Toward a Competency-based Approach to Co-designing Technologies with People with Intellectual Disability

ANDREW A. BAYOR, MARGOT BRERETON, LAURIANNE SITBON, BERND PLODERER, and FILIP BIRCANIN, Queensland University of Technology, Australia
BENOIT FAVRE, Aix-Marseille University, France
STEWART KOPLICK, Endeavour Foundation, Brisbane-Australia

Ability-based design is a useful framework that centralizes the abilities (all that users can do) of people with disabilities in approaching the design of assistive technologies. However, although this framework aspires to support designing with people with all kinds of disabilities, it is mainly effective in supporting those whose abilities can be clearly defined and measured, in particular, physical and sensory attributes of ability. As a result, the ability-based design framework only provides limited guidance to design with users with intellectual disability, whose cognitive, physical, sensory, and practical abilities vary along a spectrum. In this article, we reflect on a long-term co-design study where we leveraged what we termed “competencies,” i.e., the representative practical skills people develop from their participation in life activities, in particular, mainstream technologies, such as social media and the Internet. Our reflection is based on our experience in designing SkillsTube, a web application we co-designed with young adults with intellectual disability to support them to learn life skills through videos. The app’s design, which explored and leveraged their social media participation competencies, supported the fundamental participation of all participants and their peers. Their familiarity with the app’s social media-inspired design features fostered confidence in their participation, usability, and engagement. Drawing on the findings and design process of the app, we discuss a Competency-based approach to designing with people with disabilities that extends upon ability-based design, by grounding it in user competencies.

CCS Concepts: • Human-centered computing → Accessibility design and evaluation methods;

Additional Key Words and Phrases: Competency-based design, accessible design, competencies, social media, intellectual disability

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1 INTRODUCTION
Toward ensuring accessibility for all users, including people with disabilities, several accessible design approaches have been developed [20, 53, 56, 77, 87]. Fundamental to most of these approaches is the prioritization of the needs, aspirations, and abilities of users with disabilities [63, 97]. This is evident in landmark frameworks such as ability-based design, which strictly focuses on designing with the abilities rather than dis-abilities of users, advocating for the contextual adaptation of systems to user abilities [96, 97]. For this reason, in adopting ability-based design, clear comprehension and identification of the abilities and requirements of the user(s) are fundamental, as the design is premised upon them.

However, whereas physical abilities and strengths may be easy to identify in people with physical impairments (for example people with visual impairment may have an enhanced sense of hearing, touch, and proprioception), the abilities of people with cognitive impairments may be varied, contextually dependent, and cover a wide range of aspects of cognition and adaptation. The abilities of people with intellectual disability (a disability characterized by limitations in both cognitive and adaptive functioning), are often expressed in highly contextual ways and are mostly complicated by the presence of other co-occurring impairments [1, 93, 98]. This makes it challenging to define, represent, or generalize a person’s fundamental functional abilities, which, however, requires characterization when using the ability-based design framework to contextually situate the design. An analogy may be drawn with Norman’s description of affordances and cultural conventions [64]. Norman intended the term affordance to reflect physical affordances, such as a doorknob’s ability to be turned by a grasping hand. The use of a cursor and scroll bar to move through a document is somewhat different from the use of a doorknob. The cursor is not physically constrained to be used only in the scroll bar. One has to understand the cultural convention of moving the cursor in the scroll bar to use it to navigate the document. The bringing together of the physical ability to move the cursor in the scroll bar, the understanding of the purpose of a scroll bar, and the cultural convention of how to use the scroll bar can be considered to be a competency.

For people with cognitive and intellectual disability, abilities best manifest in circumstances where they are sustained, often through everyday tasks they are able to undertake independently or with support [82]. As such, these abilities are best expressed in contexts with which users are familiar. Moreover, it must be recognized that these abilities, expressed contextually, may not easily generalize to other contexts, especially dissimilar contexts, such is the nature of intellectual disability. As a result, we propose that we should not only concentrate on generalized physical abilities, but on abilities that are expressed contextually, which we refer to as competencies. Competencies are revealed by participation skills in everyday activities (or in the case of interaction design, use of systems).

In this research, we ask, how can a technology/system be designed such that it supports the participation of a group of users who have complex variations in their cognitive, adaptive, and practical abilities, which also manifest differently in different contexts? We suggest through this study that opportunity abounds in exploring the mainstream technology participation interests of such user groups, as they may share skills and competencies in using popular technologies that could be broadly leveraged in design.

To this end, toward supporting the request of young adults with intellectual disability to learn life skills using videos [4], we investigated how to reveal their representative social media participation skills (social media competencies) and co-designed an application that leverages them [3]. In our previous research [4], participants experienced limits to what they could do when we tried leveraging YouTube for such skills learning purposes. Participants experienced distractions from ads and animated videos on YouTube, which made it challenging for them to focus on searching and engaging with videos about skills of interest. Also, because most participants stuttered or
were slow in speaking, using the voice search tool on YouTube was challenging for them. Due to delays between speaking their first and subsequent words, the microphone’s listener terminated after their first word and started querying before they could finish speaking their entire search query. This was very frustrating for most participants, especially given that the majority of them had spelling challenges and wanted to use voice search. Moreover, though participants had an interest in sharing their favourite skills videos with each other, sharing on YouTube was complicated, given that they did not have YouTube accounts.

Therefore, we aimed to support life skills learning and sharing by designing a more accessible interface that reflected the competencies that most participants had developed from using YouTube and other mainstream technologies. That way, the app design could be representative enough to support the variable participation requirements of participants and many of their colleagues within a Disability Support Centre (DSO) who were all interested in using the app. As such, a design approach that explored specific and contextual participation skills of young adults was necessary.

As all participants and the majority of their peers already participated in social media (mostly Facebook or YouTube), we capitalized on the opportunity it provided for exploring their social media competencies. Through workshops, we engaged participants in contextual common daily use activities on YouTube and Facebook to reveal their competencies. We found that participants shared essential competencies such as sharing content, adding friends, navigating menus, playing media, and recognizing icons. Participants exhibited significant functional association and familiarity with most social media icons. For example, they concretely related the bell icon with notifications, and what they called the “two friends” for adding friends. Leveraging these competencies, we co-designed SkillsTube (Figure 1), an accessible custom app that supports them to learn life skills of interest through videos. We observed that the easier-to-use social features of the SkillsTube app, such as sharing, and participants’ familiarity with many design features and icons fostered engagement and collaboration between participants, their colleagues, and proxies.

The principal goal of this article is to contribute a Competency-based approach to designing accessible technologies, to complement and build upon existing work in ability-based design. We
illustrate this Competency-based approach by reflecting on the long-term co-design process and findings of SkillsTube [2–5]. The Competency-based approach focuses on revealing and designing with user competencies, such as their representative mainstream technology participation skills, and facilitate enhancing such competencies further. It builds on Wobbrock et al.'s ability-based design [97], but is grounded in leveraging user competencies, as this is needed in designing with people with intellectual disability. We believe this approach has important implications for designing accessible technologies with all users, especially people with cognitive impairments or co-occurring disabilities.

2 RELATED WORK
Our literature review reflects on the increasing participation in technology by people with intellectual disability, the challenges they face, and the opportunities their technology participation skills present for design. We review design frameworks developed toward supporting accessibility, highlighting gaps in adopting them with people with intellectual disability, and show how a Competency-based approach offers opportunities for bridging those gaps. Our intention is not to position Competency-based design as a separate school of thought, but rather to show how it fits within and can extend the reach and applicability of prior accessible design frameworks, such as universal design, inclusive design, and ability-based design to people with intellectual disabilities.

2.1 Technology Participation and Intellectual Disability
According to the American Association on Intellectual and Developmental Disabilities (AAIDD), an Intellectual Disability is “a disability characterized by significant limitation in both intellectual functioning and in adaptive behaviour, which covers a range of everyday social and practical skills, that originates before the age of 18” [1]. People with intellectual disability may also have co-existing sensorimotor complexities and other co-occurring impairments that make it challenging for some of them to effectively communicate or express themselves [1, 93]. Due to the adaptive functioning challenges that some people with intellectual disability experience, they may find it overwhelming to manage some cognitive processes such as planning, remembering details, or paying attention [1]. However, this definition and characterization of people with intellectual disability reflect a medical perspective, focusing on what one cannot do in comparison to socially constructed norms [66, 76]. Although cognition plays an essential role in user-technology interaction, the cognitive challenges people with intellectual disability may experience do not mean that they do not have the skills to participate in or use technologies. They may struggle at times, due to complexity in the designs, but they can overcome these struggles through workarounds, practice, assistance from a helper, or ultimately through more inclusive forms of design that present fewer barriers and embrace their competencies.

Research has established that people with intellectual disability have potentials and skills that can be explored, harnessed, and enhanced into competencies. In their exploration of computer skills of people with Down syndrome, Lazar et al. [57] identified proficient skills relating to input and visual abilities (e.g., mouse and CAPTCHA use) with many of the participants. The study showed that participants had skills in using the Microsoft Office suite of programs such as Excel and Word, and communication applications such as Instant Messenger and Facebook. More recently, Bayor et al. [4, 5], in their exploration of social media participation and skills development of young adults, identified competencies such as adding friends to their networks, searching for and sharing content, and safety awareness on social media. Other studies, such as Dawe [24], identified a mix of social engagement, memory recall, speaking, and listening functional abilities in the phone use patterns of young adults with cognitive disabilities.
These studies demonstrate the existing skills of people with intellectual disability, and their potential to further enhance and develop them. As such, reflecting on the design opportunities that such representative skills from technology participation, what we describe as competencies, could offer for more broadly accessible design is timely. This is particularly important given the challenges in adopting ability-based design with users with varying abilities such as people with intellectual disability and older adults [73]. Thus, designing to rely on more accessible competencies offers potential for supporting the participation of a broader user base, including people with intellectual disability.

2.2 Technology Participation Challenges of People with Intellectual Disability

While it is encouraging to note that people with intellectual disability, especially young adults, are adopting “mainstream” technologies such as the Internet [17, 58, 69, 70] and social media [5, 16, 21, 48, 78], their participation is not yet on a par with the larger society. One of the reasons cited for this disparity relates to online safety and risk concerns. People with intellectual disability have reported being sexually and financially exploited [18, 48], bullied, and harassed [15, 26], especially on social media. Consequently, concern for falling prey to these risks keep most people with intellectual disability from participating in technologies such as social media. However, with increasing advocacy for enhanced privacy and safety on social media, most sites now have improved safety controls, making them safer for use by people with disabilities compared to when they first emerged about a decade ago.

Furthermore, one of the most cited factors contributing to the technology participation gap between larger society and people with intellectual disability relates to inaccessibility due to design. Designers and the frameworks they employ have been criticized for their failure to engage with and accommodate the needs and abilities of people with intellectual disability during the design process [51, 52]. Consequently, this mostly results in the design of technologies that are inaccessible or pose serious accessibility challenges for people with intellectual disabilities [14, 51]. Moreover, the inadaptability of designs to user abilities and their lack of design simplicity has been noted to affect their adoption and use by people with intellectual disability [22, 23]. However, in the last few decades, many accessible computing approaches have been deployed to improve design accessibility and participation for everyone, including people with intellectual disability [20, 53, 56, 77, 87]. Also, toward engaging people with disability in design research, participatory and collaborative approaches such as exploratory prototyping [65], probes [30], and co-design [13, 35, 39] have also been employed to directly engage them.

2.3 Accessible Design and Intellectual Disability

Accessible design is a process that ensures that the design of products, services, and environments encompasses the broader needs and requirements of most people in society, including people with disabilities and older adults [45, 67]. Accessible design supports both the societal inclusion and technology participation of people with a disability, a fundamental human right ratified by the United Nation’s convention on the rights of people with disabilities [90]. Therefore, a number of frameworks, principles, guidelines, and methods have been developed to encompass broader user requirements, including those of people with disabilities.

2.3.1 Universal Design. With foundations in architecture, universal design [20, 59, 88] involves the design of buildings, products, and environments in a way that makes them accessible to the widest range of user groups in the widest range of situations. It embodies principles such as equitable use, flexibility, error tolerance and intuitiveness, and goals such as comfort, personalization, social integration, and cultural awareness [85], encapsulating the needs and requirements of wider society such that designs that employ it are to a larger extent usable by everyone. Universal
design is mostly linked with Design for all [86, 87], a philosophy that focuses on ensuring barrier-free access and use of products and services in the information society by all people. Examples of universal design systems include smooth entrances without stairs to make buildings accessible to wheelchair users. This has the advantage of also making buildings accessible to people with delivery trolleys, strollers, suitcases on wheels, and so on. In interactive systems, a universal design approach might combine both visual and auditory outputs for engagement by both visual and hearing-impaired users.

Although a well-known framework, universal design has been criticized for its “one size fits all” approach. Critics argue that users are intrinsically different with varying abilities [42], submitting that designs should reflect individual user needs [62, 96, 97]. No doubt, designing for the “universe of all” is challenging in that it demands attention to resolving a wide variety of fundamentally different human abilities and strengths into an elegant design solution. However, if a design can employ competencies at using existing elements of systems and technologies that most people, including those with intellectual disability possess, then due to their prior engagement or attempted engagement, it will support greater participation. Subsequently, once the preliminary and basic participation of a user is ensured, system adaptation based on the principles of ability-based design could then automatically tailor such designs to individual requirements and preferences. In this regard, Competency-based design is similar to universal design in that it strives to engender competencies that are found broadly across diverse users, toward a “one size fits many” design. Further, bringing a focus on competencies provides an opportunity for universal design to leverage what can be described as “universal” user competencies found in particular contexts, such as the use of globally popular mainstream technologies used across the breadth of society. Thus, Competency-based design provides an effective avenue for achieving universal design’s vision of “design for all,” through exploring and designing with the existing representative technology competencies of a variety of users, including people with intellectual disability.

2.3.2 Inclusive Design. Inclusive design [46, 52, 53, 53] focuses on ensuring design inclusion by drawing attention to factors and barriers that cause exclusion. Inclusive design does not target a “one size fits all” design; rather, it focuses on individual users’ requirements, ensuring the design encompasses enough diversity to accommodate various user groups. Because of its “one size fits one” approach, inclusive design is sensitive to the diversity of individual users and their specific needs. It craves and demands creativity and problem-solving. Inclusive design is mostly employed in the design of interactive systems. It may lead to different interface elements, subsystems, and approaches to accommodate a wide diversity of users, and a challenge is to keep the attendant complexity manageable and the overall design elegant and maintainable.

Inclusive design is also challenging, because it requires the full participation and engagement of users to elicit their requirements. Tools such as interviews, surveys, workshops, and other participatory and co-design approaches that are typically used, may need adapting or completely rethinking to successfully engage people with a diverse range of cognitive, behavioural, and functional abilities. For example, due to the different receptive and expressive language capabilities of people with intellectual disability, adopting approaches such as contextual enquiry or interviews to engage them during design may be unsuitable [3], particularly if the researcher is a person who is unknown to them. However, engaging them through contextual activities of interest (e.g., on their favourite social media app and in a familiar supportive setting) could, in addition to supporting their research engagement, reveal their participation skills for leveraging in design. Thus, focusing on the mainstream technology participation interests of people with intellectual disability and their participation skills in using technology could provide a pathway toward inclusive design with people with intellectual disability.
Similar to inclusive design, the Competency-based approach endeavours to encompass a diversity of different users by engaging and identifying user needs and competencies at the individual level. However, typically it begins with a “one size fits many” agenda by designing to reflect representative competencies among a broad range of people with intellectual disabilities, to maximize opportunities for applicability and participation. It then looks at how to accommodate individual ‘edge cases’ by utilizing the principles of accountability, adaptation, and transparency as discussed by Wobbrock et al. [97]. As an example, consider that even people with profound intellectual disabilities use YouTube, because it does not require a sign-in and one can browse videos and related videos by having the competency of knowing to click on a play button or relevant link. Thus, basic aspects of use are within the reach of many, even if more sophisticated use is not. Design can work to make more features available to many through easy to master competencies, through supporting individual competencies, providing training to support people to master and further competencies, or the system could be tailored to learn to adapt to individual use, by inferring intentions and supporting action, using predictive systems akin to autocomplete. However, research may be needed to make such systems work well for particular users.

2.3.3 Universal Usability. Toward ensuring the usability of interfaces for all, universal usability [56, 77, 91] developed principles for accessible user interface design to ensure wider access to the information society. Its principles consider diverse factors such as age, culture, skills, and gender, along with design simplicity and flexibility to ensure the reach of design to the larger society [77, 100]. These principles have been employed in web and product design, testing, and compliance. Universal usability does not make special provisions for people with disability, and it leans toward a “one size fits all” approach. However, it emphasizes multi-layer, adaptive, or multimodal design, (i.e., having multiple versions of a design or enabling varying levels of adjustments and adaption for different users). Universal usability engages users through the design process and strives to bridge skill gaps that users require to engage in the design. A key challenge in universal usability as with universal design is accommodating the varying requirements of different users influenced by age, gender, literacy, disability, and culture in the design. This challenge extends to people with intellectual disability as they may have other co-occurring impairments and varying skills that make their needs unique. Moreover, their skills may differ depending on their exposure to technology, executive functioning abilities, and the severity of their disability. To ensure universal usability includes people with general intellectual disability (i.e., a large and varied group, rather than only groups with known characteristic abilities, e.g., people with physical disabilities, Down Syndrome, high functioning Autism), we advocate exploring their technology use activities to reveal competencies that many of them share, or that are within reach and can be practiced. These skills and nascent skills can be leveraged in designing for them.

The Competency-based design approach complements universal design, by drawing attention to contextually based competencies and how to identify them, so that they can be catered for in universal design.

2.3.4 User Sensitive Inclusive Design. User-sensitive inclusive design, in a sense, is an extension of user-centered design [63] to accommodate people with disabilities and older adults. It underscores the difficulty in designing technologies that are accessible by all potential users, underlining challenges that arise with varying user characteristics and specifications [63]. The approach, therefore, is anchored in ensuring that designers develop a relationship with users, to understand their requirements. This ensures that the values “sensitive” to end-users’ needs are considered in the design. However, as observed with universal design, it is challenging to design for users with fundamentally varying abilities and skills. Approaches that seek to find common design ground through developing a relationship with users in understanding their
existing and emerging technology use may serve to extend the reach and efficacy of user-sensitive inclusive approaches. In particular, the Competency-based approach engages users to explore their technology participation competencies, so that design is undertaken with an awareness of these competencies. It complements user-sensitive design, by ensuring that, the fundamental competencies, abilities, and skills of different users are reflected in the eventual design.

2.3.5 Ability-based Design. Ability-based design is a pro-ability design approach that focuses on designing with the abilities rather than deficits of people with disabilities [97]. Defining abilities as “all that users can do,” the framework is built across three categories, namely, the stance, interface, and system.

The stance category consists of the Ability (1st) and Accountability (2nd) principles. These first two principles are required of every ability-based design and inform the approach’s philosophy of focusing on abilities (what a person can do) and ensuring accountability by “placing the burden of change on the system and designer rather than user” [97]. The interface category proposes the Adaptation (3rd) and Transparency (4th) principles. These principles focus on the interface design of ability-based systems and recommend that designs tailor automatically or through user-adaptation to different user abilities, and are transparent by ensuring that users have options to manage and preview adaptations. For the system category, the framework recommends the Performance (5th) and Context (6th) principles; and encourages the principle of Commodity (7th). The fifth and sixth principles relate to user-system interactions. The system principles recommend ability-based systems to be able to model and predict user performance and automatically sense and adapt to different user abilities and contexts. The commodity principle encourages ability-based designs to consider system cost by using cost-effective available hardware and software resources in the design.

As a landmark framework, the ability-based design framework has been employed to design accessible interfaces, input devices, and applications for people with physical disabilities such as motor impairments [31, 36, 37, 50, 54, 95], visual impairments [7, 27, 49, 92, 99], and hearing impairments [9, 38, 43, 55]. However, with people with intellectual disability, their abilities are diverse, nuanced, highly contextualized, and often complicated by other co-occurring impairments. This makes it challenging to identify representative abilities to prototype a design that can support the participation and engagement requirements of most of them. Consequently, as user-system interaction is a prerequisite for automatic adaptation and contextualization, the fundamental system design must support the participation skills of all users for these principles to be implementable. Thus, in contrast to the “system-centric” approach to adaptation in ability-based design, the Competency-based approach focuses on harnessing existing representative competencies of diverse users, such that beyond their mostly variant physical abilities, it encompasses competencies that support the design inclusion of all of them.

Further, we urge caution regarding the fifth and sixth principles of performance and context that advocate modelling and predicting user performance, and automatically sensing and adapting to different user abilities and context. In this respect, the ability-based design framework embraces a rather technologically optimistic view. As articulated by Dourish [29], context is emergent, dynamic, and requires careful consideration of the entire socio-technical environment. The sensor data and use data that technology can capture may be a much-reduced representation of the actual situation at hand. As a result, technologies are inherently poor at understanding user intent and the dynamics of an emerging context. Thus, while adaptation may be a laudable goal, it should be pursued with a realistic appraisal of the capability of the analysis of data and sensor values to reflect intent, the likely efficacy, and the trade-offs between investing resources into automation attempts versus other kinds of design strategies.
Towards a Competency-based Approach to Co-designing Technologies

We take note that emerging technologies such as artificial intelligence promise potential in pattern recognition and user modelling, however in designing for people with cognitive challenges, the context goes beyond aggregated metrics by a sensor as many other socio-technical and environmental factors mostly apply. In line with this, alternative approaches, such as seamless design [19], promote the idea that rather than technologies automatically making decisions on behalf of people, key seams or pieces of information are exposed to the user in visible ways so that the user can make choices themselves about how to act in light of the information presented (synonymous to the transparency principles of ability-based design). A canonical example is phones displaying the caller number/identity of the person calling, (and discreetly vibrating) so that the user can make the decision as to whether to answer, as opposed to the technology attempting to decide, based on context, whether or not the phone should ring, a decision that at many times an automated system will invariably get wrong due to a lack of understanding of the emerging situation and a failure to correctly judge intent.

In light of both the aspirations and limitations of existing frameworks that have emerged over time, in particular with respect to people with intellectual disability, there is a need to explore new ways to operationalize the spirit of ability-based design and other inclusive design approaches with people with intellectual disability. We advocate for developing processes and approaches that support designing with their competencies, which we define as their representative proficiencies at performing specific tasks. This will ensure their participation and subsequent adaptation if required.

We note that this approach of understanding representative proficiencies is quite common in the world of understanding and assessing intellectual disability, although it has not been applied in fields relating to design and interface design. Assessments of various kinds often seek to understand a person’s various life competencies such as self-care, expressing needs, following instructions, doing up buttons, and so on. The answer to many a question in such assessments is often “it depends” or “sometimes,” because the context and individual motivations are key to whether or not the person with intellectual disability is able to mobilize the attention and effort to master and demonstrate the competency. As such, a Competency-based approach must not only consider which representative proficiencies are common or rare, and the kinds of contexts in which they are demonstrated; it must also seek to create supportive and motivating contexts that foster these proficiencies. In this respect, the role of context cannot always be separated out from the competency.

2.3.6 Participatory Design. Originating from Scandinavia, participatory design is an approach to design that tries to actively involve all the stakeholders of a design irrespective of their expertise, in the design process [61]. It has two fundamental tenets: pragmatic – that those for whom the design is intended have the best knowledge of their own lives; and moral – that they ought to have a say in the design that is intended for them. Participatory design fosters collaboration, participation, and democracy, and leads to innovation and empowerment [8, 10, 84]. However, issues surrounding the depth of participant engagement and empowerment [83] in participatory design, and challenges adopting it with older adults and people with disability have been discussed [33, 44].

The Competency-Based design approach of necessity embeds stakeholder participation in all its phases, to understand and reveal their competencies and interests. As such, it tends to embed the moral and pragmatic values of participatory design and these can be used as a reflective lens to appraise the design process.

2.3.7 Co-design. Co-design is a participatory user-centred design approach closely related to Participatory Design, but deriving from slightly different origins with a more pragmatic than moral
Table 1. Participant Demography for Each Phase of the Research, their Social Media Participation, and the Methods and Approaches We Employed to Engage Them

| Participants/Social Media Use/Methods | Gender/Social Media Use | Phase I Technology Use Exploration | Phase II Competencies Exploration | Phase III Co-design of SkillsTube App |
|-------------------------------------|-------------------------|-----------------------------------|---------------------------------|--------------------------------------|
| No. Participants                    | -                       | 27                                | 11                              | 11                                   |
| Gender                              | Male                    | 15                                | 6                               | 4                                    |
|                                    | Female                  | 12                                | 5                               | 6                                    |
| Social Media Use                    | YouTube                 | 27                                | 11                              | 11                                   |
|                                    | Facebook                | 19                                | 8                               | 8                                    |
|                                    | Instagram               | 7                                 | 2                               | 2                                    |
|                                    | Snapchat                | 8                                 | 2                               | 3                                    |
| Engagement Methods & Approaches     | Survey & Contextual Interviews | TechShops                          | TechShops with RAID               |

focus. In co-design, the target user(s) and stakeholders of a design are collaboratively engaged throughout the design process [71]. Co-design ensures that the requirements and needs of the end-user(s), who are usually co-creators, are satisfactorily reflected in a design, so that it becomes usable by them. In accessible design, co-design ensures research inclusion, participation, and expression by people with disability and older adults [28, 32, 74].

The Competency-Based design draws upon the philosophy of participatory design and co-design in co-creating the design with end-users. It requires reciprocity and trust-building to create an environment in which people with intellectual disability confidently participate [3, 12].

3 THE CO-DESIGN PROCESS FOR SKILLSPIPE

In this section, we describe the co-design process for SkillsTube, which evolved over three phases lasting 2 years in total. The first phase explored participants’ technology participation through a survey and individual contextual interviews. While this gave us basic insights into their technology use pattern (mainly through the survey), we found some shortcomings in using these methods, largely due to our feeling that asking many questions felt somewhat like a test, even though conducted in a friendly manner. As a result, in the second phase, we offered group-based sessions, in which we would train about and co-explore using social media together in the spirit of reciprocity. Participants engaged willingly and these evolved to become peer-learning sessions, then to a highly participatory and collaborative technology-based workshops approach, that the participants called TechShops [3]. The TechShops approach was then leveraged to engage participants throughout the enquiry and co-design process. In the third phase, we again leveraged TechShops to engage participants and employed the Reflective Agile Iterative Design (RAID) framework [47] to co-design the SkillsTube app. Table 1 shows the methods and approaches employed to engage participants in each phase.

3.1 Research Setting

The entire research was conducted within the premises of a collaborating DSO that offers daily support services solely for people with intellectual disability. The DSO provides support services for literacy, numeracy, career coaching, social and independent living skills development. Young adults attend the DSO daily, where support staff and therapists assist them in attaining their set goals in the aforementioned areas.
Technology plays an integral role in the DSO’s programs. State of the art technologies such as interactive screens, tablets, iPads, Virtual Reality (VR) systems, 3D printers, computers, and Internet connectivity are all available in the centre. Most of these technologies are used in supporting the skills development activities of participants. For example, YouTube is mostly used during Oz-sign language sessions, and VR is used to support participants to develop skills in taking public transport.

3.2 Participants

Participants in the research were all young adults with intellectual disability between the ages of 18–34 years. Participants’ medical diagnoses were broadly classified under intellectual disability, verified by the DSO, which focuses solely on supporting people with intellectual disabilities. In the first phase of the research (phase I), we engaged 27 young adults and explored their technology participation through contextual interviews and surveys. The second phase (Phase II), which involved 11 participants, explored participants’ social media participation competencies using TechShops, and the third phase (phase III) engaged 11 participants to co-design an app. Participation was open to all interested young adults who were available on the days the TechShops were organized. Though most participants self-nominated, support staff suggested others. All participants had some familiarity with technology and owned either an iPad, tablet, or smartphone with which they surfed the Internet. All participants participated on YouTube and sparingly on other social media apps, including Facebook, Instagram, and Snapchat. Reading and literacy skills varied across participants, with most participants having challenges with spelling words and reading sentences. Though some participants were verbal, others had minimal verbal and communication abilities. Table 1 shows the demographics of participants, their social media participation, and the approaches we employed in engaging them.

As a co-design research project, our position is that we (the research team) are also participants within the research, contributing and shaping it in many ways. We believe that our role as design researchers, our on-going engagement and relationship building with participants, and the established research partnership with the DSO contributed to and helped shape the research.

3.3 TechShops Activities

3.3.1 TechShops Structure. The TechShops were structured to include a maximum of eight (8) participants in a session, lasted up to an hour and a half, and conducted twice weekly. We anticipated non-research participants wanting to take part in the TechShop sessions, so we made provisions for a maximum of eight participants per session, five of whom were to be actual research participants, and three other young adults interested in taking part.

However, in some TechShop sessions, more than three other young adults at the DSO, who were not part of the participant group usually insisted on joining the workshop, and were allowed to sit in and participate. The TechShops focused on two key phases of the research: exploring participants’ technology competencies in phase II, and co-designing an app that reflects these competencies in phase III. The TechShops involved engaging participants in contextual activities that enabled them to use technology to explore their interests while also discovering, demonstrating, and practicing their competencies. The TechShops were offered in a spirit of reciprocity, enabling us to undertake research, while also helping participants to master technologies of interest to them. The collaborative approach helped to create a learning environment and an exploratory context in which participants felt engaged and supported rather than one in which they felt assessed and examined, a problem we had encountered with surveys and contextual interviews [3].

In all sessions, a support staff of the DSO was always present to offer facilitation support to two researchers (the lead author, who was present in all sessions, and one of five other researchers
from the broader research team at a time, in turns). The participating support staff also replicated the workshops with participants who missed a session, and with other young adults who were interested in the TechShops but who could not participate because they attended the DSO on days when the workshops were not conducted. To ensure collaboration and interaction among participants, they sat around a table, each with an Internet-enabled tablet or iPad with which they participated (Figure 2). Participants were encouraged to ask questions, offer support to each other, and freely engage with their peers and facilitators. Throughout this research, TechShops were leveraged as a vehicle to explore participant competencies and conduct co-design activities in phase II and phase III of the research.

4 DATA COLLECTION AND ANALYSIS

Data for the research was collected through observations, participant enquiries, and short videos recorded during the TechShops sessions. Each of the three facilitators wrote field notes based on observations in TechShops. We catalogued aspects of the TechShops that participants liked (providing them motivation and supporting their interests), the key skills and competencies they exhibited, and participation activities that were challenging due to lack of competency or interest. At the end of each session, the observational notes were shared and discussed in a debrief session amongst the facilitators and thematic patterns identified. The thematic patterns were then reflected on by the broader research team and inductively refined, guided by the principles of thematic analysis described in Reference [11], and finalized as findings.

5 PHASE I: EXPLORING PARTICIPANTS’ TECHNOLOGY PARTICIPATION

Phase I involved 27 participants, and consisted administering a survey and contextual interviews to characterize participants’ technology participation

5.1 Characterizing Participants’ Technology Participation

As part of exploring participants’ technology participation patterns and skills, we conducted a survey and contextual interview on their ICT use. The surveys were designed to be administered in person by the first author in the presence of a support staff member who knew the participants very well and, for that matter, was very conversant with their technology participation.
Administering the survey personally also ensured that participants could understand questions before they answered. The survey catalogued participants’ technology use and device ownership, their Internet access and ICT participation challenges, and their ICT skills development interests. During the survey administration, participants were encouraged and allowed to bring their devices to help contextualize the discussion, facilitate engagement, and to support participants who were minimally verbal to show and point to the apps they used, and/or demonstrate how they used them.

5.2 Phase I findings: Characterized Social Media Participation

Mainly through the survey, the findings highlighted the characterization of participants’ technology participation, their participation interests, and challenges, presented in detail in Reference [5].

5.2.1 Interest in Social Media Participation. The survey data revealed social media as the favourite and most commonly used ICT by participants. Most participants were interested in enhancing their participation skills in social media apps that they were already using, and/or developing participation skills in using those they were not yet using, but desired to use. Participation statistics varied from YouTube to Instagram. Though everyone used YouTube, 19 participants used Facebook, while eight and seven participants used Snapchat and Instagram, respectively [5]. Because most participants were interested in developing their social media participation skills further, we engaged them through TechShops [3], to enhance their skills. The TechShops were focused on YouTube (which all participants used and wanted to enhance their skills at using), and Facebook (which most participants wanted to enhance their participation skills in and learn how to use). YouTube appealed to most participants, because they could use it on the browser without creating an account, and its audio-visual content attracted and engaged them conveniently [5].

5.2.2 Different Motivations Characterize Social Media Participation. Participants indicated different motivations for using different social media sites. While they used YouTube mainly for entertainment content consumption, they used Facebook for connecting with family and friends, yet they used Instagram and Snapchat for playful and satirical interactions [5].

5.2.3 Socio-technical Participation Challenges. Further, participants indicated challenges in remembering their social media passwords, spelling words when searching YouTube, as well as netiquette and issues relating to accessibility. Some of these issues, such as netiquette, were incorporated into the subsequent TechShops sessions with participants to develop their social media participation capacity.

6 PHASE II: EXPLORING PARTICIPANTS’ COMPETENCIES

The TechShops activities in phase II involved 11 participants, spanning 10 weeks each across two school terms, and focused on revealing participants’ social media participation competencies. In phase II, we engaged participants in TechShops using Facebook and YouTube to reveal their competencies. For participants who were new to Facebook, the TechShops supported them to develop fundamental participation skills such as searching and adding new friends, enabling safety and security settings, and posting content. For participants who were already using Facebook, the TechShops focused on furthering their skills in areas such as netiquette, which proxies found particularly important. On YouTube, the activities focused on finding videos about social participation skills such as etiquette and manners. Participants formulated search queries on these topics, searched for related videos, watched them, added them to a playlist, and discussed what they liked or disliked with their colleagues This enabled us from a research vantage to reflect on the suitability or otherwise of leveraging participants’ participation and competencies in YouTube to support them to learn life skills related to their interests.
6.1 Exploring Participants’ Social Media Competencies

On Facebook, we engaged participants who were already using the app in contextual everyday participation activities such as searching and adding friends, posting and sharing content, enabling privacy settings, and discussing netiquette (which was a key area of skills development interest for the DSO and families). During the TechShops sessions, participants demonstrated how they engaged in these activities while logged onto their Facebook accounts on individual tablets and iPads. This enabled us to identify their existing skills and to offer support in areas where they had challenges during the TechShops. For participants who were not already using Facebook but were interested in learning how to use it, the TechShop activities focused on developing their participation skills, such as how to create an account, enable privacy settings, add friends and post, like, and share content. The TechShop sessions included showing steps, using scenarios, and completing practical assignments. Participants followed steps from a projected screen and implemented them using their personal iPads and tablets. In keeping with the ethical provisions for the research, participants followed the activities on shared accounts we purposely created for the study. Through these activities, participants developed the needed skills to be able to sign up and use Facebook independently.

On YouTube, because most participants wanted to enhance their social skills further, the TechShops focused on supporting them to learn practical everyday social participation skills such as empathy, etiquette, and manners. Leveraging YouTube’s large video repository, participants created search queries on these topics, searched YouTube, and added videos to their playlist. They then watched the videos, discussed applying what the videos taught, and role-played them. The videos were then shared on a closed Facebook group of only participants to observe how they might engage with each other using the content. This enabled us to ascertain the suitability of YouTube in supporting skills learning, noting all the participation and accessibility challenges participants faced in the process [4]. Through the TechShops on Facebook and YouTube, the existing participation competencies of participants on these sites were revealed, and we supported them in enhancing their skills participants who were new to these sites also developed skills to be able to use these platforms.

6.2 Phase II Findings: Revealed Competencies

For this article, the findings highlight the skills participants exhibited during the TechShops. Detailed findings relating to the characterization of participants’ social media participation, how participants leverage social media for skills learning, and the participation, design, and accessibility challenges thereof have been discussed in prior research [4, 5].

6.2.1 Representative Competencies. We observed from the TechShops that participants had developed common competencies such as searching, sharing, swiping, browsing, and functional association with particular icons from their Facebook and YouTube participation. We noted that all participants were conversant with the idea and process of searching. They understood how to use the search features on YouTube and Facebook to find their favourite music and friends, respectively. They could scroll through the searched content to make desired choices both on Facebook when adding friends, and on YouTube when searching for their favourite music video or entertainment content. Visual content such as profile photos of friends and images of their favourite artists were always helpful in supporting participants to make choices from their search results. Some participants had challenges spelling words they were not familiar with or getting distracted during the search process, but they could still conduct a successful search process once they became focused and had the search word spelt for them (sometimes on a piece of paper for them to type in, or done letter by letter as they type it in the search bar). Most participants often used
the word suggestions during searching, especially when they were not sure of the spelling of the search keyword. This meant that they had only to know the beginning letter(s) of a query and could leverage past queries. Sharing was another competence of interest that participants shared. A key participation activity of all participants that participated on Facebook included re-sharing and “liking” posts within their networks. Though participants never shared content on YouTube, they often mimicked their favourite content, and showed it to their colleagues, by showing them their screen.

Generally, all participants had navigation competencies and could switch between menus on Facebook and YouTube. They could use the word suggestions during searching, and use the media control tools to play, pause, or amplify video media on YouTube. All participants had fundamental competencies needed to use mobile devices and apps such as swiping, selection, browsing, and surfing on their iPads, tablets, Facebook, and YouTube. Perhaps, the most important competence observed across participants was their interest and desire to seek support toward enhancing their existing skills and developing new technology participation and life skills. Outside of the workshops, some participants readily sought support in spelling and creating playlists from the support staff who had helped facilitate the workshops.

6.2.2 Functional Association with Icons. We also observed that participants had developed functional familiarity with some social media icons from their Facebook and YouTube participation. They associate and extend the functionality that these icons play on social media sites (Facebook and YouTube) with icons in other applications. This provided the opportunity for design to leverage such icons, to achieve similar functionality in the app. For example, all participants associated the bell icon with notifications, the magnification lens with searching, and what they called the “two friends” with adding friends to their networks. They also associated the star icon with favourite or best content and the microphone with voice searching. This familiarity and functional competency with visual icons offered opportunities to create a similar visual interface design for the app.

7 PHASE III: ITERATIVE CO-DESIGN OF THE SKILLSTUBE APP

The given the expressed interest of participants to improve their social skills and make friends, and the desire of parents and support staff for them to develop such skills, we focused on supporting participants and their colleagues to effectively leverage YouTube videos to learn social skills. However, due to the accessibility (e.g., detractions from ads and other videos) and participation challenges (e.g., difficulty sharing content with friends on YouTube), participants faced during the skills learning TechShops on YouTube [4], we needed to design a more accessible interface for them to effectively engage.

Therefore, engaging 11 participants, we set out to co-design an app with an accessible user interface that addressed these challenges, while integrating it to search content from YouTube such that participants could effectively find and engage with videos of interest about skills learning. The interface needed to support the participation skills of not just our workshop participants but also all of the young adults in the DSO, over 60 in number, who were interested in using the app to develop their individual life skills interests.

However, since participants’ cognitive, sensory, practical skills and abilities varied, we reflected on activities that most of them participated in and on the kinds of skills that were broadly shared. Since all participants used YouTube, and most of them participated on Facebook, we capitalized on their representative skills at performing specific tasks on these platforms, observed in the TechShops for skills learning, and tailored the app’s design to reflect these competencies. We envisaged that this way, the app could effectively support the basic participation skills of all participants for them to be able to at least begin to participate. This initial participation could then provide the
avenue for the principles of system adaptation and other design strategies to be explored to suit individual users.

The TechShop activities of Phase III spanned 10 weeks each across two school terms, and focused on co-designing SkillsTube, an accessible app that was designed to reflect participants’ competencies, and supported them to access skills development videos of interest. Phase III involved three key TechShop activities: (1) An exploration of a prototype video search interface with participants, (2) the iterative design of the SkillsTube app using the RAID method [47], and (3) the final iteration of the trial of the SkillsTube app.

In the first TechShop activity, participants were engaged in using a prototype video search interface to explore life skills learning. The prototype video search interface addressed some of the accessibility challenges observed during the YouTube life skills learning TechShops in phase II. We requested participants to list three skills of interest, create search queries and search for videos on each topic using the prototype video search interface. They then watched the videos, archived one or more to their playlist, and discussed what they liked or did not like about the videos. This enabled them to reflect on the usability of the video search interface prototype, and supported us to observe how they engaged on the interface, and what needed to be re-designed. Bringing together all we had leaned, we designed the first SkillsTube app for further iteration with participants.

For the second TechShop activity in Phase III, participants tested the first iteration of the SkillsTube app, by identifying three different life skills of interest, formulating search queries on them, and searching for videos using the SkillsTube app. That is, they undertook a similar task as in the initial YouTube activity, and the prototype video search interface activity. This engagement allowed us to make contextual observations while they used the app, probe further with participants to develop reflective understanding of their requirements, and to incorporate updates quickly in subsequent iterations, as per the RAID method.

For the last activity of phase III, we conducted a final design trial of the app. The TechShops were structured in such a way that participants tried all of the features of the SkillsTube app. Participants made a list of their top three skills of interest, created accounts, added a couple of colleagues as friends, searched for videos on their chosen skill topics, which they watched and shared with their friends. Engaging participants in these typical use case scenarios afforded us the opportunity to make final inputs into the design of the SkillsTube app, per the principles of RAID [47].

7.1 Co-design Activity I: Video Search Interface Exploration

In the first phase of the co-design, we explored with participants an accessible video search interface prototype that our lab had previously designed with people with intellectual disability based on findings published in Reference [80]. The search interface was designed to accommodate some of the design and accessibility issues observed in Reference [79]. It also supported writing short notes about videos and allowing videos to be archived pictorially in frames from the video. The aim of the note-taking feature was to enable people with intellectual disability to write short key points to remember about a video, while the pictorial archival method supported people who could not read or make sense of titles to find saved videos. Since some of the fundamental search and accessibility issues that the video search interface addressed were relevant to our participants, using this prototype as a form of technology probe aimed to help us understand two key issues: (1) we wanted to understand how participants would engage with searching videos on an interface that was not a regular YouTube interface, and (2) we also wanted to observe the usability and engagement of participants with some of the design features that this video search interface adopted, since they were not social-media inspired.
In TechShops, participants used the prototype to search for three videos on their skills interests. This enabled us to observe their participation in the video search interface. From this activity, we realized that even when participants wanted to take notes and share with friends, difficulties with spelling made this challenging. This suggested that a key design requirement was to incorporate a simple sharing feature that allowed collaborative sharing among participants, utilizing some kind of speech to text converter to allow participants to comment and share their thoughts on videos with colleagues.

In addition, we observed that the black icon and button outlines of the interface confused participants in making icon choices. We needed to consistently colour-code icons, for example, colouring all primary action icons blue and all cancelations red. In addition, we observed that some participants found errors and video buffering delays due to bandwidth frustrating, confusing, and difficult to handle. They preferred an immediate response to their requests and commands, especially when they expected a particular outcome from a click.

7.2 Co-design Activity II: Iterative Design of the SkillsTube App Using RAID

Equipped with the various accessibility requirements from the YouTube and video search probe TechShops, and more importantly, participants’ competencies, we co-designed an app that participants called SkillsTube, with a new accessible interface. The co-design process employed the principles of RAID [47], in the context of TechShops. The RAID methodology consists of three stages: development, use, and reflection [47] (Figure 3(A)). After the initial development of a rough usable prototype, users are engaged on the early prototype, and through analysis and reflection, design and usability issues are identified responded to iteratively (Figure 3(B)). As a result of its reflective and iterative design process, the RAID methodology supports the conceptualization of theoretical frameworks in addition to developing artefacts through design research [47].

As RAID supports rapid prototyping, features of the interface were quickly designed, trialled in TechShops with participants, and refined. We engaged participants in contextual activities such as searching, sharing, and archiving of content based on their interests in learning about particular skills during the co-design TechShop sessions. Through these activities, participants used and engaged with all the design features of the interface, affording us an opportunity to observe usability challenges and then iteratively re-design using RAID [47].

7.2.1 Overview of the SkillsTube App. The SkillsTube app presents a simple and accessible interface that allows users to search and watch videos from YouTube. The app can be accessed on the browser and can be ported as a shortcut on both android and iOS devices. As the app is meant to
Fig. 4. SkillsTube, showing its social media-inspired features (icons at the top left) and a more focused search bar that illuminates periodically to attract user attention.

support young adults to learn skills, it runs an algorithm that prioritizes querying and presenting videos that relate to teaching or learning to do something. It allows users to create accounts, add friends as networks, search videos, and watch or archive them on their playlists. Users are also able to collaborate on favourite videos, as they can comment and share them with friends who also use the app. The app’s design features and icon choices were all social media-inspired, as can be seen in Figures 1 and 4.

7.2.1 Icon Design and Colour-Coding. Due to participants’ functional association with some social media icons, the search icon, adding friends’ icon, notifications icon, and voice search icon (all shown in Figure 4) were all adapted from Facebook and YouTube. We also provided consistent colour codes for the icons; all dialog interactions have a blue “ok” button and “red” cancel button, as can be inferred from Figure 6.

This is consistent with Facebook and YouTube button colours, where blue buttons are generally representative of primary actions, while grey represents secondary actions. Challenges that participants had had with the black and white icons of the prototype video search interface were resolved with colour-coding, as most of them understood what the colours mean.

7.2.3 Logging in and Signing out. Users initially needed to create an account using their name, email address, profile picture, and password, similar to Facebook. However, this mechanism was challenging for most participants who forgot their login credentials. Those who could remember their login credentials (passwords and email addresses), were also prone to typographical mistakes during login. Therefore, we iteratively implemented the Quick Response (QR) system that participants could use for accessing their accounts. After creating an account, a unique QR code is generated and tagged to the account. Participants could then print their account’s QR code, which they could scan to login instead of providing a regular email address and password. As most participants used their personal tablets or iPads during the sessions, we also supported them to configure their devices to remember their login details to the app. However, to make provisions for participants to be able to access their accounts when they switched to a new device or accidentally logged out, each participant was given a printed and laminated QR code of their account.

7.2.4 Adding Friends. In supporting the desire of participants to share their skills’ interest videos with their colleagues, we made provisions for adding friends on the app. For two people
to become friends, both of them must have accounts on the app. A friend’s request is then made using the email address the person used in creating their account. The request then needs to be accepted for the two users to become friends. We, however, observed in the co-design sessions that this was challenging, as participants could not remember the email addresses of their friends. Adding friends using their email address was also a different approach to what most of them were used to on Facebook, where they added friends by simply clicking an “add friend” button.

Therefore, we iteratively redrew the process of adding friends using their QR codes (Figure 5). With the QR codes, a participant could simply add a colleague as a friend by asking their permission and scanning their QR code with their tablet. Since adding friends through QR code scanning required the explicit permission of the person being added as a friend, no acceptance decisions are required. Support staff said this was an excellent mechanism to ensure that users who really wanted to be friends were friends on the app. This approach, however, worked best when people were co-located and could directly share their QR codes, although one could send a photo of their QR code via private messages using their phones (text message) on the Internet via Facebook. They also requested for provisions to unfriend friends added, which was implemented. Participants immediately liked this iteration and went around asking the permission of their colleagues to add them as friends on the app.

7.2.5 Searching Videos. The search feature was implemented to accommodate some fundamental design and accessibility issues observed from the probe use and TechShops session in phase II. We observed that participants were mostly detracted by the many animated videos on the user interface of YouTube during searching. Therefore, we designed a plain and search focused interface for the app (Figure 4). The search bar was made larger and prompted participants using colourful illuminations. As most participants could not spell, we included a voice search tool to allow them to search speaking their queries.

The iconography for the search and microphone were understood functionally by the majority of participants. The voice search allowed participants to enable and disable it manually, resolving the recording time out challenges we found with YouTube’s voice search tool. Because the voice search tool that YouTube uses automatically switches off and runs the search on the first few
words it picked after a few seconds delay, participants who were not quick in speaking found it problematic to use. With the update we designed for the app, participants could tap the voice search on, have the time to record their entire query, and tap it off after they were done before running the search. Users could also search specific channels from the DSO by checking a box on the search window (Endeavour channel), as can be seen in Figure 4. They could switch between searching on “open YouTube” and “How to” search (Figure 4). Searching on “open YouTube” through the app returned the same search results as one would have searching on YouTube, while the “How to” searching prioritizes skills learning videos during searching. The app also makes available simple search suggestions to help participants with spelling issues. Though some participants with verbal challenges still found it challenging to use the voice search due to pronunciation issues, overall, the redesign improved and supported participants’ searching.

7.2.6 Sharing Videos. The sharing feature enabled users to be able to engage others on their skills videos of interest. Videos could be shared with multiple friends, but the app was designed so that a comment must be provided before the video can be shared. Users can record their comments using a speech to text converter we implemented for comments.

Besides the interest participants had in sharing their content with friends, support staff said the sharing feature would be useful for them to support collaborative learning using skills videos with participants. Staff thought of sharing skills videos with all young adults interested in developing a particular skill, and the feedback among staff, young adults, and families followed through comments (which they suggested should allow for posting short videos in addition to text). Although sharing was one of the most loved features, most participants wanted to share videos with their friends without comments. Others wanted to share other media besides text such as personalized videos or photos. Figure 6 illustrates the sharing feature of the app.

7.2.7 Archiving Videos to Playlist. For users to save their favourite videos, a provision was made for archiving content in playlists. Users can create and name as many playlists as they wish to, and add as many videos as they desire to them. Videos saved in the playlist can then be easily retrieved anytime users wish to watch them. Playlists supported participants to categories their favourite skills videos. Participants who had spelling challenges often resorted to naming their playlist by their search keywords, e.g., sports, cooking, or travelling, an effective yet simple strategy. Some also added unrelated videos to playlists. This was one of those features that showed promise in participants developing competence through use.

7.2.8 Notifications. To ensure that users are notified about requests and shared content, there is a provision for a real-time alert on the app. The number of notifications is indicated in blue numerical numbers on the app’s shortcut icon and on its home window when launched (Figure 4). Participants were very familiar with this feature, knowing right away after launching the app whether they had new notifications. Reviewing the notifications was however a little challenging for some participants, especially when there were multiple notifications.

7.3 Co-design Activity III: Final Iteration Design of SkillsTube

For the final iteration of the app’s design, we again leveraged TechShops to engage participants in a series of intended use activities. The activities were structured such that participants would use all the features of the app. Participants were requested to make a list of their top three skills development interests. These included developing skills on how to make coffee, take care of pets, and maintain relationships. Using the app, they created accounts and were requested to add their colleagues as friends. Other activities required them to search for videos on their skills interest, comment on them, create playlists and archive the videos, and share them with friends. Other
activities included using QR code scanning to login and add friends, using voice for searching and commenting and responding to notifications.

7.4 Phase III Findings: Designing with, and Enhancing Competencies

7.4.1 Designing with Competencies in Mind. Throughout the app’s design, all of its features were designed by reflecting on the competencies that participants exhibited during the YouTube and Facebook TechShops in Phase II. The app’s design features such as the icons, colour-coding among others were all based on their existing competencies. Design features that reflected the competencies of only a few participants were avoided. For example, we excluded the home and forward and backward navigation buttons from the app’s design, because the majority of participants were confused about their use, even though they were handy for easy navigation. Table 2 maps the design features of the app with participants’ competencies.

We noted that leveraging participants’ competencies in the app’s design fostered their confidence to participate, and thus facilitated the usability of the app. Whereas participants were always timid to participate in usability trials of other apps that our lab designed and wanted to trial, we did not observe such tendencies in their use of this app. Their acquaintance and familiarity with the
Table 2. A mapping of Participants’ Competences and SkillsTube’s Design Features

| App’s Design Feature | Competencies Leveraged |
|----------------------|------------------------|
| **Iconography**      | • Social media participation competencies, e.g., functional familiarity with social media icons such as relating the bell icon for notifications.  
  • Relational competencies of social media icons |
| **Colour Coding**    | • Social media participation competencies, e.g., relating different button colours and tab highlights to specific actions on Facebook and YouTube  
  • Associative competencies from social media, e.g., red buttons for cancelling or closing dialogs or tabs selection |
| **QR Code**          | • Competencies in taking photos and selfies, which is similar to scanning, and following easy step-by-step guidance  
  • Competencies in relating to concrete and tangible objects/images containing their contact details (e.g., all participants always carry a laminated sheet of paper that contains their emergency contact details) |
| **Searching**        | • Social media participation competencies, e.g., searching for favourite music videos on YouTube or friends on Facebook  
  • Competence in typing text into a search bar, or speaking search queries  
  • Competencies selecting and playing search results |
| **Sharing**          | • Social media participation competencies, e.g., sharing and tagging photos on Facebook with friends  
  • Competence in physically showing videos/content of interest to peers |
| **Archiving videos** | • Competent skills in grouping and arranging content  
  • Competence in following easy step-by-step instructions |
| **Notifications**    | • Social media participation competencies, e.g., familiarity with Facebook notifications |
| **Adding Friends**   | • Social media participation competencies, e.g., adding or sending friends request on Facebook  
  • Competence identifying friends using their photos, permission seeking to add a person and accepting requests |
| **Login / Logout**   | • Social media participation competencies, e.g., creating and logging into a Facebook account  
  • Competence launching an app from the apps widget  
  • Competence in following instructions to automatically login on Facebook. |

social media adapted user interface icons and design features used in the app’s design developed the needed initial confidence to engage. This confidence supported peer support among participants. This was particularly necessary to ensure the needed engagement for further adaptation and tailoring of the app.

7.4.2 Sustaining Participation and Enhancing Competencies. As observed in most studies, sustaining participation is a major challenge in the use of technologies by people with cognitive
disabilities [4, 5, 70, 75]. For most people with intellectual disability, support is necessary for effective technology adoption and sustained use. Similar observations were made during the study. We observed that participants needed support for sustained participation, enhancing, and developing new competencies. Some features of the app, such as creating user profiles, archiving videos on different skills interests, and finding good skills videos, required facilitation support to further enhance their competencies.

We found that much of the content on YouTube regarding skills development is not particularly well designed to be easy to follow and engaging for everyone [81], let alone people with intellectual disability. However, once a useful video is found, it can be shared within the friend group and saved to playlists. Moreover, due to the value the DSO found in SkillsTube, their support staff started developing accessible videos on specific skill development of interest to participants such as cooking, making coffee and dressing beds. With available content, support staff envisaged running TechShops to introduce the app to other young adults in different centres and supporting existing users to enhance their skills in using features such as playlist to archive their favourite videos. The app’s iterative design process and TechShops supported and enhanced the development of participants’ competencies that were not directly related to their social media participation. For example, the QR code scanning feature that the app’s design used for logging in and adding friends was neither a YouTube or Facebook feature. Thus, the QR code scanning leveraged broader competencies participants had developed from related activities such as taking selfies with their iPad. Though the QR code scanning feature was not directly related to anything participants were familiar with from their social media participation, they quickly adopted it and developed competence in using it. Similarly, the favourite video archiving feature of the app, though functionally the same as creating a playlist in YouTube was not a feature that all participants had an overwhelming competence in using (because most of them did never created or used playlists in their use of YouTube [5]. However, the easy-to-follow steps in using the feature we provided in its design, coupled with the participatory design process TechShops provided, facilitated, and enhanced the competence of participants in using the feature.

7.4.3 Collaboration and Engagement through Social Features. We observed from the usability TechShops that the social features of the app such as sharing and adding friends, generated a lot of excitement among participants. For example, one participant exclaimed on receiving a shared video on his dancing skill interest: “I love this video and the app. So thank you so much.” Most participants wanted to share their skills interest videos with peers within the sessions, parents, proxies, and other networks they associate with outside of the DSO environment and home. Participants were interested in sharing their interests with their friends, while others thought about what interests their friends held and shared videos relating to them as explained by a participant “…I shared a horse-riding video with her, because it’s her interest.” Some participants were interested in creating and sharing their own content on some skills activities they engage in such as swimming or horse riding. They were interested in sharing videos that were personal, instead of sharing only skills interest videos available on YouTube. For example, one participant requested to share his horse-riding video on his device with a friend. However, that required the video to be uploaded on YouTube such that the app can query it.

Further, using some of the app’s features facilitated social engagement among participants. For example, because adding a person as a friend required their consent to scan their QR code, participants had to seek permission from their colleagues by asking to add them as friends on the app. This allowed peer interaction and collaboration. On some occasions, the videos shared generated interesting discussions among participants. For example, a video about social media netiquette that was shared through the app to all participants by a participating support staff generated
Fig. 7. The Competency-based design approach, illustrating its three key design phases.

interesting discussions around the topic in the workshop, with participants recounting excerpts of the video. The app’s social features (sharing and adding friends), therefore mediated collaborative engagement and social interaction among participants and their friends.

8 DISCUSSION

8.1 Toward a Competency-based Design Approach

Reflecting on the design process of SkillsTube and how it supported the participation of diverse young adults, we propose a Competency-based design approach that focuses on designing leveraging the competencies of users with varying abilities, multiple or co-occurring disabilities (Figure 7). The approach focuses on users’ mainstream technology use to reveal their competencies, which are then leveraged during design and further enhanced through using the design. To reveal and enhance user competencies, adopting participatory and collaborative approaches that engage users is necessary.

The Competency-based design approach extends ability-based design by effectively operationalizing it to be adopted with people whose abilities cannot be directly measured or have variations in both physical, sensory, and cognitive abilities such as people with cognitive and intellectual disabilities. It extends the abilities stance of ability-based design by incorporating competencies and reflects on the entire socio-technical context. We elaborate further on this in Section 8.2.

Similar to universal design, the Competency-based approach strives to support the participation skills of an expanded user base by leveraging competencies that broadly apply (e.g., social media participation competencies). Unlike universal design, the approach does not try to achieve a “one size fits all” design, but ensures that the design is premised on the fundamental participation competencies of a broader user base as in inclusive design. The Competency-based approach broadly encompasses the values of universal usability by considering factors such as user skills and competencies during design.

Because the approach is grounded in user competencies and its process tries to enhance user skills, it is effective in supporting and enhancing technology participation and can be applied along with other accessible design approaches such as ability-based design [97], universal and inclusive design [59, 63, 88] in designing accessible technologies.

We acknowledge that, context specific factors such as participants’ familiarity with technologies such as social media may have influenced their participation and impacted the findings positively. However, it is essential to note that the very essence and foundation of the Competency-based design approach is premised on practical representative skills users have developed from their engagement and experience in activities such as using mainstream technologies. Therefore, while acknowledging the context in relation to participants’ prior technology familiarity, such an
influence would not constitute a bias on the findings and proposition of the Competency-based design approach, but regarded as supporting the spirit and letter of the approach.

8.1.1 Revealing Competencies. The first phase of the Competency-based design approach focuses on revealing the competencies of users. Focusing on the representative skills of users is particularly important when you are designing a technology that would be used by a group of users who have fundamental variations in their practical, cognitive, social, and technological skills. As such, leveraging their shared skills and in performing specific tasks successfully does not only offer the designer a glimpse of the possibilities, but essentially support the participation of most users in the group. Here, mainstream technologies such as the Internet, Google, social media, and smart devices provide an avenue for such skills to be explored toward designing. Focusing on social media participation, this study shows that such shared competencies have potential and can be broadly adopted.

As tools for exploring these competencies, we suggest adopting methods that foster engagement, collaboration, and participation among participants (e.g., TechShops [3], design after design [13], and RAID [47], to mention a few). Through these approaches, or blending/adapting similar strategies that foster participation and engagement [25, 35, 40, 41, 60], design features that represent the competencies of only a few users are avoided as the engagement and design process enabled these to be observed. In addition, these approaches enable co-creation and create a feeling of ownership and empowerment in participants as they are actively engaged throughout the design process.

8.1.2 Designing with Competencies. The second phase of the approach, which involves prototyping and designing the technology essentially, does so in the awareness of the competencies that are revealed from the first phase. As illustrated in the design of SkillsTube, its design features and iconography were all based on the Facebook and YouTube participation competencies of participants (which to a larger extend applies to most young adults). The competencies to include in the design have to be representative, i.e., they must be skills users can practically execute. For example, though a good number of participants were already using social media and must have signed up and accessed it using login credentials, only a few participants could remember these credentials. As such, accessing systems through login credentials cannot be described as competencies, since many participants could not practically use that feature without challenges (similar challenges have been observed with people with intellectual disabilities in Reference [5]. It did not also seem to be one of those skills that could be enhanced into a competence through training support (because the fundamental challenge of most participants in remembering their login credentials persisted through the entire design process, even though we provided training support through TechShops). As such, we provided other avenues to access their accounts without having the challenge of remembering their login credentials.

In this phase, participatory and co-design processes that foster engagement [34, 68, 72], support iterative design [13, 47], and facilitate self-expression [94] are useful for a collaborative, engaging and timely design process.

8.1.3 Enhancing Competencies. The third and final phase of the approach ensures that the design supports enhancing existing skills and developing new competencies. This is achieved by considering the context of use of a design from the onset and ensuring that the design incorporates skills that can be nurtured into competencies. For example, the playlist feature that was not part of participants YouTube participation, yet was still incorporated into the design of SkillsTube as participants showed potential (by exhibiting the skills to follow easy step-by-step guides/prompts) in using the feature with some support during the co-design sessions. Thus, including the playlist
feature in the app provided an opportunity for participants to develop competence in creating and archiving content. Similarly, though the QR code scanning feature was neither a YouTube nor Facebook feature, participants through the design process got acquainted with the feature and quickly developed competence in using it to help them log in and add friends. Therefore, including design features that support the existing skills potentials of participants is important to reflect on in the Competency-based design approach, as such skills can be enhanced and further developed into competencies through continuous participation and support.

8.1.4 Considering the Socio-technical Context. For each phase of the Competency-based approach, careful consideration of the socio-technical context of the design is essential. These include considering the environment in which the technology would be situated and used from the onset. A clear understanding of the users and the context in which the design would eventually be used are all important to put into context during the design. In designing SkillsTube, we reflected on factors such as the support seeking competence of young adults, the availability of staff and proxies to offer support, vis-à-vis their social media competencies and potentials contextualize and situate the design.

As elaborated in the interdependence accessible design framework presented by Bennet et al. [6], it is essential to reflect on the relationship between the contextual environmental factors such as abled people (in this case proxy availability and training support) in designing assistive technologies for people with disability. This is especially necessary given that support is integral in technology adoption and use by people with disabilities [75, 89]. Careful consideration and understanding of the socio-technical context ensure that contextual skills and potentials of users are put into perspective during the design phase and that the design is appropriately situated for sustained participation. For example, because of the operational structure of the DSO, participants could always seek ready support from support staff whenever required. Hence, we designed SkillsTube with the contextual understanding that participants would use their support seeking competence to seek help from the DSO staff and other proxies to enhance their participation competencies.

Therefore, considering the broader socio-technical context and situatedness of the design, such as understanding the context of use, contextual skills of participants, and availability of support in relation to enhancing user competencies is necessary for adopting the Competency-based design approach.

8.2 Competency-based Approach to Extend Ability-based Design

The Competency-based approach extends Wobbrock et al.’s [97] ability-based design by adapting and broadening the scope of its stance and systems’ principles, to include people with intellectual disabilities, whose abilities are made manifest in particular contexts.

8.2.1 Stance: (Abilities→Competencies). First, we suggest that the abilities stance of ability-based design extends to encompass what we term user competencies (i.e., practical shared skills users have developed from engaging in contextual activities). The current abilities stance of the ability-based design framework reflects what a person can do by virtue of their physical capabilities, thus seemingly making it challenging to employ in designing with users with intellectual disabilities, whose cognitive, physical, sensory, and practical abilities vary widely and express differently, according to different motivations and in different contexts. Thus, adopting the abilities stance of ability-based design becomes difficult to operationalize.

However, observably from the YouTube TechShops, all participants and their colleagues in the DSO, had favourite content they liked, which they watched on YouTube. All of them had developed similar skills and strategies that transcended their varying abilities and challenges, to be able to access such content on YouTube. Therefore, through engaging in similar activity, somehow,
they had all developed skills in retrieving and enjoying their favourite content on YouTube. This practical skill to be able to search, access, and play their favourite content on YouTube that all of them shared, then becomes a competence that can be leveraged in designing with them, with the assurance that everyone can practically use such a design. Thus, the Competency-based design approach advocates exploring activities of shared interest to users and leveraging their representative skills (competencies) in those activities to design. This ensures that designs are grounded on inherent contextual competencies that users already have, and can be extended based on features that utilize these competencies, or near variants of them, or other learnable competencies that are identified through the design process.

Further, considering the widespread participation in mainstream technologies such as the internet and social media, such technologies provide an opportunity for revealing competencies that broadly apply to a universal user base, not just people with disability. As such, focusing on competencies furthers the vision of universal usability and universal design, by making systems and interfaces usable by practically the widest range of people.

Therefore, the Competency-based approach extends ability-based design to be adoptable with users with multiple disabilities, varying abilities, or sensory and cognitive disabilities by considering and encompassing their shared competencies in designing with them.

8.2.2 System: (Context → Entire Socio-Technical System). We also suggest that the system’s principles of ability-based design—that systems be able to model and predict user performances, automatically sense, and adapt to different user abilities—be considered from a practical vantage point of feasibility, and the commodity principles of system cost. We suggest that the design be contextually located from the start, i.e., it should consider the entire socio-technical context in which the design would be used, instead of solely focusing on adapting the system per se. As discussed earlier in Section 2.3, there are many contextual factors that are challenging to model with matrices and sensor data, as recommended in ability-based design, and so providing reliable, individually tailored predictive support is very challenging, especially with people with cognitive or co-occurring impairments. Some may benefit at some times from mainstream systems such as predictive text, but even such mainstream systems require a lot of review, recovery, and repair by the user, suggesting automated individual predictive support may be unreliable or infeasible. However, in the Competency-based approach, we take cognizance of the entire socio-technical context, which includes the social factors in the design environment, such as the role of proxies and support. For example, in designing the SkillsTube app, we considered the socio-technical context of the DSO staff in offering continuous training support to participants when required. Participants also had the opportunity to leverage such contextual support to sustain their participation and further enhance their competencies through using the app. Considering such contextual factors especially when designing with users with varying abilities, offer practical opportunities for accommodating complex user requirements that can sometimes be challenging to navigate solely through system adaptation.

Given that we have been discussing context, and leveraging technology (social media) participation competencies as a foundation for the Competency-based approach, a fair question at this stage, could be: how the Competency-based design approach applies to users who do not have any familiarity with technology or are first-hand users of technology and for that matter have no reliable competencies? As a response, we suggest that in such cases, the socio-technical context would offer opportunities for navigating such issues. For example, in such situations, the socio-technical context would make it apparent from the onset of the design that the users would require fundamental skills support to be able to use the design. Thus, a reflection of socio-technical factors such as the availability of support becomes an integral part of the design and its implementation.
process. In addition, other essential components of the Competency-based design approach, such as participatory methods, would provide support for skills and competencies development.

8.2.3 Competency-based Design upholds other Ability-based Design Principles. Besides extending the abilities stance and “system-centric” adaptation context of ability-based design, the Competency-based design approach upholds its other principles. For example, we adapted the accountability, transparency, and adaptation principles of ability-based framework to design most of the features of the SkillsTube app. The iterative design of the features of the app such as adapting the QR code scanning for logging in and adding friends, to respond to users’ poor performance leveraged the accountability principle of ability-based design. Further, all use activities on the app, that require a choice action, such as responding to a new friend request, creating a new playlist, or deleting a playlist or friend, leveraged the transparency principle of ability-based design. For all such actions, users were prompted through pop-up dialogues to confirm if they were sure, they wanted to go ahead with the action. Other principles, such as adaptation were incorporated in the app’s design to allow users to switch between using voice or typing when searching or writing comments during sharing content.

9 CONCLUSION

In this article, we have presented a Competency-based design approach that is grounded in revealing the existing contextual competencies of users and leveraging them in design. This approach builds on and extends ability-based design by making it adaptable for users with various intellectual disabilities, whose abilities are best manifested contextually, through incorporating their competencies. The Competency-based approach ensures that designs can reach a wide range of users, by working with a varied group, while also understanding the limits and extra support in tailoring needed for particular individuals. It is empowering, as it uses the competencies of people with intellectual disability, yet provides room for enhancing skills and developing them further. We believe this approach offers potential in supporting the design of accessible technologies not only with people with cognitive disabilities, but across all user groups.

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