Designing an Accessible Mobile Makerspace with an Intellectual Disability Support Organisation: Insights from a Co-Design Approach

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Figure 1: Participants engaging with bodystorming scenarios to A) develop makerspace design ideas and B) evaluate the resources that support the C) delivery of a eMaking program of support to people with intellectual disabilities.

Abstract

Makerspaces, both fixed and mobile, have been established for several underserved populations to encourage creativity and hands-on learning. However, opportunities for individuals with intellectual disabilities to contribute to maker cultures and the design of makerspaces are limited. We collaborated with a multisite Disability Support Organisation (DSO) to co-design a mobile makerspace for individuals with intellectual disabilities. A three-phase approach to co-designing the makerspace was employed where people with intellectual disabilities, support workers and the DSO's leadership team participated in preliminary interviews, embodied ideation and reflective interviews. We provide insights into accessible co-design practices, notably bodystorming and illustrate its effectiveness in eliciting the implicit knowledge and skills of individuals with diverse verbal and cognitive abilities when designing a mobile makerspace. However, we also address its attending limitations in understanding the rationale behind participant actions and distinguishing between collective perspectives.

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• **Human-centered computing → Accessibility technologies**.

Keywords

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1 Introduction

Makerspaces are collaborative environments that provide individuals with access to tools and resources for digital fabrication, hardware and software hacking, and traditional crafts. These spaces are designed to foster creativity, hands-on learning, and the sharing of knowledge [89]. Maker culture recognises the potential for technology design and manufacturing democratisation [87], thus empowering makers to create, modify or build technology solutions for themselves. While previous research demonstrates that making can lead to self-fulfilling innovation, access to resources, particularly makerspaces, remain constrained by a maker's identity and their societal conditions [6]. Consequently, makerspaces tailored to specific community needs have emerged, aiming to provide equitable access to women, people of colour, individuals from low socio-economic backgrounds, and people with disabilities [76, 81]. However, the existing literature indicates a scarcity in the development of accessible makerspaces for individuals with intellectual disabilities [10, 12, 34]. **Intellectual disabilities** are characterised by significant limitations in intellectual functioning [1]. People with intellectual disabilities may experience learning, memory, attention, speech, and language difficulties when participating in daily life activities [82].

Our work explores the design of a makerspace for, and with, people with intellectual disabilities and their support staff. The makerspace was created in collaboration with a multisite Disability Support Organisation (DSO) which delivers an Electronic Making (eMaking) program of support to individuals with intellectual disabilities [35]. We define **eMaking** as a subdomain of making that specifically centres on electronic and computational materials, distinguishing it from more traditional craft-based approaches. Establishing a centralised makerspace was deemed impractical due to the geographic distribution of the DSO's sites, and the requirement for specialised equipment and knowledgable staff. To overcome these constraints, we designed the makerspace as a mobile resource [29, 38]; enabling its adaption to diverse learning environments [61] while promoting inclusive exposure to eMaking materials [26]. It was decided that the mobile makerspace would take the form of a van, as the DSO was familiar with vans and operated a fleet for transportation. Additionally, a van could be parked at all sites without requiring special accommodations, unlike a larger vehicle such as a bus (see Figure 1C).

We employed a three-phase approach to designing the accessible mobile makervan. Firstly, preliminary interviews were conducted with the DSO's clients and support staff to understand their collective needs, ultimately realising the potential for a co-designed mobile makervan to enhance the existing eMaking program. Then the performative method of bodystorming was employed to equitably engage participants in co-designing the mobile makervan (see Figure 1A & 1B). Finally, reflective interviews were conducted upon the completion of the mobile makervan's design. In conducting a thematic analysis across the three research phases, we discuss how the method of bodystorming may be used to engage individuals with intellectual disabilities and their support staff in co-design through hands-on scenario-based participation opportunities. Additionally, this work discerns key features for the development of an accessible mobile makervan for a DSO.

This paper makes several contributions to the HCI and design community, addressing the following research questions: **(RQ1) How can people in an intellectual disability organisation contribute to a makerspace co-design process? (RQ2) How can design features of a mobile makerspace enable accessible engagement with an eMaking program?** We offer empirical insights into the understudied experiences of people with intellectual disabilities participating in co-design, as well as the role that support staff play in enabling participation and contributing their own perspectives. We identify methodological strategies that promote accessible participation in co-design, emphasising the use of scenarios, props, and prototypes. To the best of our understanding, we document the first study employing bodystorming with people with intellectual disabilities. We hope to inspire future research for increasing the accesibility of co-design practices with people with intellectual disabilities.

2 Related Work

We begin by reviewing community-specific makerspaces that serve underrepresented populations. Next, we explore the steps researchers have taken to enhance the accessibility of makerspaces, by bringing the making environment to makers. Then, we review how people with intellectual disabilities have been included in research and design processes, and the opportunities they have to actively participate. Finally, we provide an overview of the method of bodystorming, highlighting how it's been used with people with disabilities.

2.1 Community-Specific Makerspaces & Making

Community-specific makerspaces have emerged as accessible environments to meet the diverse needs of underserved populations and facilitate their access to maker resources. Although makerspaces are designed to provide "anyone" with an opportunity to innovate [43], there are growing critiques of the ways in which the maker movement fails to be inclusive of people from non-dominant communities [5, 89]. Indeed, Buechley [2016] [17] examined the covers of Make magazine to reveal that 85% of the individuals featured were male, with the remaining covers depicting women and failing to include people of colour. Consequently, making environments for underrepresented communities have emerged. These include makerspaces for women [39, 70], people of colour [42], low Socio-Economic Status (SES) communities [88, 93], and people who experience intersectional exclusion [6].

There is a growing body of work that looks to create accessible maker tools, activities, and environments for people with disabilities [12, 14, 81]. Making and makerspaces provide people with disabilities with an empowering opportunity to create assistive technology solutions for themselves and other persons with disabilities [10, 12, 14]. "Do-It-Yourself" Assistive Technology (DIY-AT) enables people with disabilities to custom-build assistive solutions that are less expensive and preferred to off-the-shelf devices; all while supporting the independence, self-determination and self-esteem of the makers [12, 50]. Higgins et. al [45] demonstrated that the use of DIY-AT processes within university makerspaces gave students with disabilities access to a range of expertise, and fabrication resources, to create assistive technologies that more accurately reflected their needs. However, a number of barriers have been identified in preventing non-professionals from making DIY-AT [11, 49]. These include limited access to collaboration opportunities, prototyping and learning tools [11], a lack of self-confidence in practical skills, and a scarcity of, as well as apprehension to invest, time [49]. Additional preventative barriers exist for people with disabilities looking to participate in makerspaces, such as physical, cognitive, and financial access limitations as well as a lack of belonging [2].

Research demonstrates that making opportunities remain particularly inaccessible for people with intellectual disabilities [34, 36], with only a few customised [34, 80] or adapted electronic toolkits [36, 47] offering resource-specific support for engagement with STEAM enrichment activities. While Boccardi et. al [10] developed a makerspace training program for people with intellectual disabilities to develop their own assistive technology devices, details on the process of creating the makerspace was limited, restricting the potential for the replication of inclusive makerspaces by others in the field. Our work aims to offer insights into how accessibility barriers for establishing and sustaining a makerspace may be overcome by including people with intellectual disabilities, support workers and DSO staff in the design process of a makerspace.

2.2 Mobile Makerspaces

Makerspaces, though commonly established in a fixed location, are capable of becoming mobile, enabling them to traverse different locations or embark on outreach initiatives to engage a wider demographic. In the context of makerspaces, limitations frequently arise due to constraints that include resource availability, physical space requirements, funding, and the capacity of educators [26, 40]. To address these challenges, the creation of a portable makerspace, capable of moving between different locations and supporting the sharing of resources and knowledge across multiple settings, has emerged as a viable solution [29]. Mobile makerspaces have been designed as portable wheeled carts [40], modular 'kits' that contain maker tools [56], pop-up maker technology workshops [74], and vehicle-based spaces that can be driven between diverse geographic locations [13, 26, 38, 61]. It has been suggested that mobile makerspaces possess the potential to establish themselves as independent entities, with Bouchard et al. [13] observing that a brightly coloured Maker Mobile enhanced the maker program's visibility by serving as a distinctive symbol that educators could easily reference and discuss. In terms of developing a mobile maker-vehicle, Compeau [2018] [26] identified two alternatives, (i) fitting a large vehicle with makerspace resources and using the vehicle's space as a mobile classroom, or (ii) storing makerspace technologies in the vehicle which can then be unloaded into classrooms to deliver STEAM workshops. The resources contained within mobile makerspaces tend to include electronics kits, a 3D printer, a laser cutter, and hand tools [40, 56, 65].

Enabling the mobility of makerspaces has emerged as a promising strategy for increasing the accessibility and reach of these creative environments [26, 61]. By bringing tools, materials, and activities to the local contexts of mobile makerspace participants, makers' identities and their sense of belonging to their respective geographic communities is consequently acknowledged [61]. Indeed, Martin & Dixon's work revealed that individuals spanning diverse ages, genders, races, and backgrounds experienced a transformation in the perception of their design and manufacturing abilities following exposure to the mobile makerspace [61]. Our work employs Compeau's [2018] [26] second approach, in which makerspace technologies are stored and transported in a vehicle and then brought into learning environments to deliver an eMaking program.

2.3 Designing with People with Intellectual Disabilities

The inclusion of people with an intellectual disability in research and design processes has been recognised as essential for conducting inclusive design research [84]. The traditional portrayal of individuals with intellectual disabilities as passive consumers of design and subjects of research [94] has undergone a transformative shift to recognise people with disabilities as active collaborators and valuable contributors to design and research processes [44, 84]. People with intellectual disabilities have been included in the design of physical prototypes [69], digital tools [3] and applications [7, 83]. Additionally, existing methods and tools [3, 9, 31], as well as methodological adaptations [44, 71, 84] have been explored to increase the accessibility of research and design practices with this population.

The limited involvement of individuals with intellectual disabilities in co-design and co-research initiatives can be attributed to the complexities associated with engaging this specific demographic. As highlighted by Bayor et. al [7], identifying the physical abilities and strengths in individuals with physical impairments is relatively straightforward. However, the assessment of individuals with cognitive impairments presents a more intricate challenge as their abilities are diverse, contextually dependent, and encompass a broad spectrum of cognition qualities. Prior studies posit that the primary obstacles encountered in the process of co-designing with individuals with intellectual disabilities are attributed to cognition and communication barriers [3, 44, 69].

Effective strategies for including individuals with intellectual disabilities in co-design processes have been found to leverage participants' strengths while accommodating and adapting to their limitations. Studies suggest that an ability-based design framework [99], which focuses on designing with participant competencies, allows people with intellectual disabilities to participate more independently [7, 44, 71]. Additionally, the use of flexible [44, 71] and mixed modality approaches have been recognised to accommodate cognitive and verbal communication barriers [25, 71]. Furthermore, the use of scenarios [25, 84], narratives [84] and concrete objects [25] have been documented to support the understanding of complex concepts and to give meaning to co-designed outcomes for people with intellectual disabilities. Sitbon & Farhin [83] also identified that the involvement of support workers in research can enhance the clarity of communication between researchers and participants with intellectual disabilities by contextualising the responses given by participants and relating the researcher's abstract concepts to concrete elements from participants' lives. Given the nascent nature of this research domain, further exploration of inclusive participation techniques are needed.

2.4 Bodystorming

In our work, we explore bodystorming as an inclusive participation technique, which looks to transform a visual/verbal-dominant ideation activity (brainstorming) into a multimodal and experiential method of engagement. The method was introduced by Burns et. al in 1994 with the paper Actors, Hairdos and Videotape: Informance Design [19]. In this approach, participants embody design functionalities or usage scripts through the physical enactment of design concepts or by performing scenarios in-situ or in a contextually relevant space of the design intervention [20, 67, 72]. In 2016 Cozza et. al presented a revised method of bodystorming, where real users were engaged as participants in "spirit of Participatory Design" [28].

Bodystorming has been used as a method for accessibility focused design research. Gluck et. al utilised user enactment to observe the design choices for developing a shared autonomous vehicle by older adults [41]. User enactment enabled participants to demonstrate desired actions and interactions with shared autonomous vehicles, reflecting on their experiences and identifying how the technology must adapt to older adults' needs in a subsequent focus group. Bodystorming has also been used as an ideation [64] and evaluative [27] method for design research with people with vision impairments. Metatla et. al used bodystorming to engage both visually impaired and sighted pupils in discussions and to identify scenarios where voice-user interface technologies provide value [64]. While Conradiea et. al used bodystorming to validate concepts for a wearable assistive device, aimed at enhancing mobility, with users with vision impairments [27]. In all of the cited studies, the motivation for using bodystorming was to recognise people with disabilities as experts at sharing their own experiences. The method presents an opportunity to leverage the embodied abilities of people with intellectual disabilities, enabling the visceral exploration of possibilities beyond the constraints of existing realities. This paper looks to contribute to the growing body of scenario-based design literature by providing an account of utilising bodystorming with an intellectual disability support organisation.

3 Setting

In this paper we use the term intellectual disability to reflect the terminology used in the country that the work is performed in and the DSO we worked with. Intellectual disabilities are characterised by significant limitations both in intellectual functioning and

Table 1: Client demographic information.

Participant ID	Site	Age	Gender	Self Identified Disability	Language Capabilities	Research Phase Participation
P1	Site 1	21	F	Intellectual Disability & Global Development Delay	Short Sentences	2
P2	Site 1	20	M	Intellectual Disability & Autism Spectrum	Non-Verbal	2
P3	Site 1	24	F	Down Syndrome	Few Words	2
P4	Site 2	19	M	Cerebral Palsy	Full Sentences	1 , 2 , 3
P5	Site 2	20	M	Intellectual Disability	Short Sentences	2
P6	Site 2	20	M	Intellectual Disability	Full Sentences	2
P7	Site 2	20	M	Autism Spectrum	Non-Verbal	2
P8	Site 2	27	M	Down Syndrome	Few Words	2
P9	Site 3	25	M	Intellectual Disability	Full Sentences	2
P10	Site 3	27	M	Autism Spectrum	Non-Verbal	2
P11	Site 4	23	F	Intellectual Disability & Autism Spectrum	Full Sentences	1 , 2 , 3
P12	Site 4	27	M	Intellectual Disability	Short Sentences	2
P13	Site 4	20	M	Intellectual Disability & Down Syndrome	Short Sentences	2
P14	Site 4	33	F	Intellectual Disability & Autism Spectrum	Short Sentences	2
P15	Site 4	27	M	Intellectual Disability & Autism Spectrum	Short Sentences	1 , 3
P16	Site 5	26	F	Autism Spectrum	Full Sentences	1 , 3
P17	Site 5	23	F	Partial Trisomy 9p	Few Words	1 , 3
P18	Site 6	67	M	Intellectual Disability & Autism Spectrum	Short Sentences	2

adaptive behaviour as expressed in conceptual, social, and practical skills [1, 78].

The research was conducted in collaboration with a local DSO, which is based across 20 sites within a single geographic region and supports over 500 adults with disabilities that affect cognition. The DSO support coaches deliver programs of support, which span a diverse range of interests, skills, and employment focuses, to support people with disabilities in achieving their goals and ambitions. The researchers have an ongoing engagement with the DSO through supporting the delivery of an eMaking program. Implemented across six sites, each operating on a different day of the week, the eMaking program engages individuals with disabilities in accessible learning materials, tools, and activities. Each eMaking program site has access to a set of accessible electronics and robotics toolkits (e.g., Sphero and Bee-Bot/Blue-Bot/Rugged-Bots kits) used to create interactive and personally meaningful artefacts. In alignment with the United Nations' Sustainable Development Goal on Education (SDG 4), which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all [68], eMaking engagement shows promise in supporting cognition, stimulating creativity and promoting hands-on skills and problem-solving among individuals with special educational needs [35, 55, 60].

4 Methods

We utilised a three-phase approach to co-creating a mobile makerspace for the DSO's delivery of an eMaking program of support. This included 1) Preliminary interviews with DSO stakeholders to understand the context of the work, identify individual and organisational needs, and the challenges faced with the existing eMaking program; 2) Bodystorming sessions at each site that hosts the eMaking program to co-design the mobile makerspace; and 3) Reflective interviews with DSO stakeholders after the design process of the mobile makervan to evaluate the process and outcome.

Ethical approval for the research was gained from the university ethics committee and from the DSO. Informed consent was obtained from all participants with written information sheets, video and verbal explanations. Participants were able to withdraw from the program at any time and, whenever recorded for analysis, we made it clear they could ask to be excluded from the video and still take part in the sessions.

4.1 Participants

4.1.1 Clients. The term client is used by the DSO to refer to individuals with intellectual disabilities who employ their services (Table 1). The clients of the DSO exhibit a range of skills and abilities; certain clients face challenges in processing information, following instructions, sustaining concentration for extended periods, communicating verbally, and coordinating fine motor skills. Clients exhibited a range of language capabilities, ranging from full sentence communication to short sentences, limited words, or being non-verbal. As a result, data collection included capturing verbal quotes for some clients and observing behaviours and expressions for others. The diagnosed disabilities among the client participants included autism spectrum disorder, cerebral palsy, Down Syndrome, and non-specific intellectual disability.

Clients who were recruited to participate in the research were already enrolled into the DSO's eMaking program of support. The DSO disseminated the research project information via an explanatory statement (with an easy-to-read English [22] alternative) and word-of-mouth. The inclusion criteria required participants to demonstrate an ability to follow instructions and give their informed consent, via a consent form, to participate in the research.

Table 2: Coach demographic information.

Participant ID	Site	Gender	Disability Experience	Research Phase Participation
C1	Site 1 - 6	F	2 years	1 , 3
C2	Site 1 - 6	F	5+ years	1 , 3
C3	Site 1	M	5+ years	1 , 2 , 3
C4	Site 1	F	5+ years	2
C5	Site 1	F	2 years	2
C6	Site 1	F	5+ years	2
C7	Site 1	F	2 years	2
C8	Site 2	M	1 year	1 , 2 , 3
C9	Site 2	M	1 year	2
C10	Site 3	F	5+ years	2
C11	Site 3	F	5+ years	1
C12	Site 3	M	1 year	2
C13	Site 4	M	2 years	1 , 2 , 3
C14	Site 4	M	2 years	2
C15	Site 5	F	1 year	1
C16	Site 6	F	5+ years	2

Table 3: Leadership staff demographic information.

Participant ID	Gender	DSO Role	Research Phase Participation
S1	M	Chief Executive Officer	1 , 3
S2	F	Learning & Development Manager	1 , 2 , 3
S3	F	eMaking Support Lead	1 , 3
S4	M	Land Management Services Manager	2

4.1.2 Coaches. The term coach is used by the DSO to refer to the employed support workers who impart their knowledge and provide support to clients as they develop their skills and interests. Coaches who were recruited to participate in the research were assigned to staff the DSO's eMaking program of support. Two coaches, *C1* and *C2*, are specialist program coaches who alternate between coaching the eMaking programs throughout the week. All other coaches are based at a single site and support the specialist program coaches in running the session (Table 2). *C13* has a background as a field telecommunications project manager and *C8* has a tertiary education in engineering. No other coaches had any previous experience in practising or teaching science, technology, engineering, or mathematics concepts.

4.1.3 Leadership Staff. The leadership staff consisted of individuals with varying levels of seniority, all of whom had roles within the DSO that were involved with the eMaking program (Table 3).

4.2 Protocol

The clients exhibited diverse capabilities and had low or moderate support needs. All participants could comprehend and follow instructions, however variability existed in their communication proficiencies. While some clients demonstrated proficiency in verbal communication, others relied on body language and gestures to communicate.

The first author of this paper conducted all interviews with the participants and facilitated the bodystorming sessions. In order to establish an understanding of the DSO's practices and build rapport with the clients and staff members, the first author volunteered over 100 hours (over the span of a year) supporting the delivery of the eMaking program prior to conducting the study. The consistent presence of a single researcher was intended to support the research participants with building familiarity with the researcher and experiencing a sense of comfort when participating in research activities [62].

4.2.1 Phase 1 : Preliminary Stakeholder Interviews. In the first phase, we conducted one-on-one semi-structured interviews with clients, support coaches and leadership staff. The interviews were conducted with each participant at their respective site location and a support coach was made available for clients during the interview process. The interview duration ranged from 20 minutes to 40 minutes. The questions were centralised on their experience of the current eMaking program (e.g., why is the eMaking program important? What successes and difficulties have you identified with the program?). Simplified questions, using easy-to-read English [22], were asked to the clients, with their responses ranging from gestural actions to spoken feedback. The coaches and leadership staff were also asked to identify effective strategies for engaging and communicating with clients, both within the context of the eMaking program and in their broader interactions.

4.2.2 Phase 2 : Bodystorming. We employed bodystorming [19, 72, 79] as a method to support participants' engagement with co-designing the features and functionalities of a mobile makervan. Bodystorming scenarios were co-designed with each site to evaluate generalised and site-specific mobile makerspace features. Building upon Schleicher et. al's Embodied Storming method, breaks were taken immediately after each improvisational scene to facilitate discussions that captured participants' insights and reflections [79]. These rapid, iterative cycles of performance and feedback sought to reduce participants' cognitive load in recalling their experiences while promoting responsive ideation and evaluation of design concepts.

The sessions commenced with a group discussion to identify the types of activities coaches and clients might wish to do in the program and the outcomes they envisioned achieving using eMaking technologies. This discussion provided a foundation for determining the resources and materials to be incorporated into the mobile makerspace bodystorming scenarios. Participants then engaged in scenario-based activities, which involved role-playing to explore: 1) Accessing maker technologies and equipment within the mobile makerspace vehicle (e.g., how participants would enter, remove and return resources to the mobile makerspace vehicle); 2) Transporting maker technologies and equipment from the vehicle to site specific eMaking program environments (e.g., which resources could be feasibly and frequently moved by clients and coaches); and 3) Using maker technologies and equipment within site specific eMaking program environments (e.g., what types of resources clients and coaches would like to use in the program). Throughout these scenarios, discussions were held to address the challenges raised during the preliminary stakeholder interviews. Key topics included designing the mobile makerspace to support coaches in the absence of a specialist coach and ensuring that resources and materials were not misplaced or lost during program delivery. Details of the bodystorming session, including example questions and key focuses, are provided in Appendix A.

Performance props were provided for the scenario enactments, including stackable storage boxes (designed to hold eMaking program equipment) and their respective base options, tape, paper, colouring pens and a measuring tape (see Figure 6 in Appendix A). While all participants were given the opportunity to see and enter the mobile makerspace vehicle, due to safety concerns with running the full bodystorming session from the vehicle in active carparks, the dimensions of the mobile makerspace vehicle was mapped onto the floor of each site's allocated eMaking program room using tape (see Figure 3B). This allowed for bodystorming activities to be conducted both in and around the mobile makerspace vehicle, as well as within the eMaking program rooms for each site.

4.2.3 Phase 3 : Reflective Stakeholder Interviews. To evaluate the co-design process and makervan outcome, we conducted semi-structured interviews with the clients, coaches and leadership staff following their initial use of the mobile makervan by the DSO. The interviews were conducted after five weeks of C1 and C2 delivering the eMaking program to all six sites, servicing over 20 clients across the DSO. The interviews were conducted with each participant at their respective site location and a support coach was made available for clients during the interview process. The interview duration ranged from 20 minutes to 40 minutes. This provided the participants with an opportunity to reflect upon the design process and share their personal experiences with how they currently utilise, and how they intend to use the mobile makervan in the future.

4.3 Data Analysis

Video and audio recordings were taken of all research sessions, supplemented by field notes from the first author's observations, for review with all paper authors. The recordings and behvaioural observations were transcribed and reflective thematic analysis [15, 16] was performed to identify, analyse and interpret patterns across the dataset. The authors first familiarised themselves with the data, reviewing all recordings and transcripts to ensure participants' voices and non-verbal contributions (e.g. gestures such as nodding, shaking of head, pointing, and showcasing) were accurately captured and fairly represented. After all of the data had been comprehensively reviewed, the first author inductively derived an initial set of codes and themes from each distinct phase of research. We discovered that there were similar codes across the three phases and recognised that the triangulation of the data [24, 91] would provide a more comprehensive understanding of the participants' experiences, capturing the full richness and diversity of their perspectives [92].

We met as a group and conducted this process of triangulation over multiple weeks to identify several overlapping themes across the phases. We further reconciled any ambiguities in classification, leading to a final set of themes being conceptualised, refined and consolidated. The final codes (a sample of which include: program site limitations, low confidence in delivering program, resource challenges, and client engagement) and set of themes (included in Figure 2) were discussed and validated by all authors. An illustrative example of the thematic analysis process can be found in Appendix C.

5 Results

We present the results by triangulation and synthesis of the three phases of data collection, namely the preliminary stakeholder interviews (4.2.1), bodystorming (4.2.2), and reflective stakeholder interviews (4.2.3). Some of the phases naturally mapped to the sections in the results; for example, the motivation for a co-designed mobile makervan (5.1.1) was based on the preliminary stakeholder interviews and the use of bodystorming to co-design the makervan in phase 2 led to the section on situated problem solving (5.2.2). However, aspects such as fear and resource underutilisation (5.1.2), which identified coaches trepidation towards the eMaking program, emerged from both the preliminary interviews as well as bodystorming. The approach to synthesise the qualitative data is visualised in Figure 2.

5.1 Organisational Drivers Shaping Co-Design Participation & Motivating a Mobile Makerspace

Before engaging in the co-design process, we sought to understand the organisational context, existing program structures, and challenges encountered in delivering the eMaking program across the DSO's multisite network. While the coaches and leadership staff described the program as a "*really exciting and empowering*" opportunity to "*expose*" clients to different resources and support them in forming an "*understanding*" of the technology enabled world in which they live in (*S1, C8, S2 & S3*). *S1* acknowledged the barriers to participation in eMaking programs, which result in people with intellectual disabilities often feeling "*locked out*" of this domain. In this section, we examine organisational motivations and barriers as the foundation for both the rationale behind a mobile solution and the design process that followed. The insights discussed inform the form and function of the mobile makerspace, highlighting the need for a solution that addresses logistical inconsistencies, coach confidence, and access disparities, directly shaping the accessibility requirements of the design (**RQ2**).

5.1.1 Physical Site Challenges. The coaches and staff highlighted a number of the challenges they face from the eMaking program's inconsistent implementation across multiple locations. *C8* emphasised that the "*biggest battle*" their site faces is securing adequate space for storing eMaking equipment, compounded by issues of resources going missing. However, the task of coordinating an off-site day trip to access fixed-location equipment proved to be just as challenging. Due to the complexities of arranging accessible transportation and coordinating the timely arrival of multiple clients prior to departure, *C15* likened the task of organising clients for an excursion to "*pulling teeth*". Additionally, the geographical dispersion of sites, combined with a lack of formal communication opportunities between coaches, resulted in a notable absence of cross-site collaboration. Despite the coaches expressing that they "*would love it if we could communicate between all the makers groups*" (*C6*), as "*there's no between-site communication*" (*S2*), the sharing of successful practices and the collaborative evaluation of tools and activities was severely hindered. Furthermore, *C13* highlighted that having mobile equipment and resources "*removes a lot of issues*" in terms of safety and risk assessment concerns with managing an additional fixed space. It was clear from our conversations with coaches and staff that there were barriers to developing a centralised makerspace, from a resource and physical accessibility perspective. Moreover, there was a need to establish a connection between the sites. This naturally led to discussions regarding the need for a mobile makerspace to support the delivery of the eMaking program across multiple sites.

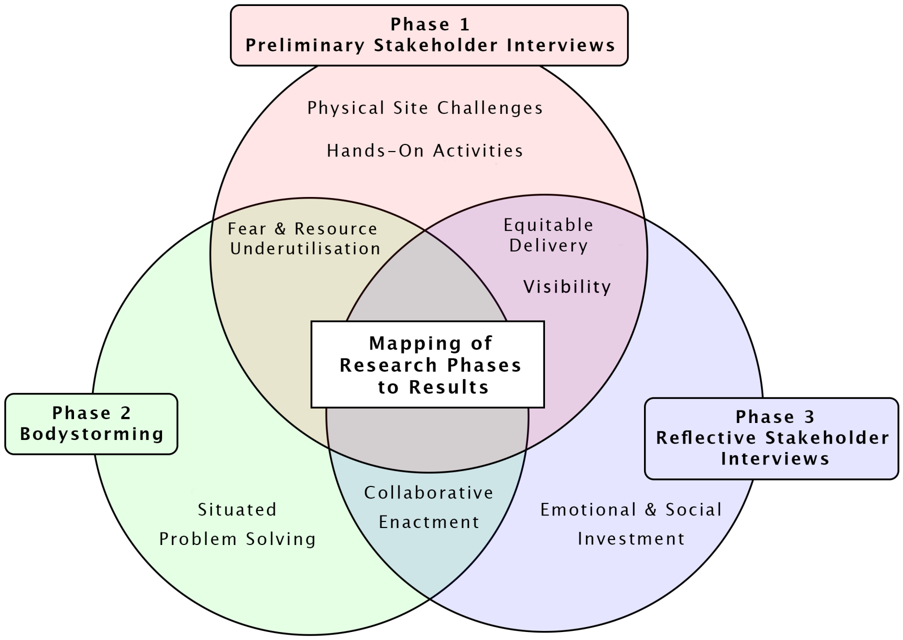

Figure 2: A Venn diagram representing how each of the research phases maps to the sections in the results.

5.1.2 Fear & Resource Underutilisation . All coaches and the majority of staff described themselves or their colleagues as being "*scared*" (*C1*) or "*afraid*" (*C13*) of engaging with the eMaking program. A number of coaches and staff attributed the reluctance to participate in the program to a lack of familiarity with eMaking resources and learning materials (*C8, C1, S2 & S3*). In support of this premise *C8* emphasised "*for some coaches who don't have a big background of science, it can be so difficult*". This difficulty was understood to be especially pronounced when planning the weekly eMaking sessions and encouraging clients to engage with unfamiliar resources.

Despite the diverse backgrounds, competencies, and skills among coaches, a common challenge of learning eMaking resources and applying them in a manner that builds upon their, and their clients', existing knowledge and experiences emerged for all coaches. All coaches encountered difficulties with learning and overcoming technical "*gremlins*" (*C13*) when using eMaking resources. Moreover, coaches across the different sites expressed struggling with the quantity of ideas, ranging from too few (*Site 1*) to too many (*Site 3 & Site 6*), to implement within the eMaking program. The eMaking sessions were characterised as "*chaotic*" (*C8*) and "*messy*" (*C3*), with coaches repeatedly admitting uncertainty, stating "*we don't know what we're doing*" (*C6*). This resulted in one coach experiencing a sense of "*dread*" before participating in the eMaking program, reflecting on the challenges of hosting the program with questions such as '*what are we going to do? How are we going to keep our guys [the clients] engaged and loving this?*' (*C6*).

Given the varying comfort and proficiency levels among coaches regarding the eMaking program, we approached the design of the mobile makerspace collaboratively. This strategy aimed to consider a range of perspectives while acknowledging participants' prior experiences to mitigate coaches' apprehension and uncertainty toward the eMaking program. Ultimately, we hoped that the employment of co-design would enhance the likelihood of adoption and sustained utilisation of the mobile makerspace by the DSO.

5.2 Bodystorming Process (RQ1)

5.2.1 Enabling Meaningful Participation Through Hands-On Activities. In order to maximise the involvement of clients with varied communication abilities in the mobile makerspace design process, the initial stakeholder interviews asked coaches and staff to share strategies for motivating client participation and engagement. All support coaches described their approach to engaging clients as "*hands-on*", accommodating complex communication needs by prioritising learning through doing. While some clients are able to communicate through verbalisation, *C11* expressed that "*a lot of our guys [the clients] will watch, and then they'll think, and then all of a sudden, they'll just start doing. But they may not necessarily communicate*". Visual cues, such as "*demonstrations*" are also commonly employed by coaches to facilitate task comprehension and instruction-following (*C8, C2 & C1*). Additionally, *S3* described using "*scenarios*" where possible to provide contextually relevant information to increase understanding and engagement. Recognising the need to accommodate varied communication abilities and to employ a research method that offers participants visually rich and contextually relevant information, we elected to employ the enactment-based method of bodystorming. This method was chosen to enable the co-design of the mobile makerspace, involving clients, coaches, and staff.

Figure 3: Participants engaging with co-design bodystorming scenarios by A) evaluating resources by moving performance props (eMaking resource storage boxes) from a site's designated parking location to the program room, B) evaluating the physical design of the mobile makerspace through assembling performance props (eMaking resource storage boxes) within the taped-out dimensions of the van, and C) actively designing scale features of the mobile makervan to share design decision-making responsibilities with one another.

5.2.2 Situated Problem Solving to Inform Design Decisions. Through enacting the scenarios in context, with contextually relevant props, participants were able to challenge their assumptions and make design decisions on the mobile makervan based upon their collective performance experiences. Scenario enactment of the program revealed that all coaches favoured the presence of generative eMaking tools (e.g., a 3D printer and laser cutter) and structured kits, which clients could follow independently or inexperienced coaches could use to facilitate activities. Coaches expressed that this approach would accommodate both experienced coaches interested in exploring eMaking technologies and less experienced coaches who could use the beginner-friendly resources (*C1-C3, C8, C13, C15*).

While the *Site 1* coaches anticipated that the one particular storage box base (2-wheel base) would be best suited to their clients, after the coaches and clients enacted scenarios using both base options, all clients expressed their preference for using the alternate base (4-wheel base). Additionally, while a number of coaches and staff expressed concerns with clients using the storage box bases at *Site 3*, due to its uneven terrain, scenario enactment revealed that both coaches and clients were able to successfully navigate the storage boxes from the mobile makervan, across the varied ground surface, to the designated on-site eMaking room (see Figure 3A). During the scenario performance *C10* commented, "*it's actually not as bad as I thought it would be*", a sentiment echoed by *P9*, who responded, "*it's easy!*". However, the embodied nature of scenario enactment made certain scenarios cognitively and physically inaccessible to some individuals. *P3, P5, P7, P10, and P14* were unable to wheel specific eMaking storage base alternatives, which functioned as bodystorming props, limiting their participation in co-design activities. The psychophysical bounded participation revealed insights into the tasks that some clients would be unable to perform independently or with assistance from their coaches upon the mobile makervan's deployment.

Although staff had initially expressed their intention for clients to participate in eMaking activities within the mobile makervan, a performance test involving participants assembling the resource storage boxes within the spatial constraints of the mobile makervan (see Figure 3B) revealed unanimous verbal and behavioural feedback. From observing gestures, facial expressions, vocalisations, and physical engagements, we determined that it would be "*safer*" (*C8*) and more comfortable for the resource storage boxes to be stacked outside of the mobile makervan. It was suggested that a sliding shelf or a platform lift could be used to accommodate physical disabilities, particularly so that clients and coaches "*don't have to crouch*" (*P11*).

Conducting practical scenario testing not only validated the feasibility of the mobile makervan's design and storage resources but also dispelled misconceptions that could have hindered end-users' engagement with the makervan.

5.2.3 Demonstraing Proficiencies Through Collaborative Enactment. Using a hands-on method of co-design saw clients exceeding participation expectations. *P10*, who traditionally did not participate in the eMaking program beyond observing the group, demonstrated skills that exceeded expectations when they participated in the scenario of transporting the eMaking resource storage boxes from *Site 3*'s designated parking location to the program room. This garnered praise from their coach *C10* who expressed "*I'm actually really happy and surprised that [P10] knew [how to do this]*". Moreover, *P11* not only actively participated, but took on a co-facilitator role during the bodystorming session (see Figure 3C). *P11* assumed responsibility for mapping out the dimensions of the mobile makervan onto the ground and led the ideation process for designing storage features for equipment. Demonstrating her enthusiasm, *P11* asserted "*you might as well get me to do the whole thing*". *C13* acknowledged their client's engagement, stating "*this is good because she [P11] enjoyed this, sitting in the van and then plotting a design, she just ran with it. That was really engaging for her, that was great*". A number of the eMaking coaches (*C8, C3, C1 & C2*)

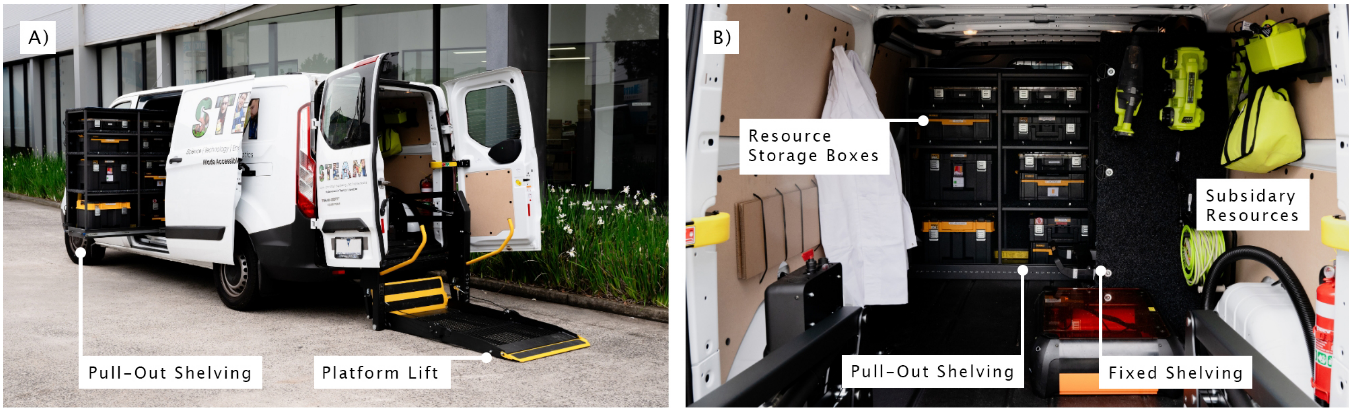

Figure 4: The mobile makervan's A) exterior and B) interior design features.

also described instances where clients exceeded their participation expectations during the bodystorming scenarios. As described by *C8* "*you always see clients doing and making things that you never thought would come out*".

However, the close involvement of coaches in supporting the clients' engagement with co-design activities occasionally made it challenging to distinguish between the voices of the coaches and those with intellectual disabilities. For instance, *C10* rationalied *P10's* difficulty with moving the bodystorming prop of a two-wheel storage box base, stating, "*he's a bit confused with that one, how that one rolls*" without offering further clarification on the physical accessibility or sensory aspects that might contribute to *P10's* limited engagement. Additionally, bodystorming does not take into account the influence of group dynamics, such as the impact of coaches' preferences on clients' responses. For instance, *C6* expressed a preference for consistent coloured resources "*so it doesn't stuff up my OCD*", before asking *P1*, "*what do you reckon?*" *P1* then echoed the preference, responding, "*one colour, just one colour!*".

5.3 Features of the Co-Designed Mobile Makerspace (RQ2)

The design suggestions and considerations yielded through the co-design process were reviewed and finalised in collaboration with the DSO's leadership staff. The following design elements were installed into the mobile makervan based upon the insights shared during interviews and the interactions observed during the bodystorming sessions: a pull-out four tier shelf to minimise physical accessibility limitations for clients, coaches and staff when reviewing the mobile makervan's resources (see Figure 5A), a fixed three tier shelf to house larger resources, and a platform lift to provide equitable access to the mobile makervan's interior while ensuring heavy eMaking resources (such as a laser cutter) can be safely loaded and unloaded (see Figure 4A). All eMaking program resources were allocated to a stackable storage box with subsidiary resources secured inside the mobile makervan (see Figure 4B). A full list of tools and supplies that were onboarded are provided in the appendix B.

5.3.1 Exterior Customisation for Visibility. Upon acquiring the mobile makervan, the DSO's leadership staff elected to embellish its exterior with the science, technology, engineering, arts, and mathematics (STEAM) acronym and images of clients participating in the eMaking program (see Figure 1C). This decision was enthusiastically received by the featured clients and positively viewed by staff, as it gave the mobile makervan "*some attitude and personality*" (*S1*). This served as both a means of advertising the work and achievements of the program's clients and bestowed a distinctive identity upon the mobile makervan. *P15* made clear their ambition to be featured on the mobile makervan and *P16* expressed, "*it's awesome seeing my friends on it*". Additionally, *S2* observed a heightened interest in the eMaking program since the introduction of the mobile makervan to sites, noting, "*they [the clients] can see the fun things and the great things that the clients are making*". The visibility of the mobile makervan instilled pride in the program's participants, recognising their contributions, while generating heightened interest in the DSO's eMaking program.

5.3.2 Equitable Delivery of the eMaking Program. The makervan, as a shared mobile resource, ensured equitable access to eMaking resources and knowledge across the DSO's sites. Ensuring clients receive a consistent service across multiple locations is crucial for evaluating and improving support programs. *S2* stressed that it is the responsibility of the DSO to deliver equal opportunities to all clients, ensuring that "*each client is getting the same access and exposure to things*" to optimise their personal engagement with the program of support. This was particularly appreciated by *Site 1*, which is significantly geographically distanced from all other sites. *S3* emphasised the inclusive value of the mobile makervan's weekly visits, highlighting that "*seeing the van come every week, it's so special for them [Site 1], the connection of having somebody coming to them*". Furthermore, *C8* communicated the benefit of having coaches who travel with the mobile makervan, as they are able to assess what eMaking activities and resources have been successful with one site and disseminate this knowledge to all sites.

Additionally, *S2* described the mobile makervan as a "*breathe easy thing*" for coaches who participate in the program, noting that the structured framework around the eMaking resources supports coaches who lack a background in eMaking. *S3* articulated that

Figure 5: The mobile makervan's co-designed pull-out shelf and storage resources being used by clients.

"*for every single staff that I've come across, the more they do [in the eMaking program] the more excited that they get because there's so much possibility*". Coaches also noted how clients' interest in eMaking developed in the presence of the mobile makervan. *C2* shared the excitement they observed when arriving at each program site with the mobile makervan, with clients asking "*'what do you have for me today?', 'can we try this?', 'can we do this?'*". In being able to stock and rotate through different eMaking resources on the mobile makervan, the probability of including materials that appeal to each client is heightened. As *S3* expressed, "*If this person is more arty, oh we've got something for that. Engineering? we've got something for that*". Furthermore, the co-designed nature of the mobile makervan allows clients to autonomously engage with the eMaking program by "*pulling out the drawers*" (*S3*) and getting to explore the resources for themselves (see Figure 5B).

5.3.3 Emotional & Social Investment in the eMaking Program. While traditional definitions of accessibility often focus on physical or cognitive ease of use, our findings demonstrate that emotional and social investment, fostered through co-design, can be an enabler of accessible engagement with an eMaking program delivered through a mobile makervan. The accessibility of the mobile makervan extends beyond its physical features; an integral aspect of its design lies in how stakeholders see their needs, preferences, and contributions reflected in the vehicle. Following the deployment of the mobile makervan, all interview participants expressed that they have found heightened interest and increased engagement with the eMaking program. The contribution of the co-designed mobile makervan was appreciated by *C3* who acknowledged "*without the van I don't know how [the DSO] would have kept on running [the program] properly*".

Participants exhibited a sense of shared responsibility towards the mobile makervan. As *C3* recognised during the co-design process, "*there's responsibility on everyone's shoulders here. We're all making collective decisions*". *S1* echoed this sentiment, highlighting the importance of using a collaborative approach when designing the mobile makervan to ensure that all involved "*feel like they belong to something*". Additionally, the coaches expressed how the mobile makervan became the "*fruits of their [the client's] labour*" (*C13*) and is something that all participants can experience "*pride*" towards (*C8*). The sense of ownership fostered through co-design has demonstrated its efficacy in supporting motivation, reducing anxiety, and encouraging consistent participation. In this way, co-design itself becomes a functional design feature that supports sustained, accessible use of eMaking resources.

6 Discussion

We have presented the co-design process and outcome of a mobile makervan for a multisite DSO's eMaking program. As discussed in earlier sections, those with intellectual disabilities are often marginalised in the design of maker products, services and experiences. In this section, we suggest ways in which co-design design strategies may be mobilised to challenge biases and promote meaningful participation among an intellectual DSO.

6.1 Co-Design as a Catalyst for Perception Change

In response to **RQ1**, our findings demonstrate that people within the DSO—including clients, coaches, and leadership staff—contributed to the co-design process through relational, interpretive, and operational roles. The insights collected from this work demonstrate the effects of these contributions, including the transformation of coaches' perceptions towards the eMaking program. Originally, coaches characterised the eMaking program as"*messy*" and "*chaotic*", expressing feelings of "*dread*" prior to participating. However, after engaging in the co-design process, the program was reenvisioned as a "*breathe easy thing*". This type of perceptual shift is a common result of co-design, where, by experiencing situational agency, co-designers' comfort zones and mindsets are transformed [73, 95].

Table 4 summarises the original program and site-specific challenges, such as limited storage, inconsistent practices across locations, and coach apprehension. It also summarises how the co-design process and resulting features of the mobile makervan directly addressed these issues. In relation to **RQ2**, physical adaptations, including a pull-out shelf and the platform lift, eliminated storage concerns and enabled access to program

Table 4: Summary of how the mobile makervan co-design process and outcome addressed the DSO program challenges identified.

Program and Site Challenges		Co-Design Process and Mobile Makervan Outcome
Limited storage space across sites, makes it difficult to manage and access program equipment.	→	Equipment and materials are stored directly within the makervan, ensuring resource access across sites.
Regular transport of clients poses significant logistical challenges.	→	The program is delivered at each site location, eliminating the need for clients to travel.
There was a lack of shared practices and collaboration between sites, resulting in inconsistent program delivery.	→	Specialist program coaches travel with the makervan, enabling knowledge sharing and collaboration across sites.
Coaches felt apprehension towards the program, as it did not reflect their expertise or interests.	→	Coaches were actively involved in co-designing the program's makervan, ensuring it reflected their aspirations and needs.
Inexperienced coaches felt pressure to deliver and grow the program.	→	The makervan is equipped with standalone kits for independent program engagement and tools for guided hands-on eMaking.

resources. Additionally, cognitive supports [59], such as having specialist coaches travel with the mobile makervan and providing structured resource kits, reduced the expectation on coaches, particularly those with limited eMaking experience, to deliver the program. The co-design process and resulting features of the mobile makervan led to a shift in how participants perceived the program, with the van becoming a source of pride that motivated greater engagement with the eMaking program. This phenomenon is common in both co-design and maker contexts, where participatory engagement can shift how individuals perceive the systems they are part of, while also fostering mindsets oriented toward growth and opportunity [21, 33, 51]. This demonstrates that both the co-design process and the makervan itself serve as enablers for accessible participation in an eMaking program.

6.2 Power Dynamics & Disambiguating Voices

As part of understanding how people within an intellectual disability organisation contribute to co-design (**RQ1**), we explored how roles, responsibilities, and power were negotiated during the design process. Clients, coaches, and staff made reference to the sense of responsibility they felt during the design of the mobile makervan. Coaches, in particular, described the pressure of making collective decisions and client *P11*, who became a co-facilitator during the bodystorming activities, articulated their own sense of responsibility when leading scenarios and planning design features by stating, "*you might as well get me to do the whole thing*". This shared assumption of responsibility across participants demonstrates the redistribution of design decision-making power away from the researchers to the end-users; a core principle of co-design [63, 75]. However, managing power dynamics, particularly in processes involving people with disabilities, remains a complex challenge [96].

A challenge we observed in the study was the difficulty in disambiguating the voices of coaches from that of clients, especially those with limited language capabilities. While it is important to acknowledge that the close relationship between coaches and clients enables coaches to effectively interpret and convey clients' needs and preferences to researchers [83], coaches often operated in dual roles, as facilitators of client participation and as design contributors themselves, making it challenging at times to separate their voice from that of their clients. This could potentially skew the views of individuals with intellectual disabilities and limit their ability to influence the design process [25, 98].

To address the entangled influence of carers and individuals with intellectual disabilities, Balasuriya et. al encourages coaches, support workers and caregivers to make distinctive contributions in the co-design process, sharing their perspective as both proxies for their clients and co-users of technologies and resources [4]. We further recommend offering participants multiple opportunities for engagement, as seen in this research through a 3 phase multi-method study design and diverse bodystorming scenarios. This approach helped to clarify the contributions of each co-designer, ensuring that participants could see their input meaningfully integrated into the final design [51] and reflect upon the co-design process with feelings of "pride" and a sense of "belonging to something" (*S1 & C8*).

Future research could expand on this work by exploring additional strategies to maximise meaningful participation in co-design through the disentanglement of overlapping perspectives in complex care settings. Prior studies have examined how children's voices may be prioritised amidst parental and institutional power dynamics. Activity-based interviews involving art, play and reflection cards have been used to effectively engage the voices of children involved in family support services [85]. In addition, parents have used passive strategies (such as spontaneous verbal and nonverbal signals) and active strategies (such as initiating a conversation or encouraging expressions) to better understand their child's perspective [54]. The role of co-design facilitators has also been recognised as crucial in identifying the power dynamics each participant brings to a research session and in adapting methods to ensure all voices are equally heard and valued [37, 52, 96]. This suggests that responsive facilitation techniques and dynamic activity-based methods may present as valuable strategies for perspective disentanglement in co-design, particularly for participants with diverse cognitive, communication, and physical abilities.

6.3 Scenario-Based Co-Design as an Accessible Method

This section explores the methodological strategies, particularly scenario enactments, that enabled people in the DSO to contribute meaningfully to the co-design process (**RQ1**). Verbal communication can be a barrier when working with individuals with intellectual disabilities, necessitating the exploration and implementation of alternative 'hands-on' communication channels [8, 48, 66]. Indeed, the majority of clients who participated in the research had limited verbal abilities, with *C8* describing the act of supporting clients engaging in activities as "*very full-on hands-on*". The practical nature of performative bodystorming mirrored the hands-on demonstrations and scenario-based approaches already utilised by the DSO, motivating its methodological employment. Scenario-based activities offered clients and coaches a familiar framework, enabling them to engage more comfortably in the co-design process.

We observed that familiarity with scenario-based activities encouraged active participation from coaches and clients when using bodystorming to generate and evaluate the mobile makervan's design concepts. This was seen in a performance test where participants assembled resource storage boxes within the taped-out spatial constraints of the mobile makervan at each site's eMaking program location (see Figure 3B). Clients and coaches acted as the height limit for the mobile makervan's roof, while other clients assembled the resource storage boxes within the mocked-up spatial constraints. Acting as both moderators and participants in the scenarios, coaches and clients demonstrated their ability to evaluate the spatial design through bodystorming.

These findings demonstrate that when co-design methods mirror existing support structures, people with intellectual disabilities and their coaches can meaningfully contribute to design activities, even when traditional verbal feedback is limited. This aligns with previous research in healthcare settings, where scenario-based co-design supported the meaningful participation of individuals with intellectual disabilities in service design [32]. The scenarios were used as part of experience-based co-design in a hospitalisation setting for people with intellectual disabilities, actively involving service users in the design of their own care. This approach led to the development of resources that helped service providers to better understand and address the complex needs of individuals with intellectual disabilities. Similarly, our work highlights the importance of performative real-world scenarios in accessible co-design, enabling participants with diverse cognitive, physical, and communication abilities to highlight their requirements for meaningful access to and use of resources [18, 71].

Although bodystorming revealed the potential for people with diverse abilities to express their preferences for the design of a mobile makerspace, it did not provide clear rationales for participant actions. The abductive nature of co-design [57, 86] aligns with bodystorming's solution-oriented approach. Consequently, while bodystorming effectively demonstrated what participants might do or imagine doing with makerspace resources, interviews were needed to provide deeper insight and offer a more holistic understanding of individual preferences and needs [18, 77]. However, interviews do not serve as an accessible method of research for all participants with intellectual disabilities, particularly those with limited verbal communication abilities. This illustrates the importance of using an assemblages approach to co-design [30, 46], where multiple accommodating processes, aimed at maximising participation and clarifying contributions, are employed.

The co-design participation observed in the results demonstrate that intellectual disability organisations can contribute not only as facilitators, but as active co-creators in co-design processes by providing contextual knowledge, shaping method selection, and scaffolding participation for diverse users. DSOs serve as a familiar and supportive setting for bodystorming activities, whereby individuals with intellectual disabilities can perform scenarios and demonstrate the conditions required for meaningful access to and use of resources [58, 90]. The findings underscore the importance of integrating bodystorming with complementary methods, such as interviews, to enhance both generative and reflective aspects of co-design. This study identifies scenario-based co-design as a promising method for involving individuals with intellectual disabilities and their support personnel in research and design, challenging traditional academic perspectives by positioning participants as active co-creators rather than advisory contributors [23, 53].

6.4 The Role of Concrete Props & Prototypes

To address **RQ2**, we examine how the use of physical props and prototypes enabled participants to engage with and evaluate the design features of a mobile makerspace. Concrete props and prototypes played a critical role in promoting communication, understanding, and collaboration among participants with diverse abilities in this study. The storage boxes and the taped-out space representing the mobile makervan provided tangible reference points for clients, coaches, and staff. These physical representations allowed participants to anchor their discussions and visualise design elements, reducing the likelihood of misunderstandings.

As identified by Gibson et. al [2020], visual and physical modalities are often more accessible to individuals with complex communication needs [25]. These modalities help participants to understand complex language, overcome exclusion barriers, and answer questions with greater accuracy. The practical application of these principles was evident with *P10*, who "*surprised*" their support coach with their ability to use and complete scenarios with the stackable storage boxes. Furthermore, *Site 1* clients, all of whom had limited language capabilities, were able to successfully evaluate the two storage box base options — a two-wheel base and a four-wheel base — by navigating the site-specific environment. Contrary to coaches' initial expectations, participants demonstrated a clear preference for the four-wheel base through their interaction with the props, emphasising the value of physical props in uncovering usability insights.

The integration of props and prototypes during these activities fostered what Wilson et al. [2015] describe as a "tangible design language" [97], enabling participants to communicate their needs and ideas more effectively. Indeed, Rajapakse et. al [2019] identified that design props and probes help to elicit interactions and communicate the interests, abilities and design aspirations of co-design participants with cognitive and sensory impairments [75]. To further stimulate engagement with this design language, "incomplete features" [83] were used, such as providing only the dimensional outline of the mobile makervan space during bodystorming scenarios. This approach encouraged participants to offer design suggestions and contribute ideas to complete the design of mobile makervan and enable its use by the DSO [83]. Sitbon and Farhin [2017] demonstrated that such prototypes not only enhance engagement in co-design activities with individuals with intellectual disabilities but also allow participants to communicate clear preferences, placing them in the "driver's seat" of the design process [83].

The findings from this study highlight that props and prototypes are valuable tools in accessible co-design when engaging individuals with intellectual disabilities. These tools provide a means for participants to articulate their needs and preferences in a manner that aligns with their communication styles, ensuring their *'voices'* are genuinely reflected in the final design. Future research could further explore how physical and visual modalities can be integrated with other co-design methods to maximise accessibility and engagement across diverse participant groups.

7 Limitations & Future Work

We recognise that our study offers a preliminary investigation into inclusive co-design practices, with bodystorming being just one approach to engage people with intellectual disabilities in design processes. We acknowledge that a more tailored mobile makerspace for specific disabilities could be needed, however, the DSO we partnered with caters to a wide spectrum of disabilities and sought a more generalised solution. Additionally, our work engaged individuals with intellectual disabilities who have a diverse range of support needs. However, we did not explore co-design practices with people with high-support needs. This is an area that is under-studied and needs further exploration.

The mobile makervan has been deployed into the DSO's eMaking program of support and it is hoped that its impact will grow overtime, as more clients participate in making experiences that transcend fixed locations. In the future, we envisage an opportunity to review and evaluate the DSO's utilisation of the mobile makervan and perhaps re-co-design the van, as the abilities and interests of participants evolve.

8 Conclusion

In this paper, we presented the co-design process and outcomes of developing an accessible mobile makerspace in collaboration with a DSO. Using a three-phase methodology, comprising of preliminary interviews, bodystorming, and reflective sessions, we explored how people within a DSO can meaningfully contribute to a makerspace co-design process (**RQ1**), and what design features enable accessible engagement with the eMaking program through the mobile makervan (**RQ2**).

In response to **RQ1**, our findings show that clients, coaches, and leadership staff played active and complimentary roles in shaping the design. Coaches facilitated communication and supported collaborative decision-making; clients demonstrated their proficiencies and needs through scenario-based enactments; and staff contributed strategic framing aligned with organisational goals. Regarding **RQ2**, we identified a range of physical, cognitive, and emotional design features that emerged through the co-design process. These included a pull-out shelving system, platform lift, and structured resource kits designed to support physical access and reduce the cognitive load for those who deliver the multisite eMaking program. Additionally the emotional and social dimensions of accessibility, materialised through the inclusion of clients' photos on the van and recognition of their design contributions in the final outcome, cultivated pride, motivation, and ongoing program engagement.

Collectively, these findings demonstrate that designing for accessibility in a mobile makerspace context extends beyond material features to include the participatory methods used to develop them. This work contributes practical and methodological insights for future inclusive design efforts with people with intellectual disabilities and calls for broader recognition of DSOs as key partners in accessible innovation.

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A Appendix: Bodystorming Procedure & Resources

A.1 Bodystorming Props & Resources

The props and resources illustrated in Figure 6 were used during bodystorming sessions to support hands-on co-design of the mobile makervan. These items enabled participants to physically explore and evaluate storage configurations, spatial layouts, and resource accessibility. The selection included stackable toolboxes, wheeled bases, component organisers, and materials such as tape measures, coloured masking tape, and drawing supplies to facilitate planning, improvisation, and creative expression.

A.2 Bodystorming Session Outline

Viewing the Van and Bodystorming Preparatory Discussion. Each session began with clients, coaches, and staff invited to view the mobile makervan parked on-site. Participants were encouraged to open the van doors, explore the storage space, and physically enter the van if interested and able. Following this, all participants returned to their regular eMaking program room, where the first author facilitated a semi-structured group discussion. This discussion invited open-ended reflections on the original eMaking program from clients, coaches, and leadership staff. Key guiding questions included:

- How do your current eMaking sessions run? What works well, and what could be improved?
- How might you (client, coach and staff) want to use the van. For example, by working inside it, using it to store resources, or accessing it occasionally or frequently during program sessions?

Ideartion, Performance Testing and Improvisation of Design Solutions. Bodystorming sessions followed an iterative and flexible structure. Scenarios were revisited and adapted in response to emerging discussion or design suggestions. The following focus areas and example questions were used to prompt participation:

- eMaking Progream Activity Interests.
  - What activities might you (clients and coach) want to do in the eMaking program?
  - What eMaking resources might you (clients and coach) want to try or use? Printed images of a range of eMaking resources (including electronics, programming, construction, modelling, robotics and craft focused resources) were provided for clients to select to support non-verbal communication.
  - What might you (clients and coach) want to make in the eMaking program?
  - What resources or personelle support would help you participate in the program?
- eMaking Van Usage
  - How might you (clients and coach) enter and spend time in the makervan storage space?
  - How might you (clients and coach) retrieve resources and return them to the makervan storage space?
  - How might you (clients and coach) utilise eMaking resources inside or around the van?
  - How might you (clients and coach) identify and locate resources within the makervan environment?
- eMaking Resource Storage
  - How can different storage containers be used by clients with varying needs?
  - How can different storage containers be used in different environments?
  - How could resources be divided among containers for ease of use?
  - How are materials accessed, and by who, during the eMaking program?
  - Where could storage containers and eMaking resources be kept within site-specific locations during the eMaking program?
  - How might inventory be tracked or monitored?

Reflection & Debrief. At the end of each session, participants took part in a group reflection to evaluate the bodystorming process. Semi-structured questions guided the discussion, allowing clients, coaches, and staff to share feedback and suggestions for future co-design activities. Prompts included:

- What worked well in this design process and what could be improved or done differently?
- How does it make you (client, coach, staff) feel to be part of the design process? Is it common for you (client, coach, staff) to be included in the planning/designing process? Would you like to be included in the future?

Figure 6: The resources and props used during co-design sessions.

B Appendix: Makervan Tools & Supplies Onboarded

- Laser cutter on a custom wheeled table.
- 3D printer and 3D printing filament.
- Mixed electronics (e.g. LEDs, DC motors, vibration motors, buzzers, conductive tape, jumper wires, alligator clips).
- Microcontrollers (e.g. Makey Makey and Micro:Bit).
- Robots (e.g. Sphero and Beebot robots).
- Construction kits (e.g. Lego, MakeDo Tools, Strawbees, and GraviTrax).
- Hand modelling resources (e.g. 3D pens, Play-Doh and modelling tools).
- Craft resources (e.g. paint, felt, carboard).
- Hardware tools (e.g. hammer, pliers, and box cutter).
- Laptops and portable Wi-Fi modem.

C Illustrative example of the thematic analysis process

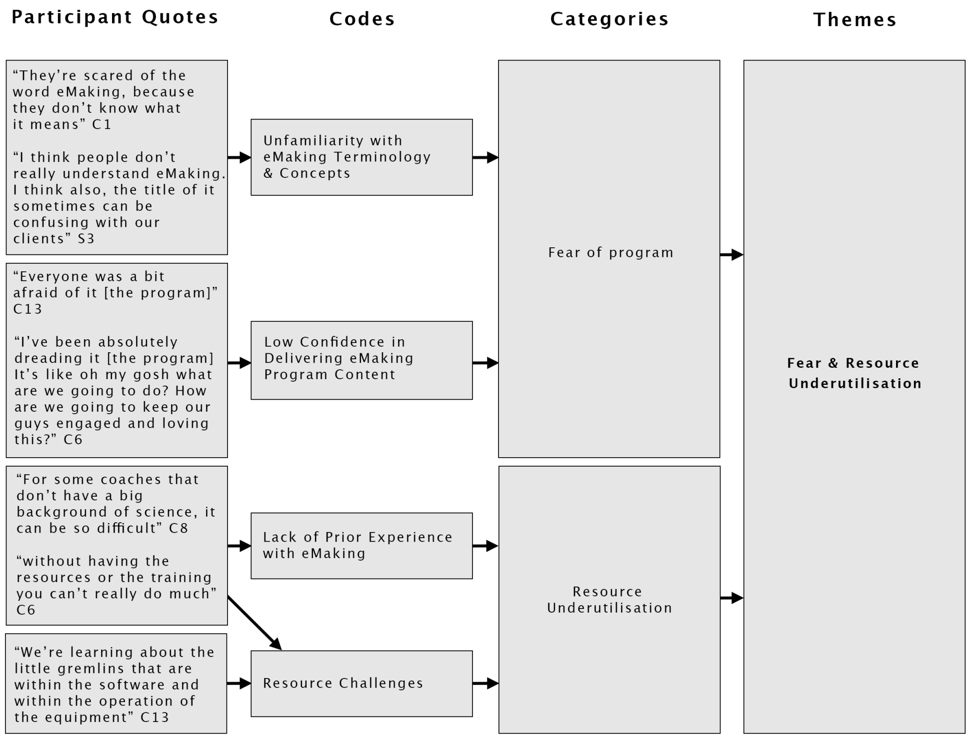

Figure 7: An illustrative example of the thematic analysis process.