Making at the Margins: Making in an Under-resourced e-Waste Recycling Centre

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HCI and CSCW literature has extensively studied a wide variety of maker cultures. In this paper, we focus on understanding what making is like for people and communities who do not have access to advanced technological infrastructures. We report on six-month-long ethnographic fieldwork at a non-profit, resource-constrained, e-waste recycling centre that engages members from a low socioeconomic status (SES) community in making activities. Our findings show that making in such a setting is shaped by local economic and social factors in a resource-constrained environment and highlight how this community engages in a wide range of making activities. In describing these making activities, we emphasize how making was conducted to purposely enable ongoing and future making by others; promoted the wellbeing and skill development of centre members; and was socially-engaged to address concerns in the local community. We conclude by discussing how such type of making contributes a new understanding of maker culture, one that is appreciative of resource-constraints, integrates different sources of value, and is embedded in local place.

CCS Concepts: • **Human-centered computing ~ Field Studies** • Human-centred computing~ Ethnographic studies

KEYWORDS
Maker culture, HCI, Design, Resource-constrained setting

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1 INTRODUCTION

The DIY and maker movements, with their potential to create innovative technologies, democratising design and development, and scaffold economic and educational systems, are seen to be contributing to a billion dollar industry [53]. Within the field of human-computer interaction (HCI), research has investigated at length the characteristics of DIY and making [5,18,20,27,29,44,48,50]. In particular, literature has covered the role of making in supporting learning and education [24,35,41], the development of entrepreneurial skills [20,28], as well as their relevance in the domestic settings [38] and empowering a wide range of communities [2,26,32,48,49].

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It has been argued that many makerspaces bring a strong 'techno-solutionist' focus [9] and often serve more affluent and technology proficient demography. However, the HCI literature in the recent years has seen a growing number of studies that explore diverse and more inclusive forms of making, which involve women makers [14], members from low socio-economic status (SES) backgrounds [46], older adults [42] and stay at home fathers [3]. For low SES demography in particular, the socio-technical nature of makerspaces has the potential to support peer-learning, cooperation of activities and community rules and expectations in addition to gaining job ready skills [46]. Indeed, we are now seeing different types of makerspaces appearing that are governmentally funded to support individuals of low SES background to develop skills and gain experience to support personal growth and employment.

In this paper, we report on an ethnographic study at an e-waste recycling centre situated close to a metropolitan city in Australia. In the spirit of the initiatives referred above, this centre is based in an area that represented a large low SES population. The main purpose of the centre was to provide a facility to support e-waste recycling; however, it also provided spaces that allowed the making and refurbishing electronic products from the e-waste that is donated and taken to it. The centre was a social enterprise that involved volunteers and individuals who were part of the 'work for the dole' scheme – a work-based welfare program in Australia [54]. Over the course of 6 months, we carried out in-depth interviews and observations at the centre, in order to study existing and emerging maker practices in situ. Our fieldwork was especially concerned with developing a deep and rich understanding of what making was like in a non-profit, low-economic and resource-constrained maker environment, where membership was drawn from a local population experiencing a complex array of hardships.

In discussing the findings from our fieldwork, we highlight how social, economic and localised factor enforced centre members to develop a complex set of practices that are both sustainable and resilient. In particular, the centre members engaged in a form of making that had benefits beyond the completion of finalized objects, artefacts, systems or devices. It showed how members engaged in making activities that explicitly sought to support and enable future making by others; how making activities were engaged in to promote personal wellbeing and growth; and how making activities were conducted with specific purposes to respond to the needs of the local resource-limited environment. In discussing the type of making we have observed, we offer two contributions to the CSCW community studying maker cultures. First, we provide an empirical account of the sociotechnical practices that go in supporting making in a resource-constrained, low SES community, which extends the existing HCI and CSCW literature (e.g. [3,15,32,36,42,46,48]) by adding a narrative from a maker culture that has been rarely studied. Second, we demonstrate that making can be viewed as an ongoing process that builds resilience within individual makers and the communities they work and live in. Such a view brings out new understanding of maker cultures that highlights different emerging values of the centre members and the community at large and the important role maker organisations that are embedded in resource-constrained communities play when they are responsive to local matters of concern. We discuss these contributions with regards to HCI and CSCW's making agenda.

2 RELATED WORK

2.1 Maker culture and HCI

DIY and maker culture are movements that encompass a variety of activities involving fabrication, hacking, and repairing of digital and non-digital objects. Makerspaces and hackerspaces are

physical places that inhabit such activities where hobbyists and technology enthusiasts come together to build novel ideas and technologies. Makerspaces are reported to focus on aspects related to open innovation, peer-learning, resource sharing and ethos around care and comradery – creating a counter culture to traditional manufacturing of products and tools [29].

Within the HCI literature, research on maker culture has brought 'materiality' as a focus in design and emphasized on viewing makers as a parallel profession to research and industrial work [29]. The democratization of technology design enabled through maker cultures is well established in the HCI literature [5,44]. For example, an explorative study [38] focused on the use of 3D printers in domestic settings has shown that families envisioned different ways to replicate and modify existing household objects and explored the creation of custom objects. Kolko et al.'s [24] research has emphasised the educational benefits of maker culture, in that it has shown how such environments allow students to develop self-efficacy and identity around acquisition of technical skills. Kuznetsov and Paulos contend that members of DIY communities value sharing and learning over making profit and commercializing their work [25]. The role of 'care' is also well emphasised in makerspaces, as community members work together to maintain and continuously negotiate their relationships within social settings [50]. Makerspaces are also seen as sites that nurtures entrepreneurship. Socio-technical resources available at makerspaces enable entrepreneurial skills [20], where makers are able to use both online and offline resources that enable modelling, scaffolding, coaching and exploration. Focusing on the growth of makers in the developing economies, Lindtner and colleagues have shown how making is connected to building national identities [4] and how it blurs boundaries between design and manufacturing [28]. Making has indeed become part of different innovation business models such as maker-to-manufacture, maker-to-startup and maker-to-market [16]. We are seeing increasing interests by governments and business communities to start building innovation ecosystems [17] that can consolidate and cultivate local technology communities [31].

2.2 Repair and Recycling work

The research around making and maker culture has also brought attention to repair and recycling work. This is particularly relevant to our work, located in an e-waste recycling centre. e-Waste has adverse effects on the environment and new approaches and methods are required to efficiently recycle it. Kim and Paulos [23] have developed a framework for reuse around e-waste to encourage creative reuse: reuse as-is, remake, and remanufacture. Studies by Jackson et al. [22] and Rosner and Ames [15] have looked at amateur repairers' practices and contended that such work should be taken as seriously as skilled workplaces of production and manufacturing. Focusing on the developing countries, prior studies [1,19,21] have shown that repair work involves craft-based knowledge that is situated in local practices. In addition to earning a livelihood, repair work also enables the creation of new identities to amateur repairers. However, repair work and creative reuse of objects [1,19,21,45,51] is not only connected to restoration and reuse of objects, but it represents a form of creativity. Maestri and Wakkary [30] have discussed material qualities of physical objects and developed insights into how qualities such as flexibility, substitutability and reclaimable attributes can be incorporated into digital technologies so that repair work can be supported. Repair and disassembly work has also been shown as a meaningful practice that can improve the shared material understanding of artefacts that can be relevant for design practices [33]. Recent attempts [11,12] to use waste as a material for design have argued that turning waste into design material "exposes form and processes of waste that challenge HCI

scholars to highlight the wider infrastructural arrangements on which digital design practices depend" [11]. Rifat et al. [34] argued that e-waste recycling practices are not well studied within the HCI and CSCW communities. Their work on "bhangaris" in Bangladesh has shown the importance of bhangaris' skilful uses of their hands to repair and recycle e-waste.

2.3 Participation from a wider audience in making

Recent HCI literature has seen a growth in more inclusive and diverse narratives on maker cultures, going beyond a focus on hobbyist and relatively technologically affluent populations. This body of literature highlights issues related to empowerment, identity, and inclusivity. Fox et al. [15], for example, worked with feminist hackerspaces to explore and contest women's role in technology design and how women makers with common interests negotiated their identities around making and hacking activities. Their study highlighted the importance of focusing on the 'recognition' that women participants aim to achieve rather than simply getting 'access' the makerspaces. Similarly, a study [3] on stay-at-home fathers practicing DIY in domestic settings has shown how fathers engaged in entrepreneurial thinking as a form of male labour. Studies involving older adults as makers have also added to the growing chorus of new ways of looking at maker cultures. Rogers et al.'s [36] work explored the use of MaKey-MaKey kits among older adults and found that participants exhibited creativity and coordination while working together and felt a sense of achievement. Similarly, Sun et al.'s [42] work on Chinese older adults highlighted that making occurs in historical and political contexts, enabling older adults to exercise their social status, trust and collective identity.

Recently, this area of research has also involved vulnerable groups including refugee children [41], low socio-economic status community members [46], and people with disabilities [32]. Stickel et al. [41] studied the use of 3D printers in Palestinian refugee children and explored the role of such type of making in education. Their findings show that the use of 3D printers increased playfulness and self-expression in vulnerable children. A study involving participants from low socioeconomic status background in a makerspace-like organization has shown that such participation benefited from peer-learning, community engagement and learning of work ethics [46]. Another study [9] focused on making amongst women in crisis situations showed that making provided healing resources and a platform for women to bounce back.

This paper builds on and extends this growing body of literature across making cultures in HCI. We extend this work by contributing empirical insights from a specific case where making activities are, at once, implicated in reuse and recycling for community benefit and in personal growth and development for individual makers. Furthermore, we highlight the tensions inherent in the operationalisation of community-oriented making activities by local government and enterprises.

3 THE STUDY

3.1 Research Setting

For our fieldwork, we collaborated with a non-profit e-waste recycling centre called Substation33 that operated as a social enterprise. Initial contact with the centre was established in August 2016, after which an ongoing relationship was developed. The centre was located near a metropolitan city in Australia. Upon its initial creation, the centre focused on e-waste recycling activities, and provided spaces for local residents and members of the public to spend time, develop skills and

work on projects. Specifically, the centre supported the Australian government's work-for-the-dole (WFTD) program [54]. WFTD is a social benefit program that enables people seeking employment to gain work experiences in government approved organizations that involve activities such as restoration, recycling, packaging and light-weight manufacturing. The WFTD status is given to individuals who are on the job market for over a year. At the time we started to engage with the centre, however, it had stated to develop into a makerspace-like environment where in addition to supporting the WFTD participants, centre staff had started to develop small-scale innovation-oriented projects to create a sustainable growth for itself. The centre had a manager, admin staff, and several full-time employees who would manage specific projects, as well as WFTD participants, volunteers and amateur makers working on different sections of the centre.

The centre had a high number of participants from a low SES background, as all the existing participants were either looking for an employment or were in the process of gaining skills to attain relevant work experience. The suburb in which the centre was located had a high population of people with low-income, low educational attainment and high unemployment, compared to other suburbs in the area[2]. The management frequently employed participants for different work activities at the centre that ranged from cleaning and organizing the place to training newcomers. However, due to a lack of funding, it could only employ a smaller number of participants.

Fig. 1: The open setup of the e-waste recycling centre.

The centre (Fig.1) was located in a large shed with large open plan spaces. The centre did not have much of the latest equipment and tools that might be expected of a typical makerspace. In the initial stages, it relied mainly on volunteers who were interested in helping in different projects at the centre. Later, it was able to pay its employees through the projects it got from the

[2] In a recent survey by the Australian Bureau of Statistics, the suburb was at the bottom part of the Socio-Economic Indexes for Areas (SEIFA) survey results. The report is available here: https://profile.id.com.au/logan/seifa-disadvantage-small-area

local city council. The centre regularly received a wide variety of non-industrial e-waste from the local communities and other e-waste recycling agencies. This was the main source of their base material for making any new item. The centre had to rely on this material to develop their own 3D printers and filament extruders that were later used to build battery cases, circuit boards and even plastic spanners and nut-bolts. It repaired tools such as drills, saws, welding machines, and so on to be able to use these in making activities. Local hardware warehouse companies also donated basic repair tools and equipment to the centre. In all, it had to work around the financial, personnel and equipment-based support that one would expect in a typical makerspace.

The centre also regularly adapted its physical structure based on specific needs. A large part of the centre was allocated to disassembly of e-waste such as printers, PCs, laptops, TVs and other non-industrial products and equipment. This section mainly involved WFTD participants and on rare occasions some volunteers. Other parts of the centre were divided based on specific projects and activities.

Battery Work: Recycling batteries was at the core of the centre's activities as many of the centre's projects involved their use. In this section of the centre, members would go through a set of tasks to create battery packs and modules that can be plugged into different products. While this project did not involve prior experience of working with electronics, it required focus, dedication and cooperation with others while sharing tools and equipment.

Flooded road warning signs: This project was funded by the local city council, where a set of road signs were developed that will warn road users of flooding. Local communities, of which many of the centre members were from, frequently suffered from rain floods hence such a project was initiated to design road signs from recycled material. Generally, paid employees, funded by the council, worked on this project with the help of highly skilled volunteers and WFTD participants.

PowerWells: This project was initiated by a local entrepreneur who collaborated with the centre. PowerWells are a set of containers full of solar-powered batteries that can be placed in rural areas in and out of Australia to help communities that struggle with power shortage. PowerWells use technologies and battery packs developed at the centre, while enabling WFTD participants to learn new skills through working on this project.

3D Printers: This was one of the first projects of the centre. As the centre required making and repairing things across multiple project, they started designing and building their own 3D printers. While the centre had developed several 3D printers involving different members, recently they started involving university students to develop new designs.

Generally, there was a person in charge employed by the centre to oversee the progress of all these sections. These projects and activities however only provide an initial picture of the types of projects engaged in at the centre. In our fieldwork conducted over six months, we saw that the centre was involved in developing electric bicycles from recycled batteries, making amplifier devices from military ammunition boxes and providing computer repairing services. Furthermore, many volunteers and WFTD participants developed their own self-initiated projects. We discuss these in more detail in our findings.

3.2 Methods

Our engagements with the centre commenced on August 2016, where the lead author was involved in a student project that focused on understanding of social interactions that took place at the centre when it was in an early stage of development. However, the study reported in this

paper started in April 2018, at which time our work became more focused on understanding the pluralistic practices, motivations and benefits surrounding the types of making activities engaged in at the centre. Over a period of six months we applied observations and contextual interviews. In the observations, we aimed to get an overview of the everyday interactions that took place at the centre and to understand the collaborative activities of the centre. Our goal here was to study the natural circumstances of participants' activities, the tools and methods they use, and how the process of making was achieved. During our observations, we started recruiting participants for the contextual interviews. We interviewed a total of seventeen centre members. In addition to the centre manager, we had five employees who worked on different project at the centre, six volunteers who frequently helped in specific projects, and five WFTD participants in our study. Participants' ages ranged from 20 to 64. Four of the employees initially started as the WFTD participant before gaining employment in the centre itself.

Our interviews were designed to be as unobtrusive as possible, as we aimed to learn participants' work practices and natural engagement with others at the centre. We were mindful to enable continuation in participants' ongoing activities, who were required to work for a certain hour in a week – the WFTD participants. We followed each of the participants for half-a-day (3-4 hours) and asked them questions during this time. Our questions were based on understanding their motivations for joining the centre, their current work and projects, their aims and desires from working at the centre, the social environment afforded by the centre, the activities of their liking at the centre, and the overall impact of their participation on their health and wellbeing. Importantly, we aimed to gather detailed accounts of specific experiences and process of making, where we were interested in understanding material practices, effects of the social environment and the effects of such an endeavour on the larger community.

Our engagements with participants started by them signing a participant consent form. The form clarified the aims of the project, our role as researchers in it and that their identity will be protected. Field notes and photographic documentation was used to capture specific instances of interest during observations, while the points at which we interviewed participants we audio recorded our conversations. At the end of the sessions, participants were provided with a $10 gift vouchers for their time. We included field notes, transcriptions of audio recorded interviews and the photos in our analysis. We conducted thematic analysis [8] on this data corpus. We started by creating detailed notes based on the audio recordings, after which we summarised the transcribed data through open coding. We subsequently developed short memos that summarised codes and groups of codes. This resulted in the development of three overriding themes that summarise our analysis of the data.

4 FINDINGS

Through our analysis of the data, we identified three overriding themes that characterise different aspects of making at our field site – that it is oriented towards promoting future and ongoing making activities, that it brings forth personal growth and promotes positive wellbeing, and that it is oriented towards developing the local community and increase its resilience. We describe these three themes in the following sections. We use pseudonym to refer to our participants.

4.1 Making for future and ongoing making

Perhaps unsurprisingly given the overall ambitions of the centre, much of the work engaged in by its members involved the creation and repair of artefacts. It was immediately notable however

that it was very rare that the artefacts themselves were considered "outcomes" or finalised products. Instead they were seen as just a step in a wider making endeavour. For example, it was common to observe projects by members who focused on making tools that would enable further making activities in the future. Sean, who joined the centre in its early days, explained that:

> *"Our first idea was to create battery packs, but we needed to make containers where batteries can be stored. We initially tried a commercial 3D printer but it didn't work out well. So, we thought to make our own 3D printers that can make battery containers in different sizes. We initially bought filament from eBay, but later on developed our own filament extruder from recycled electronics."* (Sean, employee)

Important here was that the work of the centre, from its earliest incarnation, was focused purely on the recycling of existing components from electronic artefacts (specifically, lithium-ion batteries from laptops). However, in order to recycle these items in ways that would be useful, further tools were required. The resource constraints of the centre forced its members to look for cheaper alternatives from the e-waste material that was available to them. As Sean explains, members have engaged in a range of projects where the focus has been on taking a series of 'steps back' from the creation of finalised artefacts to focus on the creation of tools that promote reuse and recycling. Hence, in order to develop a set of battery packs (discussed later in this section), centre members had to think about a series of tools such as developing their own 3D printers, filament extruders, and battery charging boards, each of which ensured they had the tools available to them to warrant resourceful making of reusable battery packs in the future (see Fig. 2). Centre members had learnt that parts from traditional paper printers can be reused to develop 3D printers, for example. Additionally, they used online reading material and maker/hacker websites to design these tools.

As noted, the creation of the battery packs was a significant focus of much of the making activities at the centre. This was quite strategically thought-out by the centre staff, as all electrical systems and tools required power to run them, and recycled batteries could replace such reliance on mains electricity. While battery packs were created partly as they exemplify the reuse of potentially expensive and environmentally impactful technologies, they were also seen as a platform on which a whole range of other systems and artefacts could be built upon. Over the years, the centre has learned and adopted sophisticated ways to develop battery packs. Jay, a volunteer who helped out at the centre for environmental motivations, explained the battery recycling process (see Figure 3):

Fig. 2: from left to right: a 3D printer, 3D printer filament extruder, and battery charging board, all created from recyclable materials at the centre.

Fig. 3: Battery pack making process. Taking battery cells out of laptops, charging battery cells, testing and categorizing battery cells from grade A and E, and completed battery packs on the shelf.

> *"When batteries from laptops comes to us, we take the battery cells out, try to keep them in pairs... then we have to test them. If a battery is tested below 1 volt, we discard them as they may not be useful. We then charge the others and keep for 2 weeks to see how quickly they degrade. We then categorise them from grades A to E. Grade A batteries are good quality that can power heavy duty tools."* (Jay, volunteer)

Being a recycling hub, the centre aimed to reuse a majority of e-waste that arrived on site when making new products. Its aim was to recycle almost 90% of the e-waste it received from different sources. The centre was running on mainly community support and had many financial constraints which prevented them from buying new equipment. Hence, it was important to make sure that the processes they created were easier for any newcomer with or without the knowhows of electronics can learn. As can be seen in Jay's account, a very simple process was created so that WFTD participants can easily enter into the battery work space. The process of making battery packs was important for a number of reasons. First, batteries were a core component to power a number of other systems and tools designed at the centre. Second, the centre was able to support its core value of environmental sustainability by recycling lithium-ion batteries, which are notoriously hard to dispose of, and giving it a longer shelf life. The centre's manager, Tom commented:

> *"It's a means to an end. We build all the tools here to allow us to further manufacture. We try to make things as generic as possible so that it can be made multipurpose. So, as you can see in battery modules here. We used them in eBikes, road flood signs, power wells, amplifiers, so they get used everywhere. It's a generic product."* (Tom, centre manager)

The centre was also involved in making of tools and technologies that can serve to be a platform for other more fully-fledged technologies and systems. As noted by Tom, the intention was to create a suite of reusable and modular items that can be utilised for a range of different equipment and devices. Examples of these were battery management systems, specialized sensors, and circuit boards that could be used in a range of different systems. Tom, the founder of the centre, commented on the centre's motivation for building what he called 'platform technologies':

> *"For us, we don't have a huge amount of resource. It's better for us to make a generic product, even though it may not suit the specific need exactly. Generic products can be adapted to specific*

needs and used across multiple projects. We can't design technologies specially every time there is a new project." (Tom, centre manager)

Platform technologies were developed so that they can be easily plugged into larger systems to make them work. The circuit boards (Fig. 4a) that were developed at the centre were used in multiple systems ranging from flooded road warning signs, PowerWells and 3D printers. The focus on the making of artefacts that supported ongoing making activities also came through in other ways. A significant amount of effort was put into the repair of old and worn out tools to either return them to working condition, or to extend their use by recycling other materials. The creation of the battery packs was especially useful here, where old tools – such as cordless drills and circular saws (Fig. 4b) – were brought back to life through adaptation and integration with the recycled battery packs created at the centre. These power tools were then used for building new technologies. Such a philosophy highlights centre's vision on sustainability and resilience embedded in making. Repairing old technologies was also seen as a way of learning. Often senior members of the centre will bring broken technologies to the centre in order to repair them. During our fieldwork at the centre, we saw Sean working with a roof solar inverter. He commented:

"We are doing more and more solar batteries these days, so looking at inverters would be worthwhile. It only costs about $500, but by opening this up will help us learn the technology." (Sean, employee)

As in Sean's case, many of the centre staff and volunteers had a great curiosity around the workings of technologies, and they used the opportunity to dismantle and take apart donated items and e-waste as a means to understand how technologies were manufactured and how they might be repurposed.

While a lot of the activities in the centre were oriented towards the creation of tools to enable making, there were instances where over time these tools and platform technologies made with them led to more finalised "products". For example, the centre was involved in designing PowerWells (Figure 5a) a solar-powered portable charging stations to power mobile and electronic devices in rural areas. The initial versions of PowerWells used recycled military emission boxes and later large paint boxes were used to house a large number of recycled

(a) (b)

Fig. 4: Platform technologies (a) and recycled battery powered saw and drill (b).

(a) (b) (c)

Fig. 5: Latest version of PowerWells (a) and (b) initial version of a recycled battery powered torch and a water-proof version of the torch (c).

batteries. Similarly, as shown in Fig. 5b, Brian – a 25 year old local maker volunteer in charge of the PowerWells project shows his ongoing explorations of making torch from recycled bamboos. Brian explains,

> *"We are bringing PowerWells to rural Indonesian villages where there are plenty of Bamboo trees. By experimenting with the local materials, we can equip the local communities to develop more such devices."* (Brian, volunteer)

The idea here was to mainly develop a proof-of-concept through explorations so that it can be used to encourage the local community members to enable further making of such devices in future themselves. They were evidences however of shift in focus at the centre over time, away from just the creation of tools, towards the creation of new electronic objects that made use of other discarded or locally sourced materials. We return to this in our final theme.

4.2 Making for individual growth and wellbeing

Throughout our fieldwork, we noted that being involved in making activities had an ongoing effect on individuals. The centre catered to a highly diverse population, and it was clear that for many of these individuals – but especially those who were on the WFTD scheme – they were building a sense of purpose through involvement with the centre. While for some individuals' participation in the centre's activities was primarily seen to be a way to get their government benefit payments, for others, it was about doing something good for the environment, doing something useful in life, gaining skills important for job market, and to be part of a social setting to support friendship and comradery. Henry, a 54 year old member of the centre, commented:

> *"I found out about this place from a newspaper. I visited the place and liked it. It's better than staying home and doing nothing."* (Henry, employee)

Henry started as a WFTD participant. He had been unemployed for over a year before he joined the centre. Based on his performance he was able to gain a paid position at the centre itself to manage projects and help newcomers to settle in. Another example was 64 year old Carl, who started attending the centre on a volunteering basis. He was on a disability pension but was able to perform tasks that did not involve a lot of heavy lifting. Carl studied horticulture and was an environmentalist himself. In the beginning, Carl visited the centre regularly, volunteering at different sections and learning how to take apart e-waste and rebuild these into working systems.

Over time however he started his own smaller projects at home, such as making a battery powered bike, biogas plant, among other things, using the skills and knowledge gained from his time at the centre. He then only visited the centre when he needed some help. He commented:

> *"This is like a small island of sanity that offers some ray of hope for being able to offer opportunity to minimize waste... As an environmentalist I was interested in knowing efficient ways to engage with the community and recycle...when I read about [centre] in the newspaper, I thought I should visit. I did not come here to find a job, but mainly to engage with the community... I have spent two years on the bench opening up computers and electronics."* (Carl, volunteer)

Members took a great pride in their work. Like Carl, several participants commented that the kind of work they were doing was going towards helping the environment and minimizing waste. Others saw their work as a contributing to the local community by making IT products such as refurbished laptops, music players and other PC components more accessible to a community that was from lower socioeconomic status. Similarly, members felt a level of empowerment and sense of pride with the kind of work they did at the centre. Carol, a 30 year old female member of the centre, commented:

> *"I learned how to make these circuit boards and now I am teaching others how to make them".* (Carol, employee)

Carol was one of the few female members at the centre, which was heavily male dominated. Carol began as a WFTD participant and has now become an employee at the centre making circuit boards that goes in the flooded road warning signs. She found her way around in the centre by working with male members. Prior to Carol joining, the centre had witnessed several female members starting to work there but retaining them was a problem. With Carol being well integrated into the centre's activities, newcomer female members started to work alongside her. She took a great sense of pride in being able to teach others about how to build circuit boards, and especially in her role in starting to diversify the participant and volunteer membership of the centre.

Members also reported multiple social and emotional benefits they gained through working for the centre. This was particularly important given the population that the centre supported, many of whom had experienced significant financial and personal hardships. Shane, a 26 year old WFTD participant, was bullied at school and reported he was unable to complete his education. When he came to the centre, he felt well supported. He commented:

> *"I don't speak to my family anymore. I was always bullied at school... Basically every job I have done has failed me. I came here through the work-for-the-dole program. Initially, all I just wanted to do my hours and leave. But once I started talking to people, I started liking it here."* (Shane, WFTD participant)

The social interaction enabled by the open-floor planning of the centre meant that members like Shane were able to ask questions to others and get help. Peer learning was also quite central here as the centre was not able to afford professional trainers to help newcomers. Instead, participants helped each other or sought advice from people who were managing specific projects

at the centre. Nigel, an employee at the centre, helped Shane in getting his way around the centre. Nigel commented about how Shane came through from being a "clean slate" to developing confidence and became assertive in his project work.

One of the reasons for the success of the centre in this regard was that it was seen to be a "no-judgement" territory where people were not looked down upon. Dennis, a 22 year old WFTD participant, had changed schools 9 times in 10 years. He explained how he had anger management issues and was thrown out of jobs because of that. Once he was at the centre, he was initially able to do what he always liked – drawing and sketching. Senior members at the centre helped him to cultivate his skills towards 3D modelling using CAD tools. During our interview sessions he showed the logos and artistic 3D printed models (Figure 6a) he had created with the centre's equipment. Relatedly, several participants reported that working and using specific tools at the centre was somewhat therapeutic in nature. Tracy, a 22 year old female participant, had faced difficult domestic situations, and coming to the centre was a big positive change for her. She referred to the use of soldering device as relaxing and satisfying, where she could forget all the personal problems in her life.

The centre, being part of an e-waste recycling program, gave people an opportunity to learn about building electronics and IT product repairing. Henry, getting inspired by ongoing projects at the centre such as PowerWells, designed what he called an 'entertainment cooler' (Figure 6b) on his own time. He modified his ice-box cooler into a music and charging device that he can use while travelling. There were other members who came to the centre with a specific agenda and sought career direction. For example, Will – a 58 year old WFTD participant, came to the centre with an aim to learn electronics. Due to the introduction of new technologies in his previous job he could not keep up. Will aimed to learn new skills so that he can go back in the job market. He commented:

> *"You can keep yourself motivated while you're looking for real wok. Especially for me, being on my own it's hard to motivate myself. But at least here it keeps you active."* (Will, WFTD participant)

As well as facilitating the learning of basic skills, the centre aimed to develop a pathway for members to navigate through towards getting employment or developing their own projects. Tom the centre manager mentioned that through their experience at the centre, several volunteers and WFTD participants were able to go into the job market. Centre staff frequently approached members who worked in the disassembling section to give them opportunities to work on specific

(a) (b)

Fig. 6: Dennis' 3D printing work showcased at the centre (a), and Henry's 'entertainment cooler' (b).

projects. As we showed members such as Henry, Carol, and Tracy moved up to working on specific projects run by the centre. Similarly, centre enabled highly motivated members to host their projects by providing the role of an incubator. Brian, who studied Mechanical Engineering, was able to run his crowdfunded project to make amplifier devices at the centre. The centre also enabled the WFTD participants to work with Brian, where participants can learn from watching Brian do his work and ask questions whenever there is a need. This way Brian was able to get people to work on his production of amplifier devices at the same time helping WFTD participants get a useful work experience. The centre allowed Brian to use the recycled batteries to run his amplifier devices.

While the emphasis on personal growth and development was a great strength of the centre, it also posed challenges. Tom commented that when some good employees and volunteers get a job outside it also affects ongoing projects in the centre. In our earlier visits to the centre, we saw that there were ongoing projects on battery-powered bikes and computer repair. However, as members were getting jobs outside, these sections became less active and eventually the centre decided to halt some of those projects. Tom commented that in the year 2018, a total of 100 people who attended the centre were able to find employment outside, out of 600 people who were registered at the centre that year. Furthermore, while the centre had placed importance on helping its members find long term options in the job market, it found difficulties in helping some participants. For example, despite his own and the staff's best efforts, Will was unable to get jobs outside. For Will, the centre provided a venue where he can build his work experience. It was critical for him in making sense of his changing identity – from a full-time employed in a skilled profession, to his skills being reallocated to new automated systems and being unable to operate these, to starting to understand how these systems that replaced him worked. He gained a sense of control and agency again. However, at the time of our study Will was still looking for a suitable job opportunity for over one year. His age, he felt, was a key factor stopping him from finding new work, with the perception that he was unable to adapt to modern workplaces despite his renewed skills and know how.

We found that there was ongoing learning happening at the centre. Even though the work that is done at the centre was not in line with participants' previous job profiles, by being involved in some sort of technical work was perceived to be useful for building motivation and future job prospects. Members were able to learn specific skills in projects and then they were able to apply those skills in another project.

4.3 Making for community development and resilience

Our final theme addresses how making was not just oriented towards individual and personal growth, but also occurred at the community level, both within the centre and outside of it. Core to the ethos of the centre was working closely with local communities to ensure they understood the value of the work conducted there and also so that they benefitted from it. One way in which members of the centre involve the community in their activities was through the making of artefacts and devices that respond to local needs and matters of concern. During fieldwork we observed multiple projects along these lines, including the creation of the underlying technologies for emergency flooded road warning signs alongside main roads in the community, and working with a local special education school to install 3D printers produced at the centre. Participants saw working responsively to the needs of local communities as critical to the success of the centre:

"It's a great sense of accomplishment. Not only that I get to help [the centre] but I am helping a community who might not be able to have access to computers or other IT stuff. They [the centre] sell things dirt cheap; I have a laptop from here which is only 50 bucks." (Anthony, volunteer)

Beyond this general sense of doing good however, the ways in which members of the centre worked with local communities was intimately tied to the low SES of many residents and a desire to engage them in practices that support skills development. In various projects, rather than centre members conducting the technical work themselves, they would ensure that local residents were proactively involved to ensure transferring of skills and know-how to support the longer-term sustainability of projects. For example, the centre collaborated with local schools and frequently gave talks around how to build things. The centre manager, Tom, gave several 3D printers to local schools:

"We don't give out fully built 3D printers. We give them out as DIY kits so that school kids can learn how to assemble them." (Tom, centre manager)

The aim behind projects such as these was to ensure local residents not only had the opportunity to make use of technologies produced at the centre, but understood how they were built and configured so as to repair and maintain them. In another project, some members of the centre were actively helping local residents to install solar panels in their homes. This project involved inviting residents into the centre to help build the panels, and also asked the residents to help with their installation in the home. Similarly, the centre also helped other volunteers to build battery powered eBikes, and gave them the tools and information needed to help people outside of the centre build and maintain their own.

There was a prevailing sense across the centre that their work needed to help others who might not have access to technologies. By supplying these products in DIY kit forms the centre enabled both the education as well as the affordability of these products. The people who were a part of the WFTD scheme were involved in making these kits, which not only gave them the knowledge of electronic making but also provided them with an opportunity to collaborate with others and develop skills and expectations for the workplace. The centre was involved in commercial projects such as the flooded road warning signs where they worked closely with local city councils. However, again projects such as these prioritised catering for local needs. The locality where the centre was based frequently suffered from flooding caused by rain. Following the ethos of the centre, even in a commercial project like this, the centre utilized recycled materials and involved volunteers and WFTD participants. In a different example, the centre was in the process of building mobile homes made out of solar panels and trailers. In this instance the purpose behind such an endeavour was to help the homeless.

The centre also collaborated with university researchers, individual entrepreneurs and frequently organized innovation days and hacker weekends to increase awareness about their work and exchange ideas. After generating some media attraction in local newspapers, several amateur makers visited the centre with their prototypes and design ideas to initiate collaboration. The centre also established internship programs for university students who could work on their projects at the centre. Aligned with their making ideals, all this was done to garner interest in the wider community and attracting them to contribute towards the ongoing projects and resilience and resourcefulness that are embedded into them. Figure 7 shows two examples where university students were involved in making 3D printers. Figure 7 (left) shows a set of 3D printers in the

process of being built; and Figure 7 (right) shows a new version of a 3D printer built by a university student team. This particular design showed how the centre was interested in iterating their designs of 3D printers through engaging with others. Sean commented:

> *"I am really proud of this one. Students designed it with minimal supervision from me. What I like about it that it's really easier to put together, it uses less motors, less likely to go wrong if somebody want to develop it. In this one, one can literally build the whole thing in one day. There are not many screws; there is only one screw that holds the motor."* (Sean, employee)

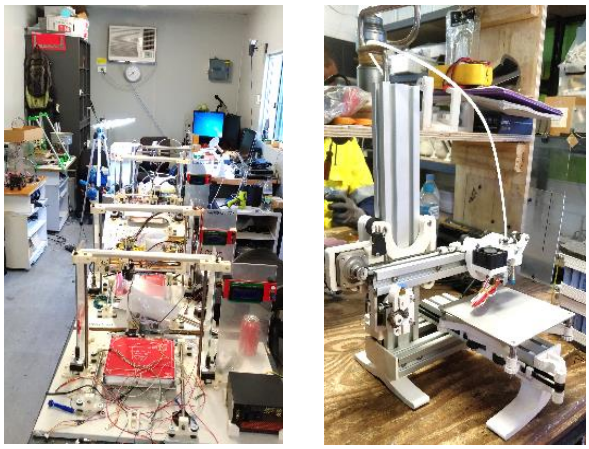

Fig. 7: from left to right: Making of a set of 3D printers by students and a new design of 3D printer developed by a team of students.

As we discussed earlier, even within the centre, there was a strong emphasis on building a strong community support where members can help and mentor each other towards successful outcomes. In the case of Henry, who started as a WFTD participant, he had recently become a full time employee of the centre at the time of our interview with him. He looked after the battery modules and had been teaching others about different processes that go in this. While Henry has his own tasks within the batteries section, he frequently walks up to different members working in the section. He commented:

> *"I had three guys [WFTD participants] come and said we want to learn. I said to them, "alright, I will teach you."... I know that one day they will be teaching others."* (Henry, employee)

Regarding the centre's strategy on supporting members, Tom indicated that because the centre could not hire trainers to teach newcomers to the centre, they would get people to work with others so that they can learn from watching. The centre carefully orchestrated participation from a diverse group of people in a way that they can create their own career trajectory. However, what become clear through our data is that this attitude goes beyond the work and people within the centre, but also to the ways in which it engages with local residents and citizens in their projects. Making exists partly to make the most of relatively scarce financial resources; but it also exists so that local people can develop the skills and capabilities to make the most of those material resources they have. In doing so, local communities might be supported to be more resilient.

5 DISCUSSION

In this paper we have described our 6-month long fieldwork at an e-waste recycling centre that supports a low SES community. In reporting on the fieldwork and interviews, we have aimed to highlight how the local economic and social issues affect the overall making process. In particular, we unpacked the practices associated with making as a way in which the centre and its membership engaged in a range of recycling and making activities. Based on our findings, we have come to conceptualize making as an ongoing activity, woven into a wide range of complex factors that went far beyond a focus on the creation of a specific artefact, object or device. We have illustrated the centrality of artefacts that are made to support the continuation of future making activities, such as remade tools, new tools created from reused materials, or indeed through a focus on the creation of 'platform technologies' that could be reconfigured and used in a myriad of other artefacts and tools.

While making tools for further making is not new in design practice and research [13], for the centre such type of making was a 'way of life' given the lack of financial resources yet abundance of old waste resources. But we also saw that making based on repair and reuse was privileged as it enabled members to gain new skills and develop competencies that would help them grow and find employment. More than this, some individuals clearly found solace with making as an activity, in being part of a social space anzd belonging to a community, and felt great benefits for their health and wellbeing in participating in the work of the centre. Making as a form of skills development and social support went beyond individuals as well to the wider community; making was a bi-product of a wider concern around how the resilience of the community may be strengthened, and how the concerns of the centre could be scaled and transferred across the local population.

In the following sections we unpack these points further, discussing the ways making and remaking becomes especially visible when working in a resource-constrained environment, where multiple forms of participation have to occur, and where different priorities and agendas shape engagements with making.

5.1 Making Value and Values in a Resource-constrained Environment

One of the aims of this paper was to highlight what making is like at a resource-constrained maker organization. As we mentioned earlier, Substation33 had constrains around acquiring the state-of-the-art tools and equipment, skilled people to train participants and funding. With such constraints and characteristics, our fieldwork at the centre made certain types of making, its motivations, and the value that comes from them, highly visible.

At an initial glance the resource-constrained nature of our field site comes from its reliance on working with electronic waste donated to it by citizens and local organisations or from official waste disposal services. However, we also saw how the way in which the centre itself operated was constrained in terms of the financial, technical and human resources it could draw from. The lack of financial resources led to a reliance on reusing and remaking with items that were donated, and the lack of technical resources led to an initial reliance on a small number of core staff and volunteers, and to learn-by-doing through taking donated items apart and finding ways to make new with them. Furthermore, much of the centre's work was a response to a social and human need in the communities that surrounded it; there was growing numbers of local people out of work, and a growing need to find a way to develop their skills, provide an entry-point to work, and produce electronic items that might be accessible financially for these citizens. As such,

working with and responding to resource constraints was embedded throughout all the centre's work, from the material it worked with, to the ethos of how this material is used, through to its organisational operation and the reasons why it served local people in the way it did. In many ways it was the continual negotiation of these different factors, and keeping them in play at any one time, that ensured a coherency to the centre's vision and work.

At the same time, we also observed tension points within the ethos and vision of the centre. In order to diversify its income streams – and in effect offset the constraints of financial resource it worked within – the centre would work with local enterprises and, most prominently, the state government to support project activities. In many respects the values of the centre were complimentary to those of funders – the government funding, for instance, was to support local people to develop skills at the centre and enter new workplaces, which developed new competencies among those living nearby, and in turn developed opportunities for them to be more financially resilient. But on occasions this meant people participated in the centre's activities without necessarily aligning themselves with its values; their main purpose was to attend the centre and treat it as job, to receive their governmental payments, and to move on as quickly as possible into paid work. We also saw how some members of Substation33's community who had come through this route were unable to enter paid work, but were seen to still offer value to the centre through their participation in projects and its community. Indeed, in many respects the value participants brought to the centre was not in their capability to quickly move on to other forms of paid work, but to find personal benefits from giving to its community, by sharing their expertise and in a small number of cases become part of the core staff team within the centre. Our findings also show that centre members saw value in 'giving back' to the community over making profit, which was in line with Toombs et al. [50] and Kuznetsov and Paulos [25]. Previous studies have shown a variety of values expressed through making activities: entrepreneurship [20], innovation [29], local and technological histories [43], and gendered visions of technology [3,15]. As such, the making activities within the centre were more in keeping with studies that have highlighted motivations for making that are more personally and community oriented [10], than any ambition to contribute to systemic environmental change when it comes to electronic waste.

What we see throughout here is the complexities of a real-world, resource-constrained, making context where the interplay of multiple different sources of value ensured the ongoing operation and sustenance of the organisation. Substation33 existed through the formation of a constellation of value [40] between multiple actors and stakeholders, but with a maintained coherency aligned with an underlying value of making the most of limited material resources. It was keeping this value in sight at all times that acted as the 'glue' that held the centre together; however, making room for other sources of value to come in was critical to ensuring the centre's work would be sustained.

5.2 Platforming as a Practice of Maker Environmentalism

A considerable body of work (e.g. [4,6,17,29,43]) has highlighted the contradictions between the notion that hacking and making is a form of resistance to dominant political and socio-technical ideologies and the practices of many makerspaces being oriented towards innovation and enterprise. Indeed, there have been recent calls to bring back to the fore the hacker, repair, recycle and ecological orientation of makerspaces (e.g. [11,12,19,22,37]) in light of their appropriation as spaces for innovation and entrepreneurship in recent years [20]. In many respects, Substation33

was full of such contradictions as well. It was grounded in framing making as a form of environmentalism that could reuse and remake electronic devices that would otherwise be discarded, and indeed may have been designed to be discarded by the corporations that produced them. Yet, as we have discussed above, at times it reinforced dominant labour logics, and a neoliberal mode of thought that citizens in receipt of state welfare should be put to work even while seeking work.

Despite these tensions, it was clear that the centre took very seriously resource scarcity as its underlying ethos, and all of the examples of tools, artefacts and projects we saw in our fieldwork embodied this. The entire workflow and design of the spaces in the centre were oriented towards not just ensuring waste was recycled, but that the "things" they create speak to this wider mission of reuse of materials in the future. It was not just enough to promote the making of new things through reuse of old materials, but the items created had to promote the remaking of future materials as well. Tools used in making activities such as 3D printers, filament extruders, drills, saws, electronic circuit boards and so on were all locally designed and manufactured on site from recycled materials. Other tools were remade and repaired, either through combinations of old tools or through the re-use of e-waste to give these tools a new life. Compared to other studies that looked at steampunk [45], adhocism [5] and artists [22], much of the making and reuse done at the centre was focused towards improving existing tools and artefacts. The centre also reflected a set of practices around recycling and repairing, while enabling work experience to a diverse range of population mainly from a low SES community. Compared to studies that reported work of repair shops [19,21], the centre's repair work (e.g. drills and saws) was mainly for self-sustaining and extending the use of objects that were being used to support making [7,30].

However, the projects conducted at the centre went further than just creating new artefacts based on salvaged [11] items, or tools that would support ongoing reuse and recycling maker activities. Much of their work focused on the creation of general-purpose tools, or as one of our participants referred to them, 'platform technologies'. These were not the end-products in themselves but a set of adaptable technologies that were modular in nature and could be plugged into others. The platform technologies such as circuit boards, sensors and battery packs, were a good example of how the base technologies were intentionally made generic so that they can be adapted and used while making new technologies. Placing deep consideration to the development of these platforms meant latterly being able to create a suite of 'products' such as flooded road warning signs, PowerWells and amplifier devices on which they were based. At an organisational level this strategy enabled a more streamlined making process from the recycled e-waste that can be used in developing a diverse range of technologies. But also, it meant a further degree of sophistication in how the centre conceptualised its environmental ethos, to produce new modular systems that could themselves be easily repaired, replaced, and maintained in the future.

5.3 Moving between Local and Global

The activities we observed at Substation33 were heavily embedded within the local community. As we have noted above how the income levels and SES of the local community was a motivating factor for the centre's existence, for some of the funding it received, and for its ethos of repair, reuse and platforming. While recent work in HCI has noted the ways in which community organisations and researchers can orchestrate workshops and events that stimulate locally-oriented, grassroots innovation [47], we observed here how Substation33 was supporting such activities on a day-to-day basis. As such, the vision of the maker movement our specific field site

portrayed is one that is localised, where it aims to reimagine the role of makerspaces not as a Silicon Valley like innovation hubs – maker-to-startup [29] or models of maker-to-market [16] - but as locally grounded, an assets and place-based endeavour, that sought to develop new systems from old donated materials that responded to local problems. Earlier studies on DIY and maker cultures [3,15,29,42] have shown that individuals construct 'identities' around their making activities. Contrast to this, our findings did not reflect any strong insights into identity construction, except in the case of Carol who took pride in being able to teach others about building circuit boards. Rather, we believe that the centre was able to provide an environment that supported self-efficacy in people from low SES backgrounds.

The participation of local residents who were WFTD members along with volunteers demonstrated that making in this setting was not limited to technology enthusiasts and entrepreneurs. Prior work has shown that individuals from low SES communities often show resilience in their everyday activities [52]. In our work, we saw how centre members demonstrated their resilience by acquiring skills over time and latterly able to share these with others to uplift the overall community within and outside of the centre. We saw several examples of how specific WFTD participants were able to move towards a career trajectory. We also saw that projects at the centre were rarely treated as one-off or outcome-focused, rather these projects were continuously iterated and were converted into new projects, typically responding to issues individuals identified from their own lives. At the same time, making was focused on the growth of individuals and communities. The resilient and sustainable ethos, inherent into the centre's functioning, were propagated through community engagement and outreach.

However, we again observed some emerging tensions around this localist ethos, especially around the ambitions to grow and scale the work of the centre, to diversify income further, and to work on more global projects. Much of what we observed were success stories, where the platform technologies and the 'products' they support created at Substation33 developed in response to its limited resources resonated with the challenges communities around the world faced in the Global South and developing economies [19,21]. At the same time, it is clear that the strengths of maker organisations like Substation33 come from their responsiveness to local needs, and their embeddedness in communities to not only develop new artefacts and systems, but to also account for the skills, expertise and social infrastructures that surround these. As noted by [39], rather than seeing the products of spaces like Substation33 as being immediately transferable across contexts and transnational boundaries, we suggest instead further inquiry into the ways place-specific maker endeavours may transfer instead. As with the work that Substation33 has conducted, this does not mean simply transferring the tools typically associated with makerspaces from one locale to another, but to embed a mode of enquiry where discarded objects are prised open, taken apart, remade, and the tools, practices and skills are themselves created with respect to the local communities the space serves.

4 CONCLUSIONS

Based on a fieldwork at a non-profit, resource-constrained e-waste recycling centre, we described a set of complex practices around localised making, where centre members involved in future and ongoing making brought benefits beyond the completion of a finalized object, artefact, system or device. While we position our study alongside the growing repertoire of studies [3,15,32,43,46,48] that argue for bringing 'inclusivity' in maker culture, our findings related to making brings forwards a perspective from low SES members of the society involved in e-waste recycling that

is not well represented in the existing literature. We contend that by looking at making as an ongoing ever adapting process, we are able to develop a rich understanding of how resilience is built at artefact, individual and community-levels during different making endeavours.

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