Gameful IoT Repair

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ABSTRACT

Electronic Waste (e-waste) is the fastest growing waste stream worldwide, and the proliferation of Internet of Things (IoT) devices is greatly accelerating e-waste production. IoT devices are often designed to limit repairability and shorten lifespans, resulting in products rendered prematurely obsolete. Additionally, guidance that should inform consumers how to responsibly manage a products end-of-life is severely lacking, leading to improper disposal and further environmental harm. This paper argues that challenging these harmful cycles requires citizens and communities to have better access to knowledge and practical skills - which are essential to successfully embrace a culture of repair and reuse towards a wider sustainability transition. This paper presents two Serious Games - *Re:Play* and *RepairLand* – interactive experiences aiming to engage and educate. Applying Research-through-Design and Speculative Design approaches, this paper presents our design decisions and critical reflections that shaped the development of these games.

Keywords

Serious Games, Research-through-Design, Internet of Things, Speculative Design, Sustainability

1 INTRODUCTION

This paper introduces two Serious Games (Abt, 1970) - *Re:Play* and *RepairLand* - produced as part of the EPSRC *Fixing the Future: The Right to Repair and Equal-IoT* project. *Fixing the Future* is investigating how the lack of repairability and longevity in the consumer Internet of Things (IoT) will adversely impact equity, inclusion, and sustainability in the digital economy. *RepairLand* is a *choose-your-own-adventure* style videogame that allows players to speculatively explore and make decisions about the future of a fictional broken IoT device called *PetTap.* This interactive game is designed to raise awareness of critical issues affecting the *Right-to-Repair* of so called 'smart' Internet of Things (IoT) devices, as well as exploring the barriers and opportunities to

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repair from the consumer's perspective. *Re:Play* is an educational toolkit that engages players in repair practice by presenting them with a broken hand-held console. As users craft, care and personalise *Re:Play*, it fosters *emotional durability* (Haines-Gadd et al., 2018) for the device, and emphasises learning to repair through play. This paper explores the process of creating our ludic experiences using *Research through Design* (RtD) (Frayling, 1994; Gaver, 2012) and *Speculative Design* (Auger, 2013) approaches. We contend our two gameful experiences can help raise public awareness of technology related environmental issues, as well as help to develop the critical IoT repair skills that communities urgently need.

2 AN INTERNET OF WASTEFUL THINGS

Electronic Waste (e-waste) is the fastest growing waste stream in the world (Smieja, 2023). In 2019 alone, the world generated 53.6 million tonnes (Mt) of e-waste, a figure expected to reach 75Mt by 2030. The UK is currently the second largest contributor to global e-waste per capita (Dennis, 2023). By 2030 it is estimated that there will be over 29 billion physical IoT devices in use worldwide (Vailshery, 2025). *Smart* versions of devices such as toasters, fridges, thermostats, washing machines, doorbells and speakers have swiftly replaced their *dumb* predecessors in households globally.

While criticism has largely focused on the security and privacy issues they pose (i.e. data harvesting), less attention has been directed towards their environmental impact. However, as Stead and Coulton (2022b) argue, these seemingly innocuous devices have harmful practices embedded into all stages of their lifecycle - *from design, to operational use, and disposal* - that threaten environmental sustainability.

Practices, such as *planned obsolescence* (Zallio & Berry, 2017) manipulate a product's lifespan through its design, materiality, stylishness (Packard, 1963), cost (Hadhazy, 2016), and warranty and repair terms (Pocock et al., 2017). These strategies cultivate harmful consumer practices, that engender frivolous buying patterns - actively discourage repair (Cooper & Salvia, 2018) and accelerating waste production.

Relatedly, *bricking* - where software failures render functional hardware inoperable (Gastón, 2016) - also sees products become prematurely obsolete (Stead & Coulton, 2022a). This can result from externalities, such as hacking and cyberattacks (Mukhtar et al., 2023), but often this is deliberate (Alzaydi, 2024) i.e. companies withdrawing software support to drive new purchases (Hern, 2016), or is a consequence of poorly designed products that fail to futureproof against inevitable incompatibilities as technology advances.

The responsibility for the ongoing care and maintenance of an IoT product, is also becoming increasingly problematic. Many companies consciously plan not to provide long term support for their products, with the advertised product lifespan versus the guaranteed support service for a product varying significantly. A 2022 survey conducted by *Which?* (the UK consumer policy body) that investigated policies from popular brand smart devices, including TVs, dishwashers, washing machines, smartphones, and fitness trackers found that hardly any brands were offering to match their smart service support policies to the product's expected lifespan

(McCallum, 2023). Many companies questioned by *Which?* stated that their support policies adhere to existing UK laws, and implied that this was the limit of their responsibility. This highlights a systemic issue within the UK (and beyond), that the law regulating manufacturers and distributors is ineffective at ensuring accountability (Laughlin, 2023) for product sustainability, as well as failing to encourage innovation towards new sustainable business models that might change the current culture of harmful manufacturing and retail practices.

End-of-life management of IoT devices is similarly problematic. Effective waste management relies on the prudent consumers to responsibly dispose of their products (Islam et al., 2021). Many consumers are ill-equipped to accept this burden of responsibility, lacking the basic enablers – *i.e knowledge, time and resources, or support from product manufacturers* – that would facilitate success. Manufacturers could improve the support they offer consumers, as many products are routinely sold without clear instructions for appropriate disposal, so valuable materials are lost (Midgley, 2024). Even *if* responsibly disposed of, IoT products are difficult to disassemble and their hazardous and non-biodegradable components make disposal, recycling and reuse complicated (Shevchenko et al., 2019). Gale (2023) argues a more sustainable mantra is "reduce, reuse, recycle (in that order)", which requires a move away from prioritizing *end of life* i.e. overpromoting recycling or blaming consumers, towards *inception* - designing products that create minimal waste and increasing the responsibility of those responsible for their creation.

3 THE RIGHT TO REPAIR

In 2021, the UK introduced the *Right to Repair* (R2R) legislation formally known as the *Ecodesign for Energy-Related Products and Energy Information Regulations*. This followed similar laws in the EU, such as the Circular Economy Action Plan introduced by the European Union in 2020 (Urquhart et al., 2024). The UK R2R law states that the "regulations aim to increase producer responsibility, reduce energy usage and electrical waste, and enable consumers to identify the most energy efficient products on the market" (Conway, 2021). It stipulates that manufacturers need to provide repair information and spare parts for certain household appliances like dishwashers and washing machines. However, these rules do not apply to IoT devices. As a result, manufacturers of these products face no legal obligation to make their products repairable; an issue that's increasingly urgent due to the prevalence of smart devices in our homes.

Compounding the problem, public awareness of R2R laws is low, and available guidance is often hard to access and full of legal jargon. At the Bluedot Festival (UK) (https://www.discoverthebluedot.com/) in 2023, we engaged members of the public in an activity called *Right to Repair Bingo*, entailing players to identify types of smart products they owned and which of those products they thought were covered by the R2R law. Most had not heard of the R2R law, and on proving this information many assumed it would be applicable to all their smart home devices. This indicates that public education about the R2R law and consumer rights needs to be improved, such as how existing information is communicated.

Schools could play a role in this, but it would require updating the curriculum. Traditionally, subjects like *Design and Technology* were responsible for developing the kinds of practical skills and knowledge associated with repair. However, the current UK Design and Technology curriculum focuses on designing new products rather than repairing existing ones, and upon reviewing the specifications written by the UK's main exam boards "*repair"* is barely mentioned. The UK's curriculum reforms in 2015, saw a shift towards theory, exam performance, and STEM content, and a reduction in practical, hands-on skills development. This skills deficit is becoming increasingly visible.

Certain foundational skills are often assumed to be *innately* or *socially* acquired, so are no longer explicitly taught, leading to a gradual loss of once-common abilities. For example, clothing repair (Meacham & McAndrews, 2016) and car maintenance (Howe, 2014) were common skills for *Baby Boomers* (born 1946-1964) but comparatively lacking in *Millennials* (born 1980-1994), or many *Millennials* who studied *Key Skills Information Technology (one subject in the compulsory Key Skills 2000 UK curriculum)* (Davidson-Sofair, 2008) to develop essential desktop computer based skills (i.e. touch typing, sending emails), have largely been lost by subsequent generations due the rise of touch technology, changes to compulsory education, and assumptions about their *digital nativity* (Zhao & Zhao, 2021) – growing up with access to technologies ensures proficiency using them.

This generational loss of core skills results in students who are ill- equipped to attempt repair, and more likely to discard products (Norum, 2013). If schools aren't teaching these skills, other approaches are needed. *Re:Play* and *RepairLand* were developed in response to this deficit.

4 SERIOUS GAMES

RepairLand and *Re:Play* are Serious Games that aim to foster a stronger culture of repair for smart devices. While *RepairLand* raises awareness about repair law and the challenges of repairing IoT devices, *Re:Play* builds players' practical repair skills through hands-on engagement.

Abt (1970) defined that the primary function of a Serious Games is to educate and is secondary to entertainment. Abt's definition seeks to delineate Serious Games from generalisations about a videogames purpose, i.e. Serious Games are designed to educate, to train, to address, to change, rather than just for fun. However, many feel that entertainment or fun are highly important within Serious Game design to facilitating learning. For example, Bogost (2011) situates videogames as a pervasive medium; their power is rooted in their ability to entertain *whilst* educating; and Rebah (2019) describes that it is videogames inherent playfulness or "playful springs" - *the want to win, collaboration, competition, strategy* (Rebah, 2019) – that initiates engagement and sustains motivation (De Jans et al., 2017).

There are many examples of Serious Games with clear educational goals; for example, *Litcraft* leveraged the popularity of *Minecraft* to bring literary texts to life for young readers (https://www.lancaster.ac.uk/litcraft/). Using a familiar cultural practice helped to increase their relevance of the Serious Game to players. In addition to educational purposes, the tools, techniques and practices fundamental to videogame

design, are being increasingly utilised by those interested in creating social change (Antle et al., 2014; De Freitas & Liarokapis, 2011; Djaouti et al., 2011), such as promoting a variety of prosocial goals, including humanitarian efforts i.e. *Peacemaker* (Swain, 2007) and *Endgame Syria* (Dredge, 2013); citizenship i.e. *Active Citizen* (Games for Change n.d.); understanding difference i.e. *Poverty Is Not a Game* (Van Looy et al., 2010) and *Depression Quest* (Parkin, 2014); self-improvement i.e. *A Little to the Left* (Stewart, 2022) and *The Witch's Way* (Rusch & Phelps, 2021); and sustainability i.e. *Fate of the World: Tipping Point* (Makai, 2024).

Sustainability has become a common theme across both mainstream and independent games. Simulation games like *SimCity*, *Wood of War* and *Cities: Skylines* embed environmental management challenges into gameplay (Papamichael et al., 2022). Indie titles such as *We Energy Game* (Ouariachi et al., 2018), *World Without Oil* (Games for Games for Cities 2007), *Working with Water* (Chaos Theory Chaos Theory Games n.d.), and *EVIDENT* (Delemere & Liston, 2024) cast a more serious lens on these issues, presenting players with speculative scenarios to promote systems thinking and sustainable behaviour.

Within this growing field, several games specifically tackle sustainability challenges tied to technology. *Edge of Tomorrow* tasks players to explore the environmental effects caused by their data footprints (Stead et al., 2022), while *Future Mundane* immerses players in the invisible effects of smart device usage (Pilling et al., 2022). Following this, *RepairLand* and *Re:Play* use a variety of *playful springs* to engage players to learn about e-waste and Right-to-Repair issues.

5 DESIGN RESEARCH FOR SERIOUS GAMES

Our two Serious Games were developed using a *Research through Design* (RtD) approach (Hook & Coulton, 2017). Grounded in a constructionist perspective(Rodriguez Ramirez, 2009), RtD provides us with a methodology to generate new knowledge through a combination of tacit, design-led making and critical reflection. Researcher-practitioners can undertake RtD to create prototypes that help them to better consider the complexities of engaging with different materials and technologies, as well as understand the act of designing itself (Findeli, 2004). *RepairLand* and *Re:Play's* facilitation of dialogues regarding IoT repairability amongst audiences in conjunction with the in-depth reflection stimulated within the design research team is fundamental to RtD practice (Larjosto, 2019). Further, our approach allows the exploration of repair futures for IoT products and services without being encumbered by *what it is* but instead inquiring *what could be* (Zimmerman & Forlizzi, 2014) in relation to future repair cultures. Our speculative and forward-looking design practice also allowed us to explore what repair futures could be, rather than being limited to current realities (Zimmerman & Forlizzi, 2014). This type of exploration is especially relevant given the urgent sustainability challenges posed by ubiquitous digital technologies (Sharma et al., 2023).

5.1 Research Design

To initiate this research, we conducted a series of participatory workshops:

- **Series 1** invited six professionals working in waste recycling and recovery, technology design, local government, technology refurbishment, and social enterprise.
- **Series 2** invited four participants from gaming research, game development, and fan fiction communities.
- **Series 3** invited eight members of international *FabLabs* and Maker Spaces across the UK and Europe.

Workshops 1 and 2 were conducted online via Miro (www.miro.com) and Workshop 3 was in-person. Data from all sessions were thematically analysed (Braun & Clarke, 2022), with key themes emerging (Naeem et al., 2023) around *Equity and Agency*, *Planned Obsolescence*, *Governance and Policy*, *Solutionism and Greenwashing*, and *Corporate Responsibility*. However, the most consistent cross-cutting themes were Knowledge, Skills, Education, and Training. Participants highlighted:

- A widespread lack of repair skills and insufficient government support.
- Limited public awareness of Right to Repair legislation.
- A need for community repair initiatives to develop knowledge, skills education and training about repair.
- A need for accredited training and opportunities for professional education i.e. apprenticeships.
- More support for small / local business to act more sustainably.
- Consumer experiences of legal and knowledge barriers to self-repair (e.g., warranty issues).
- The harmful nature of current manufacturing and consumption cycles.
- Existing grassroots repair cultures i.e. modding in gaming.
- Potential for open-source software to support repair, especially for bricked devices.

In workshop 2, participants explored the relationships they have with their gaming devices, reflecting on the *emotional durability* (Haines-Gadd et al., 2018) of their devices, how they have cared for and preserved their old consoles, and their motivation for defying conventional consumer patterns. These insights directly inspired our games. We developed *Re:Play* as a tool kit designed to engage and motivate through play, while also fostering emotional investment. *RepairLand* was designed to provide a reflective, narrative-driven space that guides players to explore the environmental impacts of their decisions and highlight consumer repair rights. **Figure 1** provides an overview of our Research through Design process, illustrating our iterative approach for developing both games, guided by user feedback from workshops and public events.

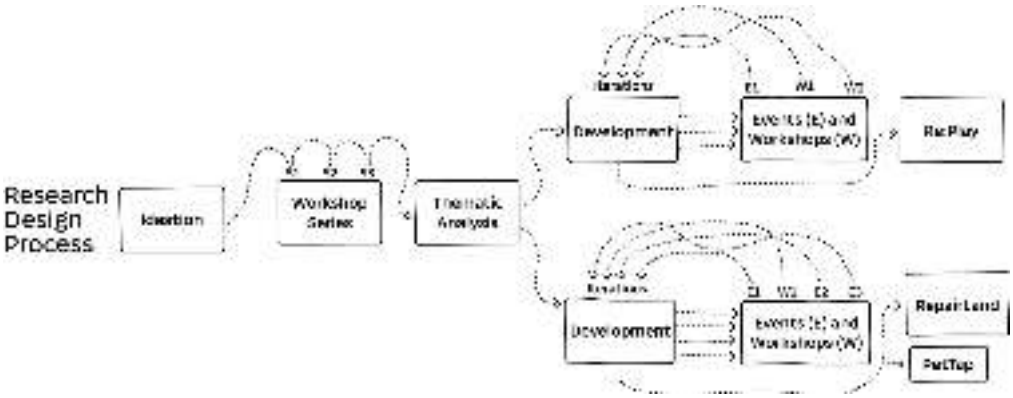

Figure 1: Diagram Outlining our Research through Design Process.

6 RE:PLAY

Re:Play is a kit that guides players learn how to repair, upgrade and customise a purpose-built handheld console. *Re:Play* was codesigned (Sanders & Stappers, 2008) with, and manufactured by, *The Making Rooms*, a community makerspace in Blackburn, UK as part of AHRC *GenerationFix,* an ancillary project to EPSRC *Fixing the Future: the right to repair and equal IoT.*

Re:Play is strategically broken, challenging players to restore its functionality. It was designed to inspire curiosity about repair practice and to build the confidence and skills needed to approach repair activities independently. Game levels are presented as repair challenges. As the player completes more levels, and fixes *Re:Play*, they are awarded with additional functionality with corresponding games. This serves two purposes. First, this process is a type of tutorial, where the gameplay (in this case repair activities) trains the player about how the game works. Embedding learning tutorials within gameplay activities, is commonly used tactic in videogames, (Boller & Kapp, 2017). Second, structuring gameplay using levels encourages progression. The initial repairs are very simple and quickly reward the player with limited functionality, allowing them to play very simple games (i.e. the perpetual running game *Flappy Birds* which only requires a single functional button). These early rewards help maintain motivation when the learning curve is steep. As players progress to more complex repairs, they unlock further functionality and game types.

This mirrors traditional game design, where access is limited to game components i.e. world areas, and completion/progression of tutorials, missions or bounties unlocks new features, abilities and content (Boller & Kapp, 2017; White, 2014). Beyond satisfying completionist whims, rewarding players also helps them to see they are making progress (Green et al., 2021). As players successfully complete repairs, *Re:Play* displays a code which they submit to a website, generating a cypher to unlock next level. These levelling-up mechanics encourage reflection, as well as generating a sense of achievement and trajectory, which supports continued engagement (Bycer, 2014).

The repair activities are scaffolded (Sun et al., 2018), ranging from supportive initial tasks involving basic maintenance - e.g., locating and replacing the battery - building to more complex tasks – e.g. replacing a missing button – which require players to apply knowledge, make judgements, and assess outcomes. These open-ended repairs

can be solved in multiple ways, encouraging playfulness and creativity through experimenting with different methods and materials. As difficulty increases, so does the need for decision-making, which fosters player agency, as players define their own standards for success, rather than completing bounded tasks.

There are other existing games and kits designed to teach repair skills, such as *Mobile Phone Fixing Store*, *Repair Master 3D*, and *Team Repair's* physical kits. However, these often focus on completing specific repair tasks, which they don't encourage the open-ended exploration and experimentation *(play)* that is well recognised as valuable for developing and embedded new skills (Crichton et al., 2020). Beyond these initiatives, opportunities for children to explore technology – such as learning through opening and dismantling them – are becoming increasingly rare (Woolcock, 2024). Many modern devices discourage attempts to dismantle and repair through their design i.e. by using glued-shut casings. While this is often justified for safety, waterproofing, or aesthetics (Greenlee, 2022), it also reduces manufacturing costs (i.e. less materials, less component space, faster to produce etc). Consequently, as more devices are designed this way, children have fewer opportunities to see inside technology, and generationally repair skills are decreasing (Lally et al., 2018; Lundberg et al., 2024). Even curious users are discouraged, as opening devices risks damage or voiding warranties. This limits the confidence needed to attempt the simplest of repairs tasks like changing batteries; Korsunova et al. (2023) notes that lacking confidence is a key barrier to attempting repair.

The *Re:Play* kit contains all the equipment and materials users are likely to need to diagnose and repair the device *Re:Play*, i.e. spare components, *Sugru*, a multimeter etc. It also encourages learning about each tool's function and appropriate use. **Figure 2** shows a prototype of *Re:Play* showcased at the Festival of Futures (https://www.lancaster.ac.uk/fof2024/) in March 2024.

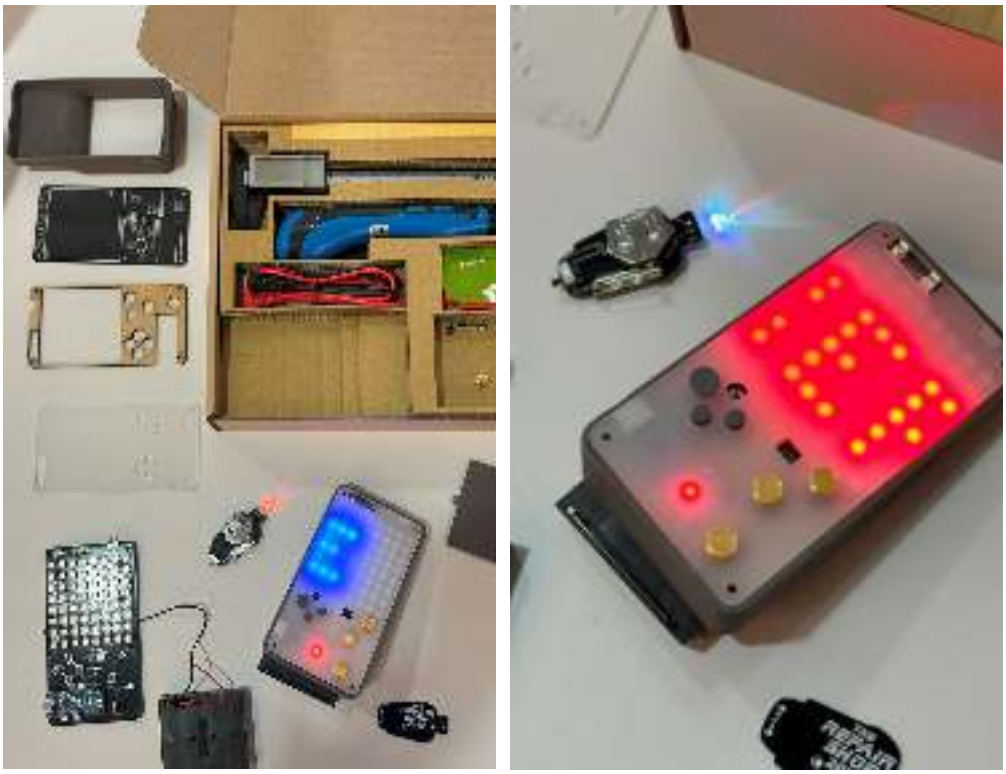

Figure 2: *Re:Play* prototype v1 as featured in the Festival of Futures, Lancaster, UK.

Participatory Workshops

As part of our RtD process, we engaged members of the public in workshops and at public events to inform the continued development of the console. The following details the participatory workshops.

Workshop 1. In May 2024, we ran a workshop at the Northern Design Festival 2024 (https://northerndesignfestival.co.uk/). Participants included university students, researchers, and members of the public, all aged 18 and above (see **Figure 3**), the workshop was open to the public as part of the festival and participants signed up voluntarily. We gave each participant a *Re:Play* kit (which contained the console, tools and materials) to inspect. From this workshop, we were interested in understanding what participants thought of the concept, what else they thought the kit might need (i.e. regarding materials and equipment), and how the current design of gameplay could support engagement in learning how to repair.

Figure 3: Participants at the *Re:Play* workshop at the Northern Design Festival 2024, Lancaster, UK.

Workshop 2. In June 2024, during the Festival of Making 2024 (https://festivalofmaking.co.uk/), we ran a participatory *Beta Testing* workshop with 3 participants aged 12-14 hosted the in Blackburn & Darwen Youth Zone, Lancashire (see **Figure 4**). In the workshop, participants were taken through a practical tutorial to test the functionality and process of using *Re:Play*. We asked them to give feedback on its usability, if they were able to follow and understand the instructions, how confident they felt in safely completing the tasks, and to consider what things they would like *Re:Play* to be able to do that it currently does not.

Figure 4: Beta testing workshop at *Blackburn & Darwen Youth Zone*, during the *Festival of Making*, led by Tom Macpherson-Pope from *The Making Rooms*, Blackburn.

A summary of key findings from Workshop 1 and Workshop 2:

- We need to consider the presentation of the instruction manual to accompany *Re:Play*, i.e. using films vs illustrations, particularly to meet different player needs such as dyslexics.
- There should be additional functionalities designed into the device such as being able to program new games, addition of sound and audio etc, that would mean it could be further upgrade.
- There should be additional opportunities for customisation of the device – i.e. create opensource 3D printer files so users can adapt the casing, provide stickers and decals or resources to make them, consider how it could be painted, coloured, using different materials in its layers etc.
- The ergonomic/anthropometrics of *Re:Play* could be improved – i.e. mouldable sections for hand grips, it's quite chunky can it be slimmer, can it fit into a pocket etc.
- The printed circuit board (PCB) could have clearer labelling/imagery that link to the instructions.

The insights gathered from these workshops is now being used to inform the development of *Re:Play* and forms an integral component of the RtD process.

7 REPAIRLAND

RepairLand is an interactive videogame (see **Figure 5**) that uses a *Speculative Design* (Coulton et al., 2017) approach to initiate critical discourse about IoT repair. *Speculative Design* can provide the discursive space for participants to explore opportunities they would not experience in their routine lives. As such, the game becomes a vehicle "through which players can rehearse plausible alternate presents or speculative futures" (Coulton, 2015).

Figure 5: Early concept design rendering of *RepairLand*. It was designed to have a very simple interface to make sure it was accessible for a range of users, as well as mimicking the style of traditional arcade videogames.

RepairLand explores the impact of consumer decisions through a broken IoT device called *PetTap* – a fictional 'smart' pet hydration system (see **Figure 6**). In this *choose-your-own-adventure* style game, players must make decisions about the future of *PetTap* and explore the outcomes of their actions. The game highlights the challenges consumers face when trying to act responsibly, such as navigating product warranties and restricted repair permissions. It also emphasises the often-unseen consequences of these choices—for example, what happens to a device when a consumer opts for a replacement instead of pursuing repair.

Figure 6: PetTap concept design rendering.

RepairLand is created in the online virtual meeting platform, *Gather Town* (https://www.gather.town). The platform enables users to create an avatar of themselves and move around virtual spaces - typically modelled after offices, meeting rooms, or conference venues (Mason et al., 2022). We used Gather Town's functionality, including the ability to import custom backgrounds and objects, to create *RepairLand*, using hand draw illustrations (see **Figure 7**). This illustrative style echoes the visual language of a children's picture book, enhancing its narrative storytelling.

Figure 7: A collection of *RepairLand* illustrations, demonstrating the storytelling aesthetic the game aimed to capture.

As participants enter *RepairLand*, they first complete a series of tutorials to help orientate themselves. Effective tutorials, along with clear wayfinding and visual notations, play a crucial role in supporting player engagement and making play feel effortless (Benvenuti et al., 2023; Darken & Sibert, 1996). *RepairLand* uses a combination of on-screen instructions, interactive objects that glow and *pop-up* notifications to guide and orient players - reminding them how to interact with items or offering gameplay tips. Players can also move between zones by walking onto specific objects i.e. doors (see **Figure 8** for examples of these features).

Figure 8: Left – Example of on-screen instructions. Keyboard arrows are part of the background image at the spawn point, along with instructions to use the arrows to move. There is a dotted line for users to follow, to aid navigation. Middle – Interactable object (gnome) and on-screen prompt/instructions. Gnome glows as you approach it to indicate it is

interactable, and a pop up appears as you approach to tell players to press X to interact with the gnome. Right – Door portal with prompt instructions. The door glows as you approach it to indicate it is interactable, pop up appears as you approach to tell players to walk up to the door to exit/enter a zone.

One of the first tutorial activities in *RepairLand* directs the player to find *PetTap* in the kitchen. Once the player finds *PetTap*, the prompt indicates there is something wrong with it. When the player interacts by pressing X, they are informed that *PetTap* is no longer functioning, and they need to decide what to do with it. The player is provided with a variety of options to explore – *do nothing, discard, repair,* and *self-repair* - which are represented by different objects in and around the home. For example, the leaflet on the coffee table advertises a local Repair Cafe on the Highstreet (see **Figure 9**). *RepairLand* is not designed so that a player can "win or lose", rather, it allows them to explore plausible trajectories when making decisions about a non-functional IoT device. The game simulates many of the frustrations and barriers people face when trying to repair, such as chat bot help lines, having to send items away for unknown periods of time, General Data Protection Regulations (GDPR), cybersecurity policies, serialisation of parts, lack of time to conduct repair, and access to resources. It also explores what the end-of-life possibilities of IoT devices could be, and the unintended and/or hidden consequences of discarding devices.

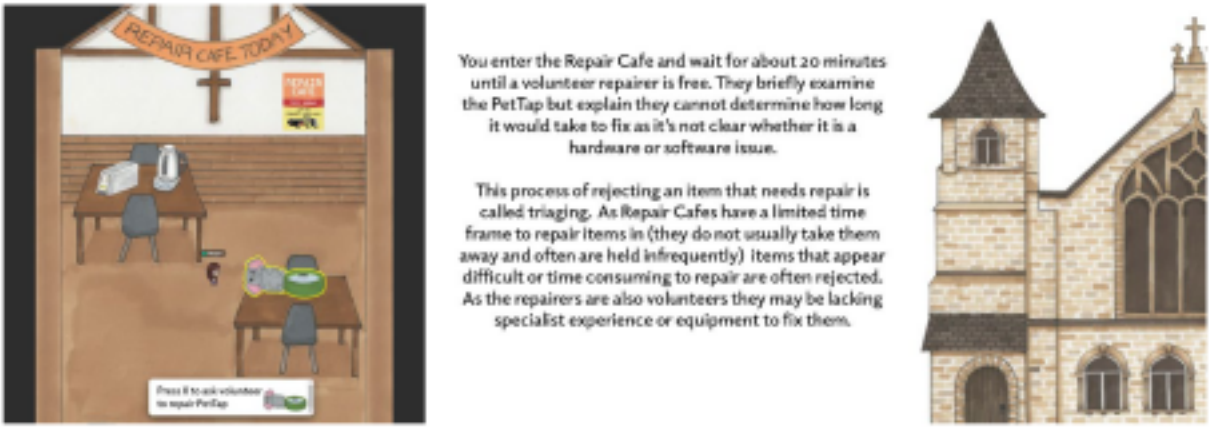

Figure 9: Left – Inside the Repair Cafe in church community centre. Right – Message that's displayed when player attempts to repair *PetTap* in the Repair Cafe.

RepairLand Development

RepairLand has undergone multiple phases of iterations during its development. These iterations have been informed by participant engagement in activities at workshops and public events. The following is a summary of the findings from these engagements.

Event 1 was conducted at the *Festival of Futures 2024*, Lancaster University (https://www.lancaster.ac.uk/fof2024/). Informal feedback was collected about the game through observation and conversation. This was the first time that the complete game had been showcased at a public event. The observations made were used to

ascertain whether players could independently use the game without needing tech support or guidance. It also was used to see if players completed the game or partially completed the game, and roughly how long that took. 10 players were observed and engaged with.

Summary of Key Findings

- Players could use the game independently but did need the "cheat sheets" provided to understand which buttons to press, even with instructions on the screen.
- Players did get stuck as certain points (i.e. how to interact with the car door to teleport to the next zone) so some adjustment to wayfinding is needed.
- The players liked *PetTap*, but the space did not permit to display the advert or the iPad for the *PetTap* app. This limited player's understanding of *PetTap's* purpose and relevance to the game.

Workshop 1 was conducted early in the development of *RepairLand* with seven researchers who specialised in research on sustainability and IoT. Each participant played the game and then answered an evaluation questionnaire (Fowler, 2014). The questions focused both on the player outcomes but also the gameplay and game paraphernalia (i.e. *PetTap*).

Summary of Key Findings

- The game helps to highlight different opportunities for repair that the public may not have considered or heard of before.
    - *"Points of failure like failing to self-repair are a good way of exploring barriers" "I liked references to triage and rejection"*
    - *"It throws light on the different repair options available and the ending showed the implications of my actions".*
- The addition of *PetTap* helps to add a dimension of reality to the game and provide context for play.
    - *"Gives a sense of something tangible and real. Watching an ad before playing the game helps to station the mind/give a context before starting".*
- It accurately represented what happens in practice to many IoT devices.
    - *"Kind of satisfying because I wanted to get it fixed - but this is the real world!"*
- The game could be expanded i.e. to highlight the laws and legislations about repair or include other outcomes.
    - *"Different outcomes based on fault would be good repair cafes could fix a broken cable for example or a Bluetooth connection etc".*
- In general, it was easy to play and navigate, though occasionally books were missed which meant players missed the storyline.
    - *"The game experience was overall well designed and executed"*
    - *"I found it easy to play in navigate but I accidentally ran past the last book before the exit".*
- The game aesthetics were nice.
    - *"Amazingly built aesthetic – with hand drawn illustrations, interactive and no hiccups".*

Event 2 was *the Festival of Making 2024* (https://festivalofmaking.co.uk/). The game was exhibited as part of a series of activities hosted at *The Making Rooms*, Blackburn (See **Figure 10**). After playing the game participants were asked to answer a succinct evaluation questionnaire (Fowler, 2014). The questions focused on the decisions that players made during play, what drove them to make those choices (the game mechanics/it's what they would do in real life/the opposite?), the final outcome from the game (what happened to PetTap), how playing the game made them feel (were they happy with the outcome?), their opinions of the game's efficacy regarding engagement (did the game invite participants in/make them want to keep playing once they'd started?) and awareness (did playing the game help participants to reflect on their own sustainability/raise awareness of issues surrounding IoT sustainability?). Questionnaire responses were collected from 20 participants, aged 18+. 40+ people played the game during the event however, some participants declined to give feedback when asked, (the space was very busy so there was not much room to sit down to write a response), some players were playing the game whilst waiting for their children to finish other nearby activities so left straight away after, and some players were too young to give consent for the evaluation. Some players declined to do the questionnaire but spent time discussing the game experience with us verbally.

Summary of Key Findings from Questionnaire

- Players found the game frustrating to play, many of them wanted to achieve different outcomes than they encountered:
    - *"Annoyed/frustrated. Tried to fix it."*
    - *"I was gutted. I tried hard. I tried not to throw it away. Annoyed it was at the dump not even recycled."*
- Players found the game realistic, and that it resonated with their own experiences when trying to repair:
    - *"Upsettlingly realistic."*
- The game did raise awareness about repair and promoted player to reflect on their attitude to repair and their consumer practices:
    - *"I definitely feel it helps me reflect on where unused products go and also the temporary nature of some of these devices (do I really need something if I know it won't last long) something I will keep in mind in real life"*
    - *"I will absolutely reflect based on this"*
    - *"I think it does a great job to help people be more conscious of e-waste."*
- The game highlighted wider issues surrounding repair such as planned obsolescence:
    - *"Highlighted barriers, electronics difficult to fix, often end in landfill, mostly due to the poor way they are made."*

In addition, we noted that younger players (under 10) found the game content too difficult to understand fully, so a sign to indicate age appropriateness should be introduced for public events.

Figure 10: Player testing *RepairLand* at the *Festival of Making 2024*. Playtesting took place inside *The Making Rooms*, Blackburn.

Event 3 was the *Digital Design Weekend* at the *Victoria and Albert Museum*, London (see **Figure 11**). After playing the game players were asked to complete a *Creative Evaluation* activity (Christou et al., 2021, 2023) where they were asked to draw an emoji and write a sentence to express how playing the game made them feel – these were drawn onto a custom sticker and then stuck to a poster being displayed on a wall. This event was very busy so, it would not have been appropriate to ask players to fill in a questionnaire due to restrictions on time and space, which is why the emoji wall was more effective in this setting. It also created space for players to visually and verbally articulate why they felt as they did, and for us to instigate more in-depth discussions with players about the barriers they face as a consumer. We also asked players to reflect on the game controls and casing, as these were new additions since the previous version.

Summary of Key Findings from Emoji Wall and Conversations at Event

- Many players felt frustrated playing the game as they could not find a way to repair PetTap:
    - *"I couldn't find a way to get rid of the broken item which caused a lot of frustration."*
    - *"The game was frustrating, cool and tricky."*
    - *"Can not fix it"*
- Many expressed that they found PetTap attractive as a product:

    - *"The adverts made me want to buy a PetTap"*
    - *"Character was cute"*
- But disappointed that PetTap was so difficult to repair:
    - *"Why PetTap?? Why?! Why so cute if not repairable? Disappointed in you little elephant."*
    - *"Shocked about that something so cute can be so destructive" "PetTap or PetTrap!?"*
- Many felt the game was successful in showing how difficult to repair smart devices:
    - *"It shows how difficult it is to repair without [producing]waste"*
- Some expressed concern about the impact on the environment that smart devices may have:
    - *"Quite nervous about environment. It needs a long time to decay"*

Game Mechanics

- Players felt the new game controls were too sensitive, so they need reinforcing.
- The internet at the venue was not very reliable so the game was lagging. This caused some players not to complete the game

Figure 11: Players testing *RepairLand* at the *Digital Design Weekend* at the *Victoria & Albert Museum*, London with 3D printed *PetTap*.

8 DISCUSSION

E-waste levels are continually rising, and action needs to be taken to reduce the damage this is causing to both the environment and human wellbeing (Premalatha et al., 2014). Novel gameful experiences like *Re:Play* and *RepairLand* have the potential

to challenge perceptions and initiate conversations around repair (Obioha, 2023), while also upskilling players in practical repair knowledge.

Instigating discussions with the public about their R2R is critical for promoting sustainable practices and empowering individuals by increasing awareness of global e-waste issues (Maibach, 2019). As Makai (2024) observes, the challenge is not a lack of scientific evidence, but rather the absence of collective political and social will to act. To understand our environmental impact, we must consider complex, interrelated factors – videogames offer a viable tool to model and explore these issues.

Serious Games, like *RepairLand,* offer a compelling way to raise awareness and challenge public assumptions about R2R. This resonates with Koenitz (2019) who highlights how video games provide a *safe space* for experimentation in which "we can fail without danger" which is valuable for addressing the wicked problems modern society faces (Kessner et al., 2020). As a pervasive medium, games can be both entertaining and educational; further than that they can also be empowering. *Re:Play*, for example, seeks to empower players by equipping them knowledge and skills to instil confidence, so they have the agency to action and talk about repair.

Creating an educational tool that inspires a genuine interest about repair in younger learners to repair was a key priority for *Re:Play.* Through structured, independent play, *Re:Play* makes learning about repair accessible and engaging, aiming to equip children with skills and mindsets that they will carry into adulthood, ergo the tools and knowledge to act more sustainably - a priority reflected in recent UK government policy on sustainability and education (Department for Education, 2023). As Ouariachi et al. (2020) state, education is crucial achieving the behavioural and attitudinal shifts required for sustainable living. *Re:Play* uses experiential learning to develop players repair literacy, giving players the language to describe problems and solutions. Its design also supports player agency, from the pace of the learning process to the boundaries of learning. Factors which we hope will increase the likelihood that players will attempt repairs beyond the game.

RepairLand takes a different approach by combining visual storytelling, interactive design, and physical artefacts *(PetTap)* to build a plausible and immersive game world. Unlike many games that offer fantastical settings, *RepairLand* does this by being decidedly mundane, using everyday contexts - homes, highstreets, waste centres to help players relate to its themes. This visual familiarity helps to establish narrative believability (Delemere & Liston, 2024; Shapiro et al., 2012). Tangible artefacts like the *PetTap* device, its companion app, and promotional materials deepen this realism, further helping players to become immersed in the experience. This strategy echoes practices in location-based games, where real-world events and artefacts are integrated into gameplay (Reid, 2008).

Limitations

There are several limitations of Serious Games; some of these have been addressed through our work, while others require further exploration.

Resources: Serious Games can be resource intensive, such as requiring digital or high-quality physical components, which can be expensive to develop and distribute, potentially limiting accessibility. Development is also frequently constrained by small teams, tight budgets, and time (Procci et al., 2012). However, *RepairLand* and *Re:Play* were developed under these conditions, demonstrating that it is still possible to produce Serious Games without the resources of a commercial studio. Whilst a limitless budget would afford different opportunities, arguably, these constraints benefited our games' development, allowing us to agilely iterate our concept, content and gameplay.

Reality: Videogames can create a misleading sense of agency that does not translate into reality. While players may solve problems and enact systemic change within a game, this rarely translates directly to real life, where progress is *much* slower and *far* more complex, so would not be solvable in a matter of hours by a lone actor (Makai, 2024). Creating a game that is both engaging and realistic is challenging, but important for educational games to ensure game content isn't misleading. While making a game more entertaining might boost playability, portraying the real barriers to repair is important for authenticity; *RepairLand* does through its intentionally mundane narrative and emulating the inherent lack of agency consumers face. Further its frustrating outcomes posed challenge to players, motivating some to play through more than once to try and achieve a "better" outcome.

Ethics: There are hundreds of studies exploring how games can influence human behaviour, both negatively and positively (Greitemeyer, 2022). As a pervasive medium, game designers must be mindful of the messages embedded in gameplay, especially when aiming to inform or influence public perception. For educational games this is of high importance, as the playing the games may be more trusting of game content then they would of a clearly fictional game. The nature of Serious Games - to challenge dominant rhetorics – can also make ethics more complex to navigate. Within *RepairLand*, players interact with a variety of venues, such as waste management services and manufacturers. It was important to ensure accurate representations of these groups, not only to avoid misinforming players, but also to maintain fairness in portraying industry practices – as the aim of the game wasn't to villainise or place blame on any one group. Our participatory workshops, particularly with industry professionals, helped ensure the content was informed, credible, and ethically responsible.

Impact: Assessing the impact of Serious Games is another persistent challenge. Proving a game is impactful or has improved learning is a challenge (Bellotti et al., 2010; De Grove et al., 2010; Girard et al., 2013). Often engagement is used to prove impact, but this is not adequate to demonstrate its efficacy. Careful reflection is needed to determine whether a game is the most suitable medium, as the novelty of game creation can sometimes overshadow considerations of effectiveness. Our motivation for *RepairLand*, was to raise public awareness of IoT repair and consumer rights and improve public repair skills. It was through our workshops and collaboration with *The Making Rooms*, that the concepts for two different Serious Games fully emerge. Regarding impact, the initial feedback from workshops and public events suggests we've had some success in achieving these goals. Many participants engaged with *RepairLand* and *PetTap*, though not all completed the game. Factors affecting this included venue setup, time constraints, game length, complexity,

and age range of players. That said, participant surveys and informal feedback indicate the game raised awareness of unfamiliar issues for some, and reinforced existing knowledge for others—especially among those already interested in sustainability. *Re:Play* elicited much excitement during the public events it was featured at, as did our youth beta-testers, which is promising towards our goal for *Re:Play* of instilling a sustained passion for repair.

Crucially, the participatory process itself has significantly shaped the development of both games. As we continue this work, the *Re:Play* prototype will undergo further testing through youth-focused initiatives at *The Making Rooms,* Blackburn. *RepairLand* will also continue to feature in public engagement events across the UK and Europe—including festivals, exhibitions, and conferences—providing further opportunities to explore how players interpret the game's message, and whether it encourages repair behaviours and awareness of sustainability and consumer rights.

9 CONCLUSION

Games can be a highly motivating medium for engaging audiences about serious topics. As Suits (1978) states "games are the voluntary attempt to overcome unnecessary obstacles". In other words, we choose to play with an expectation of being challenged - physically, mentally, or both. This allows us to introduce complex themes like technology sustainability in games in ways that offer positive, meaningful experiences.

Videogames have the power to make the mundane interesting (MacDonald, 2022), to be both addictive (Griffiths et al., 2012) and liberating (Gualeni, 2014), emotionally durable (Haines-Gadd et al., 2018) and to influence our emotional state (Hemenover & Bowman, 2018). As a medium they are incredibly adaptable, they can be used for pure entertainment as well as conscientious engagement.

Our Serious Games aim to challenge players through supportive and engaging interactions, helping them to understand the importance for society to transition towards a culture of smart technology repair, and offering them the building blocks to start that journey. This paper reflects our journey so far, the insights we've gathered, and crucially our next steps for refining and improving our games It also highlights the central role of our Research through Design approach, instrumental in shaping *RepairLand* and *Re:Play*.

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