Scaffolding Digital Literacy Through Digital Skills Training for Disabled People in the Global South

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Digital inclusion is essential for attaining the United Nations' Sustainable Development Goals and for ensuring no one is left behind. In low-and-middle countries (LMICs), people lack the digital skills to access good-quality employment opportunities. It has been shown in other contexts that scaffolding the learning of digital skills can enhance people's attainment of digital skills; specifically, these interventions target increasing the zones of actual development and independent action. However, to date, fewer studies have looked specifically at the role of digital skills training via smartphones for blind and partially sighted and deaf and hard-of-hearing people in LMICs. We conducted classroom-based training and peer learning through WhatsApp groups for 138 people in India and Kenya. Our findings emphasize the role of inclusive scaffolding and instructional and community-based peer learning. As such, we present a new digital scaffolding framework for inclusive instructional and peer learning, extending Vygotsky's Scaffolding Theory.

CCS Concepts: • **Human-centered computing** → **Empirical studies in accessibility**; • **Human-centered computing** → **Accessibility technologies**;

Keywords: digital skills, visual impairment, hearing impairment, LMIC, scaffolding

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1 Introduction

Over a billion people around the world live with a disability. People with disabilities are significantly less likely to own a mobile phone and use the internet than people without disabilities across low and middle-income countries (LMICs) [5]. As a result, they are less likely to be able to access the benefits and opportunities that mobile phone use and mobile internet can provide. This gap expands further with an ever-growing digital world, leaving behind people with disabilities, especially women, who may have benefited from these developments the most [15].

Digital technologies can be a great leveller for disability inclusion globally, particularly in the global south, where disabled people have much fewer opportunities and access to inclusive education and employment. “By global south, we mean the countries that are not only geographically located in the southern hemisphere but also those that are considered lower and middle-income countries by the World Bank[1]. Our objective is to strengthen academic literature by providing a better perspective of people with disabilities in the global south which is underrepresented in the studies related to programmes, policies and development in this domain.”

The WHO World Report on Disability 2016 states that disabled people are more likely to access health information online rather than in person. Additionally, using digital assistive technologies (AT) such as closed captioning and audio descriptions, deaf or hard of hearing (DHH) and blind or partially sighted (BPS) people can access information online without experiencing the barriers of travelling and the communication difficulties they often face in offline education and employment. Similarly, the report suggests that social media and online communities can empower people with a range of disabilities to learn new skills, offer services, develop businesses, and exchange knowledge.

Despite the abundance of digital technologies and their promising potential, people with disabilities experience several barriers to digital inclusion that branch out as a part of systemic barriers they face in everyday life [8]. These include a lack of accessibility, poor usability of digital devices and services, and limited availability of accessible information online. The affordability of smartphones and mobile internet further limits the wider access to digital tools and services, which is challenging because of the need to keep these devices safe and use them securely to avoid theft and fraud [27]. Additionally, the digital divide, the gap in access to digital technologies, is further exacerbated by a lack of appropriate and accessible training for people with disabilities to acquire the knowledge and skills to use mobile phones and digital services.

Digital disability Inclusion is critical to achieving the United Nations' Sustainable Development Goals (SDGs). Inclusive Quality Education (SDG 4) is important to reducing the digital divide, which leaves many disabled people without access to and skills to use digital devices and the Internet for education and employment. SDG 4 stipulates equitable access to quality education from primary to secondary school, focusing on increasing the technical and vocational skills needed for decent employment. Digital skills are needed across the job market in low- and middle-income countries, from informal to formal settings. According to the International Labour Organization (ILC), they are lacking across these settings. Digital disability inclusion is also covered by SDG 17, Global Partnership for Sustainable Development, which asks the world to work towards equitable access to internet use and specifically to drive an increase in the proportion of individuals using the Internet (indicator 17.8.1). For both SDG4 and SDG17 to be achieved, disabled people must not be left behind when it comes to digital education and mobile access. Together, these are also integral to the ideal of digital citizenship.

Several frameworks have been developed to support the acquisition of digital skills. For example, the training developed by Google and Microsoft are some of the most comprehensive resources available free of cost for anyone to learn to use the devices and applications manufactured by them. However, in the absence of any research on the effectiveness of these resources for BPS and DHH people in LMICs, there exists are gap in understanding how DHH and BPS people who may be new to mobile technologies can effectively learn digital skills, particularly learning to use the accessibility features of mobile phones and integrating these skills to support their activities of daily living, in education, employment, travel, and social interaction. In particular, there is a need to view the digital skills acquisition for DHH and BPS people in LMICs from a scaffolding lens to unearth the specific challenges that exacerbate the digital divide and to develop appropriate scaffolding strategies to support digital skills learning and application. In this paper, we present the result from a study involving 138 participants (69 BPS and 69 DHH individuals) from India and Kenya who took part in a digital skills training intervention for mobile literacy across two different groups. The first group received digital skills training according to the existing instructional structure based on the Google standard Android training, the second group received a more tailored version of the training that we developed following the structure of Scaffolding theory [1]. Our intervention shows that appropriate training content design and delivery can support effective learning for BPS and DHH participants. Further, we contribute to the literature on instructional scaffolding by extending the scaffolding model of instructional learning [1] [40] by adapting it to the digital learning context for people with visual and hearing impairments.

2 Related Work

2.1 Digital Literacy and Disability

Digital literacy is a complex and multifaceted issue, impacted by age, disability, socioeconomic status, culture, and access to education, among others [35][39]. Despite the sustained growth in the penetration rate of digital devices, a 2018 report surveying the digital skills of UK adults [ref] found that the main reasons for non-internet use were lack of interest, lack of skills, or not knowing where to start learning to use the internet, and not being able to access the internet due to a disability. The report also showed that disabled people are much less likely to use the internet, 25% compared to 6% of non-disabled people. The main reasons for the disabled population not using the internet were lack of skills or accessibility (“the internet is too complicated”, “I wouldn't know where to start”). A recent Ofcom report also highlighted several factors that contribute to digital exclusion. The most common factor was age; older adults (60+) are least likely to use the internet, followed by people having an impairment or impacting health condition and people on a low or limited income. Those who did not have a “connected device” cited a lack of skills or confidence to use the internet and concerns related to the safety and security of the internet.

Reduced digital literacy affects not only a person's ability to use a laptop but also a mobile phone. The analysis carried out by Sung and Kim [45], based on the responses of over 1600 people with disabilities in South Korea, highlights how, despite high levels of motivation, many disabled individuals, and especially those with visual and hearing impairment, struggle to access the internet on their mobile phones due to limited digital literacy. In contrast to their non-disabled peers, visually impaired individuals who rely on accessibility features such as screen-readers and gesture and speech-based input to interact with their phone are required to acquire a certain degree of digital literacy, even to perform relatively basic tasks [44][45][41]. As an example, both Pal et al. [36], and Barbareschi et al. [4] showed how, without appropriate digital skills training or sighted support, visually impaired individuals who transitioned from a traditional button phone to a smartphone found themselves unable to make phone calls, which they could previously do independently.

Although carried out approximately six years apart, the comparison between practices of novice and expert visually impaired users, as documented by Rodrigues et al. [42] and Jain [25], respectively, help to highlight some of the complexities that visually impaired users need to be able to navigate when learning how to use a smartphone. Gestures necessary to navigate within and between applications using TalkBack or Voice Over follow specific rules, such as the expected timing of a double tap or the length of a swipe, which are not explicitly stated and don't necessarily make intuitive sense for users [42][25][10]. Moreover, these rules can change between versions, with updates introducing new challenges that require additional learning, and, in case of failed interaction, no feedback is provided to explain how a command was misinterpreted [42][25][12]. Voice input and speech-to-text (STT) can provide a more accessible alternative in some cases due to a less steep learning curve, but they do not support the exploration of the screen to the same extent as gesture input, and they are limited in their accuracy, especially in noisy environment or for users who have non-standard speech [25][49][2]. Researchers have repeatedly pointed out how visually impaired users generally received limited structured training to develop these important mobile literacy skills, largely relying on their own capacity and determination, as well as the support of allies, sighted and non, in their personal networks [36][42][25][37][19].

On the other hand, research focusing on smartphone usage by DHH individuals reveals significantly different patterns. A survey on access to the internet and digital devices amongst people with disabilities in Sweden reported DHH individuals as having some of the highest usage rates [26]. The 2019 Report on Understanding the Mobile Disability Gap by GSMA [21] also highlighted how DHH people who own a smartphone are more likely to use SMS services and mobile internet compared to their non-disabled counterparts. However, studies have also shown how and what DHH mobile users are able to access using their handsets, which is moderated by their digital skills, the features of the application, and the nature of the content [32][13][23].

Nowadays, there are a large number of smartphone applications, as well as mobile operating systems features, available for DHH users aiming to provide different services from live captioning, amplifiers, alerts and sign language interpretation [50] [34] [7] [20] [23] [16] [24] [31]. However, experiments looking at the use and deployment of these applications have documented several limitations which can cause dissatisfaction, especially when expectations are overinflated by advertising from companies interested in acquiring new users [18][48]. While these limitations should be addressed by designers, improved digital literacy from the user side can help to understand the shortcomings of a system, make better decisions about where and when they wish to leverage these tools and applications, and actively resist the attempt of technology to alter their preferred modes of communication in favour of ableist norms [22][23][34][6].

Overall, as the rate of penetration of smartphones keeps increasing for disabled people in the Majority World, there is broad agreement over the need to promote digital literacy, but there is little guidance about how this can be successfully implemented in a way that is both comprehensive and scalable. In the following section, we review different digital literacy frameworks that have been proposed and discuss how they might relate to or apply to the needs of disabled users.

2.2 Scaffolding Theory

In order to develop the appropriate scaffolding or support strategies in acquiring digital skills for DHH and BPS people in LMICs, it is first important to understand the concepts in the scaffolding theory and its application in supporting skills acquisition. The concept of scaffolding emerged from the work of educational psychologist Lev Vygotsky [1], who posited the learning strategies and zones of development as the zone of actual development in which the learner is able to comfortably acquire and apply the skills, the out of reach zone in which the learner is unable to comfortably acquire and apply skills even with external intervention. Between these two zones exists the zone of proximal development, which Vygotsky refers to as 'the range of tasks that a learner can perform with the assistance of a more competent individual (scaffolding) but cannot yet perform independently' [17][33].

Although the scaffolding theory has broader applications, it has been predominantly applied in pedagogy, particularly in supporting children in classroom settings [47][46], where scaffolding is defined as the role of the teacher to encourage expanding the learner's capacity and building self-efficacy through knowledge and instructional techniques. Research on the applications of scaffolding in andragogy is scarce, particularly with people with sensory impairments. One possible reason for the widespread acceptance of Vygotsky's work in developmental and educational psychology is its alignment with the view of pedagogical learning that emphasizes the role of a more knowledgeable adult (teacher) in facilitating the acquisition of academic knowledge and skills. This perspective is also supported by prior works on social learning, such as Bandura's social learning theory [3], Lave and Wenger's situational learning theory [29], and Vygotsky's own sociocultural theory [28]. These theories suggest that learning is a social construct that is influenced by an individual's own abilities, as well as the sociocultural environment and opportunities for observation, imitation, and knowledge sharing with peers. In contrast, the andragogical or adult learning process is more self-directed and reflective of prior experiences, personal goals, and social values, which impact intrinsic motivation to acquire a skill or perform a task. Therefore, the scaffolding strategies would significantly vary between the two domains primarily due to the different approaches to learning and the needs of the learners. Scaffolding strategies for adult learning can be directed to support peer learning, independence, self-directed behaviour and support self-determination.

2.3 Digital Scaffolding

The premise of sociocultural theories in psychology is that learning happens in social settings as learners are exposed to new ideas, skills, and applications through interaction with other learners. In a collaborative learning environment shaped by sociocultural theories, the dynamics and perspectives of the group influence its structure. Such settings offer more advanced learners the chance to support their peers who may need more assistance. Within this community, learners embrace the role of cooperative members, striving together towards their shared objective—to complete the task at hand. This involves listening to one another, brainstorming, and engaging in discussions to solve problems or accomplish tasks. Additionally, this learning model allows learners to practice various social skills as they collaboratively solve problems and build shared knowledge within the community. Research has shown the positive role of WhatsApp in enhancing community interaction in both formal and informal learning communities [11][30]. WhatsApp's group chat features can be used to create learning and study groups. Students can stay in contact with one another and the teacher even outside the classroom, and they can share their queries with one another. Lessons can be shared as documents, audio messages and video messages. Thus, digital platforms like WhatsApp have a huge potential to build and support community interactions in education settings.

3 Method

3.1 Participants

We recruited 138 participants across two research settings: India (29 BPS, 29 DHH) and Kenya (40 BPS, 40 DHH). The participants were recruited through local partners who also helped facilitate and deliver the training. We used a hybrid sampling approach: (1) convenience sampling by selecting participants on a first-come, first-served basis from a pool of BPS and DHH people known to the local partners in each country, and (2) purposive sampling to select the participants that met the eligibility criteria and were from a diverse demographic and socioeconomic background. We provide a brief description of the participant groups in iterations 1 and 2 below, also summarised in Table 1

3.1.1 Iteration 1 Participants. In the first iteration in India, we trained 9 BPS and 9 DHH participants in two groups (group 1 and group 2). They were all from the state of Karnataka in India. The sample constituted 14 Male and 6 Female participants. 10 of the participants are students, and 8 of them are gainfully employed. The participants were aged between 20 - 60 years (mean=27.6, SD=9.94). Among the BPS participants, 5 were totally blind, and 4 were partially sighted. Among the DHH participants, 1 was hard of hearing, and 8 were deaf. Of these 18 participants, 8 were first-time smartphone users.

In Kenya, we trained 40 participants (20 BPS, 20 DHH) to participate in iteration 1 training through the local partners. The BPS participants (group 3) were aged between 20-60 years(mean=35.87, SD=10.13), 12 identified as male and 8 identified as female. The BPS participants were students (5), business owners (10), and teachers (5). The DHH participants (group 4) were aged between 19-58 years (mean=30.40, SD=9.47), 10 identified as male and 10 identified as female. The DHH participants' occupations were students (13) and business owners (7). All participants were residents of the Nairobi metropolitan area and surrounding counties and lived in urban and suburban locations.

3.1.2 Iteration 2 Participants. In the second iteration in India, we trained 20 BPS and 20 DHH participants in two groups (group 5 and group 6). Like the first iteration in India, all of them were from the state of Karnataka in India. All of them were students. The sample constituted 19 Male and 21 Female participants. The participants were aged between 18 - 40 years (mean=20.78, SD=3.48). Among the BPS participants, 11 were totally blind, and 9 were partially sighted. Among the DHH participants, 3 was hard of hearing, and 17 were deaf. Of these 20 participants, 12 were first-time smartphone users.

In Kenya, we trained 40 participants (20 BPS, 20 DHH) to participate in the iteration 2 training through the local partners. The BPS participants (group 7) were aged between 20 and 56 years(mean=28.13, SD=8.86); 13 identified as male and 7 identified as female. The BPS participants were students (13), business owners (2), and ICT-related careers (5). The DHH participants (group 8) were aged between 21 and 50 years (mean=30.30, SD=7.57); 12 identified as male and 8 identified as female. The DHH participants' occupations were IT (2), Carpenter (3), Teacher (3), Writer (1), Student (4), and Casual worker (2), not all participants provided their occupation information. All participants were residents of the Nairobi metropolitan area and surrounding counties and lived in urban and suburban locations. The participants had varied digital skills competencies based on their previous experiences with mobile technologies in education and employment.

Table 1: Participant groups in iteration 1 and 2

Country	Iteration 1	Iteration 2
India	Group 1 (BPS) Group 2 (DHH)	Group 5 (BPS) Group 6 (DHH)

Kenya	Group 3 (BPS) Group 4 (DHH)	Group 7 (BPS) Group 8 (DHH)

3.2 Study design

We designed a mixed-method study to investigate the design of digital skills training for BPS and DHH people in LMIC. The training curriculum was iteratively designed with collective feedback from the trainers and the participants. As illustrated in Figure 1, the study design comprised a baseline survey to assess the participants' comfort level and fluency in using Android smartphones. The first iteration of the training curriculum was based on the existing Android training developed by Google and was delivered to groups 1 – 4. Based on the feedback from the trainers and the trainees, we identified the gaps in the training curriculum and the scaffolding strategies to support the effective delivery of the training to the participants.

Figure 1

Figure 1: Overall study design

3.3 Materials and Equipment

3.3.1 Baseline survey. We conducted a Baseline Survey to assess the participants' actual zone of development, their comfort level with technologies, and their competence in digital skills. The survey was based on the mobile device proficiency questionnaire (MDPQ) [43], which was designed to assess the overall mobile device proficiency as well as proficiencies across eight domains: (a) Mobile Device Basics, (b) Communication, (c) Data and File Storage, (d) Internet, (e) Calendar, (f) Entertainment, (g) Privacy, and (h) Troubleshooting and Software Management. We extended and adapted the MDPQ by adding specific questions concerning voice calls and SMS messages. We also added an additional subscale to assess the participants' proficiency in the Android accessibility features. This was crucial to determine the participants' existing knowledge and skills related to the accessibility features. This initial assessment allowed us to categorize and manage data efficiently, ensuring the identification of participants' starting points in terms of digital skills and readiness, which facilitated tailored scaffolding in subsequent training sessions.

3.3.2 Digital skills curriculum design. As mentioned in section 2.2, the design of the training and support provided during and after the training should match the learners' needs, expectations, and goals. Therefore, we considered several factors. We designed a digital skills curriculum to train the participants on Android accessibility features and general mobile digital skills. The curriculum was designed to gradually deliver the training, focusing on the basic skills and then moving on to the advanced skills. The curriculum was based on the existing Android user manual and training available via Google Digital Garage and Grow with Google initiatives[2]. Building on the scaffolding design recommendations, the training (illustrated in Figure X) included hands-on support by trainers in addition to the training content to ensure the effective delivery and meaningful adoption of the skills by the participants. The training was adapted to address the specific needs of each group. For example, the training content and delivery was predominantly voice and touch-based for BPS participants and was more visual for DHH participants. The training was structured in incremental learning steps supported by the trainers (the scaffold).

Table 2: Digital Skills Curriculum Design (Iteration 2)

Competence Level	Competence area	Training
Module 1: Basic Functionality	Unboxing	Learn physical phone controls How to switch the phone on and off How to charge the phone Insert SIM Set up the phone / gmail account Learn the settings menu (wifi, Bluetooth, location settings, etc.)
	Exercise	Practice using phone buttons and swapping SIMs
	Configure accessibility settings	Google Assistant BPS PARTICIPANTS •Screen Reader (System Service: TalkBack) • Magnifier (System Service & App TBD) • Display Size and Text DHH PARTICIPANTS • Live Transcribe • Sound Amplifier •Live Caption (TBD: check compatibility with the phone)
	Exercise	Practice accessibility shortcuts to browse the apps
	Installing new apps	Find Play Store app Search for the desired app Install the app and open it
	Exercise	Install the following Google apps: •Lookout •Action Blocks •Translate
	Learn Lookout	Lookout app functionality (BPS)
	Exercise	Explore the room (and provided material) to use Lookout
Module 2: Communication & Social Media	Call & Text	How to make a phone call How to send a text message How to use the camera
	Exercise	Use accessibility shortcuts to perform these tasks
	Communication Apps	Install and set up WhatsApp
	Exercise	Send and receive WhatsApp messages
	Browse the Internet	Use Chrome to visit a website
		Browse the website using TalkBack
	Social Media	Install and set up Instagram / Facebook / Twitter / Tiktok
	Exercise	Use accessibility features to access social media applications and content
	Entertainment	Install Youtube app
	Exercise	Search for a video and play it. Try the accessibility features while the video is playing (Live Captions, Talkback, audio descriptions)
Module 3: Online Safety and Digital Wellbeing	Privacy and Security	Passwords What to download (viruses etc.) What to share Social media presence (bullying etc) Where to reach out for help in case anything happens (helpline, cyber cells)
	Exercise	Group discussion

3.3.3 Android Smartphone. A prior investigation into the research setting informed of the low prevalence of appropriate Android smartphones in the target research population, i.e. BPS and DHH people in India and Kenya. Thus, to investigate the participants' use of mobile phones following the digital skills training, we provided the participants with Samsung A14 Android smartphones. The Samsung A14 smartphone was selected for the study after reviewing three low-cost smartphones for availability, accessibility, and ease of use by potential participants in India and Kenya. The other two models, Techno Spark 10 and Redmi 8 Pro were deemed unsuitable due to the incompatibility of Android accessibility features with the smartphone components such as camera and physical buttons. The Samsung A14 was selected as a suitable alternative as the same accessibility issues were not present, and the Android version operated on the smartphone (version 13) was comparable to the full Android version offered on Google Pixel devices.

3.3.4 Extended digital scaffolding through WhatsApp-based peer learning. Given the evidence on the usefulness of WhatsApp groups for continued learning through peer support and knowledge exchange, we created a WhatsApp community with separate communication channels (WhatsApp groups) for each participant group. As such, we created 4 groups per country (2 BPS and 2 DHH groups) where participants from each of the training groups were added as they had a shared experience of the digital skills training and were familiar with each other.

We also used WhatsApp groups to supplement the digital skills training by posting bite-size information and additional resources and observing the organic interactions between the participants to understand the usage of the phone, issues related to phone usage, and other inter-group communications specific to community-based learning.

4 Iteration 1 Digital Skills Training

We conducted the first iteration of the digital skills training with the first group of participants (listed in section 3.1.1) to test the training content and delivery for BPS and DHH people. The research team, accompanied by trainers from local partners, delivered the training and observed the participants' interaction with the smartphones and the training content. The trainers maintained notes of their observations throughout the two-day training and their suggestions for improving the training materials and delivery. After the training, we collected the trainers' notes and the participants' feedback on the training materials and delivery in order to improve the training materials and the scaffolding strategies for the effective delivery of the training. The feedback from the participants was collected through informal exit interviews at the end of the digital skills training to investigate the structure, appropriateness and clarity of the training material and the effectiveness of the training in smartphone and Android accessibility features as assistive technology.

4.1 Procedure

Before the training, we conducted the baseline survey to determine the participants' existing digital literacy skills (actual zone of development) and to determine the appropriate scaffolds necessary to deliver the training effectively. To imitate a realistic group learning setting, the participants were grouped first by disability and then by availability rather than digital skills competency or any other demographic parameters. As such, the training was delivered over two days for each participant group in both countries respectively (see Table 1). In each country, the local partners delivered the training in a mix of English and local languages (Kannada in India and Kiswahili in Kenya). Training content in the form of presentation slides was projected on a screen in the training room to enable the trainers to illustrate the examples and mobile phone features.

4.2 Findings

We analyzed the participant feedback and trainer observations by grouping them into an affinity map and designed the scaffolding strategies to improve the training materials and delivery.

4.2.1 Need for appropriate training materials. BPS participants found it difficult to remove the smartphone from the packaging and intuitively learn the smartphone's physical features in the absence of a mental model of the specific smartphone make and model despite having some prior experience using smartphones. This process took much longer than anticipated and caused considerable discomfort to the participants. Additionally, there was a steep learning curve for BPS participants to learn the Android accessibility features; particularly the shortcut gestures, which needed to be memorised. Due to this, the trainers encouraged the repetition of certain tasks to support the participants in developing a mental model of the smartphone's physical features as well as the Android settings and accessibility menus. For example, the participants learned to turn Talkback on and off using the volume key shortcut by repeatedly pressing both volume keys for a few seconds until the notification was heard from the phone. As this task required the participants to familiarize with the volume keys and listen for the Talkback notification from the phone, it was particularly challenging at the beginning, but the participants became more confident and comfortable with it as the training continued.

To overcome these challenges, we adopted a modular curriculum design (Figure 2) to customise the training content and the delivery based on the needs of the participants. Based on the baseline survey results, the trainers would be able to decide which modules would be suitable for an individual or a group of participants with similar needs and digital skills competency.

4.2.2 Language barriers. Despite having sign-language interpreters present, the trainers found it difficult to effectively communicate with the DHH participants due to the delays in getting the participants' responses due to having sign-language interpretation. This also slowed down the communication and overall training significantly as the sign language interpreters often did not understand the terminologies and struggled to translate between spoken and sign languages.

DHH participants also experienced another challenge during the training and smartphone accessibility features used as AT as they had limited proficiency in English and regional languages. This was observed by the trainers in both countries. The trainers discovered that the DHH participants were taught local sign languages (Indian Sign Language and Kenyan Sign Language) and English (in limited capacity) and were not proficient in regional languages due to the unavailability of accessible learning resources. Many of the regional languages in the Indian sub-continent and Sub-Saharan Africa are predominantly spoken only and are not commonly available in written script resulting in the lack of learning resources and training available for DHH people.

Another important observation from the participants was the difficulty in maintaining DHH participants' attention throughout the training. For example, for BPS participants, the trainers adopted prompts such as "Clap if you can hear me" to grab the participants' attention. However, finding a signed alternative for such prompts proved to be challenging despite having a 1:5 ratio of sign language interpreters to DHH participants. As the participants focused on their phones to practice their new skills, their visual attention was quickly diverted from their surroundings. To address this issue, the trainers established a signed clap prompt[3] to indicate that the participants must pay attention to the trainer (and sign language interpreter). Similar to clapping for BPS participants, DHH participants were asked to sign clap when they saw the trainer gesturing the same sign, indicating to their peers to pay attention to the trainer and the interpreter.

As the participants became more familiar with the accessibility features such as LiveTranscribe and Sound Notification. They were quicker in following the trainers' verbal instructions, which were transcribed live on their phone screen through LiveTranscribe. Additionally, the participants set up a notification on their phones when an auditory clap was heard, resulting in their phones vibrating and flashing lights when the trainer clapped their hands to get the participants' attention.

4.2.3 General scaffolding strategies. The trainers observed that participants learned the digital skills concepts at varied speeds depending on several variables. For example, some younger participants were quicker to learn the accessibility gestures and features in both countries compared to the older participants. Similarly, depending on their familiarity with each other, participants were quicker or slower to learn as they received support from their peers. This was commonly observed among DHH participants, who had better spatial awareness of their peers and felt comfortable moving around the workshop space to communicate with each other. To address the challenges mentioned previously and to improve the overall delivery of the training, we adopted the following general scaffolding strategies:

- Encouraged self and peer-learning in smaller groups of participants with similar digital competency and familiarity with each other
- More hands-on approach for participants who demonstrated low confidence in their skills and unfamiliarity with the mobile device
- Less hands-on approach for participants who were more confident and independent in following the verbal instructions
- Short instruction sessions followed by exercises to allow participants to practice their newly developed skills and progressively build confidence
- Repeating the tasks (interactions) to build confidence and efficiency in performing the tasks

Figure 2

Figure 2: Iteration 2 training and scaffolding strategies

5 Iteration 2 Digital Skills Training

We updated the curriculum design with the suggested scaffolding strategies from iteration 1. The updated curriculum, iteration 2, was delivered to 80 participants in both countries (40 BPS, 40 DHH). We followed the same procedure to conduct Iteration 2 with the addition of the scaffolding strategies mentioned in the previous sections and the modular approach illustrated in Figure 2.

5.1 Analysis

All trainers maintained notes of their observations throughout the training, which were analyzed to identify the strengths and potential gaps in the scaffolding strategies and support the participants' learning of the new digital skills. Additionally, we observed the participants' interaction in the WhatsApp groups for three months after the training. All data, the trainer's observations and WhatsApp chat were anonymized to remove any identifiable data prior to analysis. Ethical approval for the research was obtained from the universities in both countries.

The qualitative data collected for this study was analysed using thematic analysis [9] to identify and interpret meaningful patterns in the data. In doing so, we used the concepts in scaffolding theory: the zone of actual development, zone of proximal development, out-of-reach zone, and scaffolding as a lens to interpret the data. As such, the thematic analysis approach was hybrid; first, we coded the data inductively and grouped it into sub-themes and then the sub-themes were regrouped deductively based on the concepts in scaffolding theory. The final themes are presented in the next section.

5.2 Analysis Findings

From the analysis, we deduce the following about the various zones of scaffolding. Figure 2 depicts the new digital scaffolding framework for inclusive instructional and peer learning. It consists of the following four zones:

- The first zone is the "Out of Reach Zone", where participants' baseline digital skills are assessed to understand what the participants cannot do in the context of smartphone usage.
- The second zone is the "Zone of Proximal Development", where the training material specifically tailored for both BPS and DHH participants is disseminated in a classroom setting. This defines what the participants can do with assistance in a classroom.
- The third zone is the "Zone of Extended Digital Scaffolding", which we introduced in our intervention to help participants reinforce classroom learning.

- The fourth zone is the "Zone of Actual Development", where the participants can independently learn new concepts through self-learning and peer learning.

Figure 3

Figure 3: Digital Scaffolding Framework for Inclusive and Accessible Instructional learning

We discuss these four zones in detail next.

5.2.1 Out of Reach Zone / Baseline Digital Skills. Participants were observed during the training to understand their baseline digital skills. This knowledge effectively defines their "out of reach zone". There were differences between the two groups as to what lies within and outside this zone. There were mixed experiences related to unboxing their phone and setting it up among the BPS groups. An example of frustration in the process was demonstrated by participant VI-IN1113, who became visibly upset when their sim card fell on the floor during setup. He did not like that he had to depend on the trainer and the research team to complete the setup process. Others also found the set-up process challenging. VI-IN1039 and VI-IN1042 found the process of entering their email IDs and setting up their phones using TalkBack very difficult. *"I am not able to enter my email ID. Can you please help me,"* said BPS-VE006. However, some elements of the unboxing experience were positive. About 50% of them were able to complete the setup process independently once the sim card was inserted into the phone by a sighted help and talkback was turned on. The unboxing and setup process of the phone was relatively easy for the DHH participants. They were able to follow the images on the screen and the instructions from the trainer and set up their phones without any glitches. Overall, among the BPS participants, people with prior smartphone ownership were able to follow the TalkBack accessibility feature to interact with devices using touch and spoken feedback. First-time users took some time to adapt to TalkBack. Some of them found it very different from their feature phones and found the smartphone very unfamiliar. Participant VI-IN1117 was in tears and was angry that she was not even able to make a simple phone call using the smartphone. *"I want to switch back to my button phone,"* she said. Overall, 60% of them were unaware of the accessibility features/apps such as Accessibility settings, shortcut menus, TalkBack, Lookout, Google Assistant and other Text-to-speech services. Among the DHH participants, we observed significant differences in comprehension levels. It was observed that 50% of the existing smartphone users were comfortable using WhatsApp. In fact, participant HI-IN1053 was typing in WhatsApp status to communicate with the research team during the training. Almost 30% of them were unaware of the accessibility features, such as the accessibility shortcut menu and accessibility settings for live captions. None of the participants were aware of the special app "Live Transcribe", which generates live captions and displays information on various sounds. This suggests that the "out of reach zone" for the digital skills of both BPS and DHH participants is of considerable size.

5.2.2 Zone of Proximal Development / Digital Skills Training. The training material was tailored for both BPS and DHH groups. Training content for DHH participants was enhanced with visual images and supported by ISL trainers. Multiple trainers provide support training for BPS participants to provide individual guidance and support. The training material was divided into multiple modules of increasing difficulty to support different baseline skill levels. Those participants with no prior smartphone experience were trained in all the basic modules before they were introduced to advanced-level modules. On the contrary, participants who had basic digital skills were directly introduced to advanced-level modules. It was structured to be a combination of classroom training and extended training through WhatsApp, where additional and advanced training material and support was provided to the participants. Based on the pilot's experience, the training content was modified. New content on unboxing and installation was added. Some of the advanced content was removed from the classroom training and moved to WhatsApp-based content delivery.

Training BPS participants on smartphone accessibility features was difficult. It involved teaching the usage of gestures for using the Talkback application which is essential for people with visual impairment to use the smartphone. First-time users required a lot of individual attention and guidance in terms of tactile training. One of the participants, VI-IN1117, who was a first-time user, was visibly very upset as she was unable to grasp the device. She expressed difficulty and frustration. She was able to gain confidence after a lot of one-on-one gesture training. Trainers motivated participants to learn, reassured them and instilled confidence. Each participant received individualised assistance from a dedicated trainer, and this helped in providing customised training to each of the participants based on their baseline digital skills. Improved proficiency in usage was observed on the second day of the training. Participants were more comfortable with the device. We observed them making phone calls and sending voice-based WhatsApp messages.

DHH participants were visibly very happy to learn using the LiveTranscribe app. Some of the participants were able to speak a few words like *"How are you?"* and were excited to see the same being displayed on the LiveTranscribe app as they spoke. One of the participants was elated to see the words *"Hello, what is your name?"* on the screen when one of the research team members was demonstrating the application. Many were very happy with the feature in the LiveTranscribe app, where the phone vibrates when their name is called out.

Across the training groups, one common feature that was observed is the extent of peer learning. Participants were getting familiar with one another and extending support to one another during the training.

5.2.3 Extended Digital Scaffolding. WhatsApp was used as a channel to teach, guide and support participants after the classroom training. Participants were added to a common WhatsApp group with the trainer and the research team at the end of the classroom training. Learnings from the classroom were reinforced by using these digital tools as extended scaffolds. Participants were able to apply these learnings to various facets of their lives.

Reinforce Classroom Learnings Participants used these WhatsApp groups to share updates about what they had learned about smartphone usage. For example, they post updates about their proficiency in using smartphone features to modify settings, default apps and other third-party apps. They post general queries about default smartphone features such as setting fingerprint locks, caller settings to read out caller names, connecting to 5G, etc. They also posted queries about some specific apps that they have downloaded on their devices. These include queries about using the app TechFreedom clearing WhatsApp chats, paying contacts using payment apps etc.

As the participants started exploring the phone and its features independently, support from the trainers in the WhatsApp group reinforced classroom learning. Trainers assured participants that they would help and support them by addressing their queries. They responded to queries posted by the participants. During the discussions, they make connections to the training content covered in the classroom.

Trainers provided information on various topics related to smartphone usage through WhatsApp based on the training content. They share new information regarding some new apps and additional useful features of apps familiar to participants, such as the advanced features of the TechFreedom app. Advanced-level **[MB2] (https://www.overleaf.com/project/66293736abf7ceb6adc614af#_msocom_2)** training modules are introduced through WhatsApp as YouTube tutorial links, allowing participants to learn at their own pace. Trainers shared information about new apps such as ETI-Eloquence**[2] (https://www.overleaf.com/project/66293736abf7ceb6adc614af#_ftn2)** Text to Speech app.

VI-IN1171: *"Can anyone help me in setting up the G-board?"*

Trainer's Response: *"Give the required permissions for keyboard, then go to lists and defaults in settings. The G-board will be turned off by default there. Turn on the G-board there. Then turn on google voice typing. Then set the language that you need."*

VI-IN1176: *"Can anyone send me the link for the Instareader app? Will I be able to read the amount on the notes if I install that app?"*

Trainer: *"Instareader will not help you in reading currency notes. It helps in reading pdf documents. To read what's printed on currency notes, there is one option called tech freedom. For specifically reading the amount on a currency note, there is an app "RBI MANI" which we discussed in the classroom."*

HI-IN1075: Video message in ISL: *"Need help regarding long buffers on Instagram, YouTube & video calls."*

Trainer: Video message in IS: *"You have probably consumed all daily data which might have throttled your internet speed"*

HI-IN1085: *"In the Live Transcribe App when anybody is speaking in Hindi, the app is showing that in Hindi typed in English, but it is not showing the English translations"*

Trainer: *"You have to change the language to English (India)."*

KE_VI_8: *"Good afternoon. Can somebody kindly assist and direct me on how screen shot on this phone. Thank you."*

Trainer: *"Power button + Volume down button pressed together."*

KE_VI_11: *"When i press as you have said,it takes me to power off and restart,is there another way of doing it?"*

Trainer: *"Are you sure you are pressing volume down and power buttons at the same time? It usually works. If not try to press power and hold for a few seconds. Check if one of the options on the screen is screenshot and tap it."*

Apply Learnings in Various Facets of Life WhatsApp conversations reflected participants' satisfaction with the smartphone. Participants shared how the phone had been very helpful to them. They shared their lived experiences related to the application of different apps in daily settings such as education, transportation, independence, enrichment, social interaction, citizenship activities (interacting with the digital govt platforms, registering to vote), etc. For example, they also shared how they have been using their smartphone for various aspects of their life, such as searching for routes using Google Assistant, using a voice recorder to record classes, listening to the news, online shopping, reading currency notes, using online resources to prepare for competitive examinations etc.

VI-IN1176: *"Today I set a location from Sattur to Lakshmeswar. I said" Hey google! Give me directions from Sattur to Lakshmeswar". I renewed my bus pass for one more year using my phone. I learnt how to search routes for different locations"*

VI-IN1169: *"**https://youtu.be/5mE9uJZQgCo?si=KkoNAB1dbIM4KsHi (https://youtu.be/5mE9uJZQgCo?si=KkoNAB1dbIM4KsHi)** This video helped me in learning the song for republic day"*

Trainers demonstrated constant support by encouraging participants to share what they have learnt in the WhatsApp groups. They appreciated the participants when participants exhibited the ability to apply the learning from the classroom in real life situations.

VI-IN1113: *"Envision AI: https://play.google.com/store/apps/details?id=com.letsenvision.envisionai (https://play.google.com/store/apps/details?id=com.letsenvision.envisionai). This app is for PDF reading, text reading and letting us know about surrounding objects. Please download this app. This app translates in local languages such as Kannada as well. Thank you."*

5.2.4 Zone of Actual Development. WhatsApp communications in the training groups clearly revealed the evolution of participants' digital skills. While the trainers still supported them, participants' dependence on the trainers was reduced. There is strong evidence of community building in these groups and participants continued to build their skills through self-learning and learning from the peers in the groups.

Self-learning Participants were able to independently build their skills and proficiency in smartphone usage. They explored the smartphone further and learned new topics that had not been introduced by trainers during their classroom interaction. In some cases, participants were able to resolve their own queries before the trainer addressed them. They demonstrated enthusiasm and experimented with new apps such as "Vocalizer", "Be My AI" etc. Additionally, they were also able to learn to use other digital technologies in conjunction with the smartphone. One participant connected his laptop to the internet using a mobile hotspot.

VI-IN1113: *"Good afternoon, everyone. Today I installed three new applications on my phone - messenger, Swiggy and chat GPT. Thank you."*

Peer learning Participants acknowledge the support of family members and friends in their learning process. For example, some of them appreciated help from family members in setting up their email on their phones. Some participants addressed the queries posted by others in the group. Some of them also helped others in learning additional features of the apps introduced by trainers and provided links and resources related to some new apps that they have experimented with. They encouraged one another to use some apps which they found useful. We observed knowledge-sharing behavior with the intention of empowering other participants.

VI-IN1129: *"I learnt how to save contacts, posting status and sending messages with the help of my friends."*

VI-IN1148: *"I need help. I am unable to read pdf with the apps that i have. Can you tell me an app which reads all English, Hindi, Kannada well?"*

VI-IN1145: *"(To VI-IN1148) In the phone given to you, 365 Microsoft Viewer app will be there. It can read every pdf. Explore that app. You can take help from your friends or your instructors"*

Community building Participants were closely associated with the others in the group, and they shared a lot of information that may be useful for people with disabilities. Some of these topics were not directly related to smartphone usage. For example, they were sharing links to access accessible braille-enabled credit/debit cards for the Visually impaired, and links to raise tickets if someone doesn't receive govt. benefits (such as Pensions or Direct Benefit Transfers from the Government). They also wished one another on these groups during festivals and functions. For example, they exchanged wishes on the eve of the new year.

VI-IN1140: *" https://www.youtube.com/watch?v=Pkl6ixXOT9E (https://www.youtube.com/watch?v=Pkl6ixXOT9E) I sent a link above. Its about the problem that we are facing in receiving pensions. Check it out it might help."*

VI-IN1188: *"In the next two weeks, we need to register to vote in elections. There is an app called Voterhelpline. You can go to the app and get your voter id card."*

KE_VI_21: *"Hi guys, the barrial went on well. Thank u all 4 your prayers and concern God bless u."*

KE_VI_32: *"When are we celebrating world disabilities day?"*

5.2.5 Differences Among DHH and BPS WhatsApp group Participation. Among the groups, we observed that BPS participant groups were very active, with a significantly greater number of conversations (an average of 5 messages per day). They were communicating either through text messages or audio messages in the regional language. However, participation in DHH groups was limited (on an average of 1 message in two days). They were sharing video messages in ISL to communicate with one another.

6 Discussion

Through our study, we have successfully addressed our research questions. Our intervention shows that appropriate training content design and delivery can support effective learning for BPS and DHH participants. We demonstrate that the training content must be made modular in such a way that it can be customized based on individuals' training needs and baseline skills. The content was made accessible for both participants. More individualized attention was provided wherever required. Going beyond just the training content, trainers also instill confidence among the participants. We also establish that extended trainer support through digital platforms reinforces classroom learning. Enhancing smartphone-based digital skills empowers participants with accessibility tools and applications that further scaffold their future learning process. Also, introducing advanced training content slowly through the digital platforms after participants become comfortable with the basics ensures easier assimilation of the content for the participants. Additionally, the groups created on digital platforms such as WhatsApp act as social infrastructures that scaffold peer learning and self-learning.

Further, we contribute to the literature on instructional scaffolding by extending the scaffolding model of instructional learning [1] [40] by adapting it to the digital learning context for people with visual and hearing impairments. 4 depicts the three approaches by which we extend the scaffolding theory, and Table 3 provides a concise list of the three extensions and related mechanisms. We discuss these three extensions below.

Figure 4

Figure 4: Differences between the original scaffolding model and our new model of digital scaffolding for inclusive instructional and peer-learning

Table 3: Extensions to the Scaffolding Theory

Extensions to Scaffolding Theory	Mechanisms
Strengthened zone of Proximal Development	Modular Training Content
	Tailored dissemination of content
	One-on-one hands-on training
New zone of extended digital scaffolding	WhatsApp groups for extended learning
	Advanced lessons through WhatsApp
	Trainer support in addressing queries
	Mutual support in addressing queries
Expanded Zone of Actual Development	Peer-learning
	Self-learning
	Community support

6.1 Strengthened Zone of Proximal Development

Through our intervention, we find that, for people with visual and hearing impairment, the zone of proximal development can be strengthened and expanded by tailoring the training content for the participants based on their disabilities and their baseline skills and providing more hands-on support and guidance. This helps participants learn to use appropriate tools and resources effectively in a classroom setting. Our study establishes the fact that modular and personalized training with more one-on-one attention can strengthen the zone of proximal development and empower the participants with more tools and resources which they can easily apply for future learning. This has implications for the design of training content and training programmes for people with visual and hearing impairments. This highlights the need to train participants in accessibility technologies and tools that further become part of the scaffold in their future learning endeavours.

6.2 New Zone of Extended Digital Scaffolding

We introduced a zone of Extended digital scaffolding through WhatsApp groups, which supports participants over a longer period in the classroom setting. Trainers clarify the queries posted by participants on the WhatsApp group. Discussions around these topics in the group reinforce the classroom training for the participants and help them absorb and retain the content shared in the classroom. These groups are further used to introduce advanced topics slowly to help participants assimilate the content better. This way, students can learn at their own pace. WhatsApp groups provided a conducive learning environment through active participation.

Through our study, we specifically highlight two major aspects of digital scaffolds. First, the concept of communities and their potential in the domain of education, specifically in the context of people with disabilities. This concept has earlier been examined in detail in the stream of "Communities of Practice", where trainers foster community building in their own classroom contexts by ensuring that each participant experiences the "opportunities for interaction, mutual dependence, and identification with a group [38]. Second, demonstrate the power of digital platforms in building, strengthening and retaining these communities over an extended period. These platforms are gaining traction as tools for virtual education [14]. These platforms are excellent tools for disseminating learning resources. They are particularly useful in the context of learning for BPS and DHH participants as they are much more dynamic and proactive, and the learners can communicate via audio and video messages as well.

6.3 Expanded Zone of Actual Development

Our intervention establishes that appropriately designed training interventions can help expand the zone of actual development where participants can independently learn and apply digital skills in their lives. Through the study, we demonstrate that support through digital scaffolds expands the zone of actual development in the following three ways:

- Smartphone as a tool: Smartphone in itself and other accessibility apps on the phone become portals for self-learning for people with visual and hearing impairment.
- Channel for Peer Learning: Digital platforms that help participants get together and learn from one another in groups are potential channels.
- Community building: In addition to learning from one another, community building nurtures the mutual sharing of lived experiences and useful information, which provides a fertile environment for growth and learning, participants themselves become part of the scaffold.

The above three aspects mutually reinforce one another making the participants more confident in independently building their digital skills. This expands the zone of actual development where they can perform more digital tasks independently.

6.4 Limitations and Future Work

While we make strong contributions to both practice and theory, our study has some limitations and scope for future research. First, we observe differences in the impact of the digital scaffolds between BPS and DHH participants. The engagement and participation of BPS WhatsApp groups was very high. On the contrary, the response in the WhatsApp groups of DHH participants was lukewarm. This may be due to potential spoken and sign language barriers. The geographical differences in WhatsApp use were not investigated and were out of the scope of this study.

Future research can examine the specific reasons for the limited participation of DHH participants to understand the additional scaffolds that will enhance their response. Further, we have only considered the digital skills scaffolding for BPS and DHH people. Extending this study with people with other disabilities is a fertile area for future research.

7 Conclusion

Digital disability Inclusion is critical to reducing the digital divide. To address this digital divide, we focus on the digital skills acquisition of DHH and BPS people in LMICs. With the objective of making mobile digital skills more accessible to disabled people who have low digital skills and limited access to support, we developed a training intervention based on the theory of scaffolding for instructional learning specifically tailored for people with hearing and visual impairment. We conducted classroom-based training and peer learning through WhatsApp groups for 138 people in India and Kenya. We developed modular training content which can be tailored based on individual baseline digital skills. It was designed to be disseminated through a combination of classroom settings followed by WhatsApp group-based instructional and peer learning. By analysing observations during the training and WhatsApp group communications, we arrived at a new digital scaffolding framework for inclusive instructional and peer learning, extending Vygotsky's Scaffolding Theory. Our findings emphasize the role of inclusive scaffolding and instructional and community-based peer learning. The new model provides a framework for strengthening classroom training and expanding the zone of independent learning for people with hearing and visual impairments.

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Footnote

*Both authors contributed equally to this research.

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