The water was going across the front room floor. It was a muddy, dirty, horrible brown colour, cold. It was still pitch black outside so we couldn't see a great deal outside.

WOMAN'S VOICE: It was scary. It was frightening. Once it grew light and we could see outside, we realised it was a major flood and everyone else was going to be in the same situation.
We had a laminate floor at the time and I remember watching the island of dry in the middle of the laminate floor getting smaller and smaller, as the water rose.

MAN'S VOICE: The two bins were up by the front wall floating in the water.

WOMAN'S VOICE: I remember the paint tray floating.
There were other things that were floating. My swimming costume, I think, was floating over by the back door, because it had just come through the wash and it was ready to be put away again for next week.
All of the plants were … submerged. There was very little to see. There was just this great area of muddy brown water. And when you walked in it, you made waves and made it higher.

I was also aware it was completely beyond my control. There was nothing I could do about it. I couldn't stop it. I couldn't make it go away. I just had to deal with it the best I could.

(Water continues streaming. FADE)
END

AUDIO COMPOSITION 4

- Sound FX and own text

(Background sounds of gurgling and lapping water; Wind)

WOMAN'S VOICE 1

The margins are being squeezed.
If only the warning had been passed on
The people down the coast wouldn't have drowned.

The tide is rising
And the margins are being squeezed.
Where the land and sea meet
The constructed and the natural

WOMAN'S VOICE 2 The soft channels of mud look like branches of
Trees from the air, or arteries.
They look like arteries, exposed as the tide runs out.
Or is it running in, filling with briny lifestream?

(Wind howls)

When I was sixteen I thought I could walk across.
We negotiated our journey around a maze of ditches.
We realised we were in trouble as the mud became slimier
And the trenches deeper. The tide had turned and we had to re-trace our steps.

WOMAN'S VOICES 1 and 2

Will we be able to turn back this time?

WOMAN'S VOICE 1 Why didn't they sound the alarm?
Cracks are appearing
The old defences are crumbling.
The old ways won't work anymore.
They need to be replaced.
The margins protect us.

AUDIO COMPOSITION 5

- Sound FX and own text

(Background sound of heavy persistent rain with occasional rumbles of thunder)

WOMAN REPORTER We are precipitous as a species
Always moving onwards
Rushing headlong
Making our progress
Into the future.
The weathergirl says that the precipitation
Was unprecedented, since records began.
Even parts of London are submerged.

Sources:

The 1953 East Coast Floods - Facts and Figures (2003) BBC webpage (29 January). Available at: https://www.bbc.co.uk/suffolk/dont_miss/floods/facts_figs/1953_facts.shtml

'1953 Floods' (2017) *Savage Planet* episode, Available at: https://www.youtube.com/watch?v=mXL_FK8JpGA

Essex Floods (1953), BBC Essex Television broadcast. Digitised by Essex Educational Video Unit. Available at: Essex Records Office Sound and Video Archive Ref. Essex Floods (VA 3/8/4/1)

Interview with June Webb (*7 Feb*2013) Available at: Essex Records Office Sound and Video Archive Ref. SA49/1/2/23/1

Interview with Vicky and Mike Craven-Smith about 23.12.20 River Waveney flood. (Own audio recording).

Oral history recording of Peggy Champion. Available at: Essex Records Office Sound and Video Archive Ref. SA 6/306/1

Precipitation and *The margins are being squeezed*. (Own texts).

Report to the Royal Geographical Society by Mr W. W. Williams in Wordie, J.M., Waverley, Lord, Brunt, D., and Williams, W. W. (1953). 'The East Coast Floods: Discussion', *The Geographical Journal*, 119(3), pp. 295-298. Accessed: https://doi.org/10.2307/1790641

Tide on Tide (1988) BBC Essex Television broadcast. Available at: Essex Records Office Sound and Video Archive, Ref. SA 1/313/1

Samples used for audio in *She's Got the Wrong End of the Stick*…taken from one side of conversations handwritten by different people in my mother's notebooks

- At Nelson Mandela's funeral, the man doing the sign language for the deaf was making it up!
- She had a difficult relationship with her mother who never got over losing her son when he was two and a half years old. Pneumonia, but made her mother very strange.
- A trampolinist I worked with landed on her face on the trampoline and got her nose caught in the webbing.
- We are going to meet at the bottom. There will be pickpockets.
- He fed his cats when you were in the car chatting. He said the cats would know when he was there and would come. I was a bit sceptical, but Ginger the cat ran down the road to meet him!
- He was deafened by gunfire in Greece.
- Harry was very naughty yesterday and stole a chocolate roulade and ate it and was sick!!
- I have been playing a game over the Internet with one of my friends from Oxford. The game is basically American football (a bit like rugby), but with Elves, Orcs, Vampires and other monsters. Not your sort of thing perhaps but very entertaining for me.
- I've got 'clergyman's knees!! Inflamed and swollen badly! 2 bursitis on each knee, so clergyman's knees. If one bursitis on a knee, it would be housemaid's knee.
- Near, there is a large clay-pit that has been used for bricks and tiles, but the clay has run out. So they are knocking down the factory buildings so that they can build about 500 new houses in and around the pit.
- I like to see Kenny and his pony and trap going through the village
- What is heaven like?
- Not furs, modern fabrics for keeping warm. One night we camped outside under the stars…. No we had lots of clothes and sleeping bags. We made windbreaks out of snow breaks. Camping outside is a unique opportunity. Very few people have ever done it. The trip was organised for students who are working on climate change. The trip was funded by BP. But our trip was led by a polar explorer.
- When do you go?... Well my husband is still doing the pea harvest. They should finish end of August so we may have time off in September.

- God has a purpose. When he lived in Switzerland, God laid it on his heart ‘I want you to feed people’s hearts, not their stomachs’. He was a waiter at the time.
- You tell me what I am saying, watch me. You clever, me stupid. I take some children to school who are deaf… I just know basic.
- The call was completely muffled … From the parks near Nepal….In my school they used to keep a tally of how many people fell over during assembly. The record was seven… I will be food shopping very early, 8.15, then we can pick some blackberries next door at the farm.
- His friend is a bit vague and ended up wandering into a firing range in Canada.

4 Feedback from *When We Touch Again* project and pop-up exhibition

When We Touch Again questionnaire

*Thanks for taking part in the **When We Touch Again*** project.

I would be very grateful if you could give me some feedback to help with evaluating what everyone got out of it and to help planning similar projects in the future.

As a project taking place during Covid-19:

Are there any ways it has enabled you to reflect on the effects of the pandemic? (Please give some details)

……

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……

On the theme of Touch? (Please give some details)

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Are there any ways the project has benefitted your wellbeing, socially or emotionally?

……

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Some things you have learnt technically:

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……..

Some things you have learnt artistically:

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……..

Are there any aspects of the project you are interested in developing further? Please share your thoughts if you like?

……

……

……

Any comments about the project process?

About the meetings on Zoom:

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About meeting physically

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Any feedback about how the project was led?

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Any suggestions for improvement?

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……..

……..

Any other comments?

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…….

Please return to lizwaugh@btinternet.com

When We Touch Again questionnaire responses from project participants, 13.07.21

Are there any ways the When We Touch Again project enabled you to reflect on the effects of the pandemic?

K.: *It reminded me that I live in a relatively isolated life anyway. It's just me and my husband; we have cats, no kids. We didn't experience the intense loss of close contact in the same way many others did, or as keenly.*

F.: *It made me think about the planet and the human effect on the planet with a 'wide angle lens' – nothing has ever, or in a long time- really affected humankind so simultaneously or made us consider our frailty and ubiquity.*

P.: *I had already been thinking about the effects on family life, and the project has given me the chance to think further on the effects on my family – and to share their feelings - We have talked a lot about the things we are grateful for.*

Are there any ways the When We Touch Again project enabled you to reflect on the theme of Touch?

K.: *The theme got me looking into the concept of touch and the language around it (my artistic interests lie around words and lettering.*

F.: *Again, the project got me thinking on a large scale on aspects of touch through the lens of human touch on earth, and on touch through time.*

P.: *Much of my artwork is tactile, designed to be handled. It has been interesting designing a piece where proximity, not touch, is important. I have been thinking about my time in Sunderland, when touching materials I work with has replaced human touch.*

Are there anyways the project has benefitted your wellbeing, socially or emotionally?
K.: *It gave me a welcome target for creativity and a chance to be around like-minded people. I study at Uni partly for the social aspect, which has been somewhat lacking because of Covid. So thanks for the booster.*

F.: *Socially – it's been really great to meet and work with new people on a project*
Socially and emotionally – I've not worked in a group since before the pandemic so it's been a helpful bridge back to working together.

P.: *As above, we have all talked a lot about the effects of lockdown, both positive and negative, and the joy of being reunited.*

Some things you have learnt technically?
K.: *The touch board programming was fun, if occasionally frustrating. It opens up a lot of new possibilities.*

F.:

- *Working with the Arduino interface*
- *Working with the touch board*
- *Working with electric paint, graphene ink, electro-conductive thread*

P.: *Starting almost from scratch working with sound files and i-phone recording; I feel I know much more about the IT elements of the project.*

Some things you have learnt artistically?
K.: *I need more practice painting on glass*

F.:*Starting to understand how to incorporate sound into work, trying to see work as not just a visual or spatial medium, but also aural. Another reminder of testing, testing, testing being an important stage.*

P.: *The difficulty of creating an object which is aesthetic, tactile, but also has to work technically. In the end, getting it to function has over-ridden the aesthetic, so this is something to consider for version 2.*

Are there any aspects of the project you are interested in developing further? Please share your thoughts.

K.: *I'd like to use a touch board with a stained glass panel, specifically to link to a Northumberland ballad I reference in a project 'The Laily Work and the Mackrel of the Sea'*

F.: *I'm going to consider incorporating sound into my work. Also I'm interested in other ways electro-magnetic stimuli/switches could be triggered*

P.*: By September, my plan is to recreate the glass moulded object so it fits better with the technical requirements. (Longer term, I hope to make a talking leaded window).*

Any comments about the project process?

About the meetings on Zoom?

K.: *Perhaps a little more structure and an agenda*

F.: *Worked very well. Maybe have a schedule of what each meeting's going to be about?*

P.*: Always better to meet in person, more sociable and easier to ask questions – but Liz managed the meetings very well, especially given the varied technical/IT levels of the participants, and gave me the extra help I needed. These meetings did save on travel and fitted better with the rest of life.*

About meeting physically?

K.: *Lovely, much better than Zoom*

F.: *All worked well. Enjoyed the pop-up and it was great to have the early feedback from other people.*

P.*: Very useful to meet in real life, on the principle of 'show, don't tell'. Liz has helped me through a lot of glitches as have the other participants. If we had met sooner in person I*

could have seen how complex other people's responses were to the brief and made mine more complex.

Thanks so much for organizing it and all the hard work you've put in. It's quite complicated and hard to get people working together. You've done well.

Any feedback about how the project was led? (K's questionnaire was returned with p.3 missing).
F.: *Liz has a great collaborative style of leading the project which I think allowed everyone to develop the brief around their own interests.*

P.: *It had an open quality about it which I liked, which has led to 3 very varied responses. Liz has given us plenty of instruction and help, although I don't think she realised at first what a steep learning curve I was on.*

Any suggestions for improvement?
F.: *I think a small test piece like Kathleen did is a good way of getting to grips with the materials and tech – maybe could incorporate into the schedule?*

P.*: After Covid, practical demonstrations would be very helpful.*
It would be helpful, especially when working with adults, to find out their levels of IT skills at the start.

Any other comments?
F.: *Really enjoyed the process and the project, got me thinking in new ways – looking forward to the 'performance' later in the year!*

P.*: It will be good to get feedback on how the pieces work, and other people's responses to them. I plan to improve mine over the Summer ready for another audience. I have really enjoyed working with the other participants.*

Thanks, Liz for the opportunity to learn a pile of new skills. It has been stressful but rewarding.

Feedback from the private view of the pop up 5.10.21

(recorded directly after the event)

Questions given to the participants beforehand to elicit visitor response to the exhibits:

Did they listen to the audio or just 'hear' it?

Was the work meaningful for them?

Were they engaged by the interactive element?

Does combining glass art with audio give another dimension to the meaning and references it has? How?

L. One young woman was very touched by *Bin Bag Hug*. She said she was moved because it brought back memories of having to say goodbye over Zoom to her grandfather who was dying.

Visitor J. joked the artwork was 'witchcraft'! *[which reminds me of the quote that we think any technology we don't understand is magic]*

P. Similarly a conversation started over 'Reconnecting' with a visitor whose granddaughter was born during lockdown, so they were able to share experiences.

K. felt validated when talking with someone about her *Fee Fi Fo Fum* piece which was lighthearted and joke-y. The visitor told her it was equally valid to make a piece which brought a smile to the viewer's face.

F. was concerned whether people would take time to engage with her longer spoken narratives about Touch over time, but was pleasantly surprised that people did listen to and appreciate the audio associated with the three flasks. People did not think the 'touch to listen' was of novelty value or gimmicky, but a way of engaging viewers in the narrative.

Email (02.11.21) from K.:

Feedback from a student [visiting the exhibition]: "This is such a good idea. It really opens up the possibilities of storytelling." She was especially interested in having an artwork 'speak' as you approached it.

Feedback from me [K.] about participating: I wasn't sure what to expect. It was a little bit scary at first, with so many different things to get my head around and consider. There was a lot of technical 'process' to learn: getting audio onto the SD card, getting the speakers working, choosing the program, getting the program onto the card and so on. Actually getting the artwork connected and working with the card could be a bit frustrating. But once the technology was tamed, the experience became quite enjoyable. The reactions of the audience was very satisfying. It may have helped that one of my pieces was a joke. One viewer said, "getting people to laugh is no bad thing". So from that alone, I've taken away a new perspective on participatory art, ie., it doesn't have to be dead serious. Thanks so much for letting me take part.