Actionable UI Design Guidelines for Smartphone Applications Inclusive of Low-Literate Users

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With easy access to affordable internet-powered smartphones, developing countries are adopting smartphone applications to provide enabling services to its citizens, through eHealth, eGovernance, and digital payments. The challenge is to ensure equitable access to these services by everyone, including people with semi-literacy or low-literacy who form a large part of the population in developing countries. However, extensive HCI literature has identified literacy as one of the barriers to designing user interfaces. In this work, we propose a framework of actionable guidelines for designing smartphone UIs that would be usable by low-literate users. We reviewed the last two decades of HCI literature engaging people with low literacy, to synthesize our framework—*designing SARAL*. To evaluate the framework, we conducted a preliminary study with a group of 20 practitioners and researchers working in the field of UI/UX/HCI. We also analyzed six publicly available industry reports on designing UIs for people with low-literacy. The proposed guidelines intend to support researchers, practitioners, designers, and implementers in the design and evaluation of UIs of smartphone applications for people with low literacy. We present the *evolutionary* nature of the proposed framework while highlighting the importance of adopting a *translational* approach when building such frameworks.

CCS Concepts: • **Human-centered computing → User interface design**; **User interface toolkits**.

Additional Key Words and Phrases: User interface; design guidelines; framework; mobile application; low-literate; HCI4D; ICTD

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1 INTRODUCTION

Easy access to affordable technology has made internet-powered mobile device(s) a fixture of lives across the socio-economic strata [30, 48]. The accessibility to affordable mobile technology has opened avenues for the digital economy, with developing countries adopting smartphone applications as a gateway to achieving national and sustainable development goals. In one such initiative, the Government of India has launched several enabling services like eGovernance, eHealth,

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digital payments, and more as a part of Digital India Mission [103]. Recently, the push for using smartphones to deliver enabling services has accelerated due to restrictions on mobility during the COVID-19 pandemic. For example, India made its COVID-19 contact tracing app (Aarogya Setu) mandatory for traveling via fifteen special passenger trains during lockdown [54]. However, a critical challenge is ensuring equitable access to such services for the semi-literate or low-literate segment of the population [109].

Designing technology for and with people with low-literacy is a well-studied area and continues to intrigue researchers from HCI, CSCW, and ICTD communities (e.g., [35, 61, 90, 91, 123]). Previous work has studied textless UIs [87, 89], factors affecting technology adoption [49, 81], cognitive abilities [85], how they impact user interaction [6, 69, 84], and more. A majority of this work is from developing nations like India (e.g., [65, 117]), Bangladesh (e.g., [9, 58]), Pakistan (e.g., [6, 56]), and Ethiopia (e.g., [38]), where a large part of the population is either semi-literate or low-literate. Prior research serves as evidence for literacy being one of the *"greatest challenges"*, when designing mobile applications in the field of ICTD [85, 91]. With easy access to affordable emergent mobile technology, it is imperative to question how we can design smartphone interfaces such that low-literate users can equitably access the enabling services. Post COVID-19, the need to deliver enabling services in an equitable manner has become even more crucial. In the last two decades, the HCI researchers have done extensive work in interaction design to understand the barriers that literacy poses, how they can be circumvented, and low-literate users' coping strategies. In 2018, UNESCO also released a report on digital inclusion guidelines to establish digital entry points built on some of these recommendations [128]. There are independent industry reports which also offer insights on designing domain-specific (e.g., digital payments) user interfaces for low-literate users (see [10, 14, 15, 51]).

However, these learnings are scattered across the academic literature and industry reports. We aim to extend the ongoing discussion around interaction design by distilling those learnings into a framework of actionable guidelines for designing smartphone user interfaces that would be effective and usable for people with low literacy. Our field experience of working with and designing mobile-based interventions for low-literate population across India has shaped our motivation to carry out this work. For our study, we borrowed the definition of low-literate users by Ahmed et al. [7]:

> *"In the developing world, many people are illiterate (unable to read, write, and understand short simple messages) and semi-literate (struggling to read, write, and understand short simple messages). We use the term low-literate to refer to these two classes of people."*

Here, we would like to emphasize that our positional definition of low-literacy does not encompass digital illiteracy where people are capable of reading (and/or writing) but are unable to operate digital devices. Working towards our objective, we performed a systematic literature review (SLR) of studies published in the ACM digital library over the last two decades to develop our framework—*designing SARAL* (Smartphone Applications embRAcing Low-literate users). We did a preliminary evaluation of our framework by conducting a user study with 20 participants having at least a year of experience in UI/UX/HCI. Finally, we improved our initial version of the framework by incorporating feedback from user study and learnings from the content analysis of six industry reports [10, 14, 15, 51, 93, 128] available in public domain. Overall, the contribution of our work is fourfold:

(1) Systematic literature review of the literature engaging with low-literate users in HCI, CSCW, and ICTD over the last two decades.
(2) Framework of actionable guidelines as a tool for researchers, practitioners, designers, and implementers (across academia and industry) to evaluate existing or designing new smartphone interfaces for people with low literacy.

(3) Preliminary evaluation of our framework by 20 individuals working as professionals or researchers in the field of UI/UX/HCI.
(4) Highlighting the framework's *evolutionary* nature and the need for a *translational* approach to designing such frameworks.

We envision the proposed framework both as a guiding and an evaluation tool. Researchers, practitioners, and designers could use it (alongside contextual study) to examine the usability of existing smartphone apps and their UIs for the low-literate population. It could be beneficial when designing smartphone applications with low-literate users as the only or a part of the target population group. These guidelines may also be used during the ideation phase by designers to guide the application design and/or implementers to conduct the overall development process. The framework saliently outlines fundamental challenges rooted in low literacy affecting user engagement with smartphone UIs. Thus, the recommendations could also serve as a valuable starting point for designing contextual studies and interventions in low-resource contexts or for groups with low literacy. Future work can also integrate these guidelines into pedagogy tools and existing workflows of developers and implementers to provide *just-in-time* recommendations.

The structure of the paper is as follows. In the next section, we present a detailed description of the methods used. We then present a 4W *(who, when, where, and what)* view of our dataset, followed by an in-depth description of the proposed framework. Finally, we present the results from the user study and content analysis, followed by the discussion section.

2 METHODOLOGY

We performed a systematic literature review (SLR) to collate and evaluate a set of guidelines for designing smartphone application UIs effective for low-literate users. Working towards our objective, we developed our framework by reviewing the HCI literature published over the last two decades. We also carried out a preliminary evaluation of our framework by conducting a user study with 20 researchers and practitioners with UI/UX/HCI experience. We also performed a content analysis of publicly available industry reports focusing on designing smartphone UIs for people with low literacy. Finally, we incorporated our learnings from both the user study and the content analysis to derive the final version of our framework. We now present each of our methods in detail.

2.1 Systematic Literature Review

We conducted a systematic literature review (SLR) of UI design studies conducted with and for the low-literate population using the Kitchenham and Charters guidelines [62]. We searched the ACM Digital Library using three keywords: *illiterate, semi-literate,* and *low-literate*, to collect primary studies published between 2000 up to and including May 2019[1]. In the field of computing and information technology, the ACM Digital Library is the most comprehensive database of articles and bibliographic records [1, 2]. The recognised popular venues for publishing HCI4D and ICTD works are sponsored and hosted by ACM [29], thus making it a suitable choice for our study. We limit our scope to the articles published in conference proceedings, journals, and magazines of the ACM Digital library, accessible online, and published in the English language. We performed SLR in two phases, as explained below:

[1]The ACM launched an entirely new ACM Digital Library on January 1, 2020 [3]. In addition to the ACM's complete database of articles and related artefacts published over the past 70 years, the new library includes hosted content from selected publishers [1]. Thus, the numbers reported in the systematic literature review will vary from the search results for the same keywords on the new library platform.

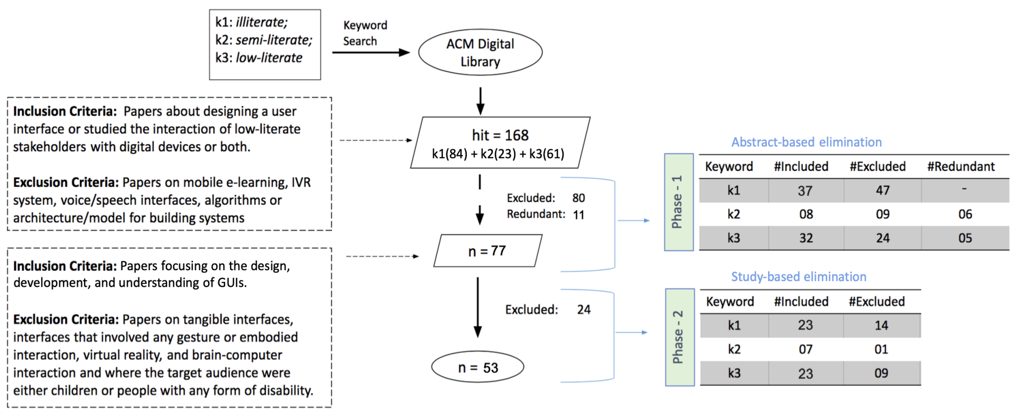


Fig. 1. We conducted a systematic literature review (SLR) of user interface (UI) design studies with and for the low-literate population published in conference proceedings, journals and magazines of ACM digital library; accessible online and published in English only. The systematic review was carried out in two phases (abstract and study-based elimination) to create a database (size = 53) of the relevant papers, which we later used to derive our framework. We scoped our review from the year 2000 up to and including May 2019.

2.1.1 Phase 1: Abstract-based elimination. In the first phase, we searched and manually retrieved papers from the ACM Digital Library against each keyword as shown in figure 1. The strength of each article (relevance to our study) was determined by reading the abstract. A paper was fit for inclusion if the abstract focused on studying, evaluating, or designing for interaction between low-literate groups and technology. We excluded papers on mobile e-learning, algorithms, or architecture/model for building systems for the low-literate community. Although USSD, SMS, and IVR-based interventions have been a popular design choice in underserved settings, with the easy affordability of data plans and mobile phones, smartphones will likely dominate future work in HCI4D [29]. Thus, we further excluded papers focusing on voice/speech interfaces, including IVR systems, to limit the scope of the paper to graphical user interfaces (GUIs). Two researchers individually cleaned the collected data over multiple passes to prepare the final dataset using the inclusion and exclusion criteria. We grouped the repeating publications across different keywords under the *redundant* category. This ensured that we counted such papers only once for our final dataset. In this phase, the search resulted in 168 hits, out of which only 77 papers satisfied our inclusion-exclusion criteria (see figure 1). There were 13/168 cases of conflicts which were resolved by discussing with the whole team.

2.1.2 Phase 2: Study-based elimination. In this phase, we thoroughly read the papers identified using abstract-based elimination to synthesize guidelines for our framework. We began by re-iterating our inclusion criteria to put a tighter bound on the papers for building the framework. We re-visited our resulting dataset of 77 studies from phase-1, where we included the papers focusing on the design, development, and understanding of GUIs explicitly for low-illiterate users. We rejected studies on tangible interfaces, interfaces that involved any gesture or embodied interaction, virtual reality, and brain-computer interaction. We also excluded a subset of the papers where the target audiences were children or people with any form of disability. We acknowledge that when we talk about people with low literacy, it includes a subset of the population (e.g., children, people with disabilities, and more) who in addition to low-literacy might face additional challenges. Thus, requiring additional care, support, and thoughtfulness when designing smartphone UIs for such groups at intersections with low-literacy. For this study, we limit the scope to the design guidelines focusing on low-literacy as the primary parameter. We further elaborate on this aspect in section 6.3. After cleaning the dataset, we tabulated the takeaways from each of the 53 studies (see figure 1) in a spreadsheet for further analysis. For each paper we recorded the title, year, author, design recommendations (e.g., *comments on text, navigation, icons, and more*), target population (e.g., *children, people with disability, old aged population, etc.*), study site (e.g., *Africa, Asia, Europe, North America*), domain (e.g., *agriculture, money transaction, etc.*), and a short description of the intervention (if any).

2.2 Developing the Framework

The final phase of SLR resulted in a database of 53 papers. We read each paper from the database to identify and record text snippet(s) where the studies proposed design recommendations. This process resulted in a corpus of 241 design recommendation snippets. A sample snippet is shared below:

> *"Functions buried in deep hierarchies are known to be less discoverable. . . "* [83]

Moving forward, the corpus was subjected to inductive thematic analysis [17], where two members of our team read the corpus line by line to open code the data. Inductive thematic analysis resulted in 16 codes: text, navigation, clicking, icons, graphics, audio, video, jargon, button, information, color, scroll bar, help, human-in-loop, human-tech interaction, and multi-modal interfaces. We further grouped these codes to form five broad themes for structuring the framework: *input/output model, visual design, content & information architecture, help menu,* and *human in loop.* Next, we performed collaborative affinity mapping [50] on 241 snippets to cluster them into five identified themes. Our team iteratively worked on cleaning and collating guidelines within each cluster. To ensure agreement, we carried out multiple passes while resolving conflicts by discussion among the team members. This process resulted in the initial framework with five themes and 14 guidelines (labeled as G#).

2.3 Evaluating the Framework

We conducted a preliminary evaluation of our framework for its usability via a user study with 20 participants (see table 2). The primary objective was to ensure the guidelines are concise and clear, i.e., easy to understand while eliminating possible misinterpretations. Taking inspiration from Amershi et al. [11], we followed a modified heuristic evaluation method with a focus on evaluating the framework of guidelines instead of the mobile applications. The heuristic evaluation is a discount usability method used to examine the usability of a user interface [98]. For our evaluation phase, we modified the approach for testing our framework's relevance and clarity against a set of applications (see table 1) [11]. We searched the Google Play Store and Apple Store for applications where people with low-literacy are potential users (e.g., apps designed by Government of India to achieve policy-level goals). Our search resulted in a set of 8 applications presented in table 1. Within our selection, five apps have been designed and developed by the Government of India, whereas three applications are developed by private entities (Google and Facebook). Unlike private-sector applications, most apps by the Government of India have an explicit focus on all socio-economic groups, e.g., mParivahan for driving license and vehicle registration, BHIM for digital payments and so on. Readers must note that even though we attempted to cover a variety of domains, we selected these applications as a proof-of-concept to test our framework, and not as representative samples of their domains.

The study was conducted remotely as per the availability and convenience of our participants (evaluators). Each participant was randomly assigned an application and provided with an evaluator guide for participating in the study. The evaluators' guide included details about the evaluation task, the assigned application, the framework under evaluation, and three user personas for reference. We asked our evaluators to conduct a walk-through [99] of the assigned application and fill an online survey questionnaire, preferably within an hour, as per their convenience. The survey served as a tool to provide a structure to participants to identify and comment on the *clarity* (if the guideline is understandable) and *applicability* (if the guideline is and could be implemented) of the proposed guidelines against the assigned application interface using a three-point Likert scale. The survey spanned five sections, one for each of the framework's five themes (see table 4). Each guideline within a section was evaluated via three questions: *"Q1. Do you think [X] application follows the recommendation [Y]?"* Here, [X] indicates the application assigned to the participant, and [Y] indicates each guideline. Options included *"follows the guideline/somewhat follows the guideline/does not follow the guideline"*, along with a supporting open-ended text box to specify the reason(s) supporting the choice. Followed by, *"Q2. Do you think that the guideline was easy to understand?"* with choices *"easy to understand/neither easy nor difficult to understand/ difficult to understand."* Finally, the participants were asked to reflect on and suggest changes to the guidelines through an open-ended question, *"Q3. If given an opportunity, how would you rephrase the guideline G#?"* We also gauged if the theme title is appropriate for the corresponding group of guidelines using three-point Likert scale (*agree/neither agree or disagree/disagree*) along with an open-ended text box to collect reason(s) for supporting the choice. We performed a descriptive analysis [78] of the multiple-choice questions. For open-ended questions, we coded responses from different evaluators and conducted an inductive thematic analysis [17] of the same. Examples of codes included *"need for examples," "non-familiar term," "club guideline and it's definition,"* and *"generic guidelines."* These helped in organizing our learnings presented in section 5.

The evaluation was carried out in two phases: internal evaluation and user study. In the first phase of internal evaluation, all the authors evaluated the framework against the Aarogya Setu[2] application (table 1). The objective of this phase was to pilot-test the survey tool and iterate the framework for clarity. Building on the results from the internal evaluation, we modified our survey questions and rephrased our guidelines. For example, we updated guideline G2 from *"Use numbers"* to *"Leverage numerical literacy."* Next, we used the updated tool and framework in the user study with 20 participants labeled as P#. We randomly assigned two to three evaluators for each smartphone application (table 1). The participants were recruited via email, WhatsApp, Facebook, and LinkedIn using purposive sampling [127] through the authors' professional and social circles. We ensured to include candidates with more than a year of experience in conducting usability studies or familiarity with HCI research. We have added notes on limitations of our methodology in section 6.4.

2.4 Engaging Industry Reports

To further add value to our research-driven framework, we engaged with learnings and recommendation from the industry and development organizations. Our primary aim was to ascertain whether the content presented in the industry guidelines is reflected in our framework. We performed a content analysis [17] of six industry reports (available in the public domain and digitally accessible) which share recommendations, guidelines, and learnings from designing smartphone user interfaces for low-literate users (see table 3). Guidelines and reports supported by pioneer international foundations and global development agencies formed our primary choice for inclusion. These reports were identified through multiple Google search attempts using different combinations

[2]A contact-tracing application for COVID-19 by the Government of India advised to be used by all the citizens. The total current users are 100+ million.

Developed by	Domain	Smartphone application	Supported platform	Participants
Government of India	COVID-19	Aarogya Setu	Android/iOS	4
	Digital Payment	BHIM	Android/iOS	3
	Transport	mParivahan	Android/iOS	3
	Health	Ayushman Bharat	Android	3
	Navigation	DMRC	Android/iOS	3
Facebook	Communication	Whatsapp	Android/iOS	3
Google	Navigation	Google Maps	Android/iOS	2
Google	Entertainment	YouTube	Android/iOS	3

Table 1. We evaluated the framework against a set of eight smartphone apps using the modified heuristic method [11]. We searched Google Play Store and Apple Store across domains for apps with potential users with diverse literacies and included those with 1M+ installations. Except for Aarogya Setu (used for internal evaluation), we randomly assigned an app to 2-3 participants for the user study.

	Participants (20)
Age (years)	Min (20), Max (38), Median (22)
Profession	Design student (11), PhD (4), UI/UX designer (3), Industry professional (2)
Domain experience	1–3 years (16), 3–5 years (3), 5+ years (1)

Table 2. We recruited 20 participants using purposive sampling with a minimum of a year of experience in HCI/UX. The majority of our participants were third-year undergrad design students trained in HCI and have worked with clients during their internships and/or course projects. Also, most of our participants (13/20) reported having worked on a project with low-literate users.

of following search terms: *"illiterate", "low-literate", "smartphone apps", "user interface", "guidelines", and "industry reports"*. We want to emphasize that this may not be an exhaustive list of industry reports. Our results are shaped by the nature of our keywords and indexing of such reports.

Working towards our objective, we performed deductive content analysis [17] using our framework as a code dictionary (see table 4), where each guideline corresponded to an element of the dictionary. In addition to *what* content is offered, we also carefully observed *how* it was presented, structured, and articulated. The learnings from the content analysis are used as feedback to better articulate the guidelines.

2.5 Positionality

All the authors are of Indian origin and interact with one or many representations of our target population (e.g., house help, vegetable vendor, rickshaw driver, etc.) in our day-to-day life. We have had our experiences where we have either helped such people in using smartphone applications or have participated in discourses on the related subject. All of us have an educational background in Computer Science, and three of the authors have varied experiences of mobile application development. Two of us have more than three years of experience, and one of us has over fifteen years of experience working on various mobile platforms. Also, two of our team members have experience designing technological interventions with and for marginalized groups across India, including low-literate population by conducting qualitative and ethnographic studies. In particular, we have conducted fieldwork with a focus on the design and adoption of mobile-based intervention across domains such as health and education. It is the technical training, learnings from the field, and the first-hand experience of witnessing challenges around adoption of mobile applications, first

Industry reports	Year	Description	Domain	Funding agency
Designing for Digital Confidence [15]	2020	Design strategies for next wave of internet users.	General	IDEO, Bill & Melinda Gates Foundation, Google
UNESCO [128]	2018	Guidelines for designing and implementing digital solutions that are more inclusive for less digitally skilled and low-literate users.	General	UNESCO
Digital Wallet Adoption for Oral Segment in India [93]	2017	Recommendations for designing mobile wallet for 'oral' (illiterate and neo-literate) people to use.	Finance	MicroSave, My Oral Village
Karandaaz [14]	2016	Toolkit to improve UX design of financial apps.	Finance	UKAid, Bill & Melinda Gates Foundation
Smartphones & Money Mobile UI/UX: CGAP [10]	2016	UI/UX principles for mobile money smartphone interfaces.	Finance	CGAP
CGAP-BISP [51]	2013	Design guide for financial inclusion of low-literate and low-income clients.	Finance	CGAP

Table 3. We performed a content analysis of industry reports offering UI design recommendations for designing smartphone apps usable by people with low-literacy. A majority of the reports have emerged from developmental organizations to promote the digital inclusion of low-literate individuals. However, 4/6 reports focused on designing a domain-specific (*financial*) inclusion application.

during Demonetisation [73, 76], and now for COVID-19 pandemic, which formed our motivation to conduct the research we present.

3 4W VIEW OF THE DATASET

In this section, we present a panoptic view of the metadata of our final database used to synthesize our framework. We position the existing research in terms of the characteristics of the population under study and specific application domain using the 4W framework [13, 100, 134]: *who (study population)? when (time)? what (research trend)? and where (location)?*

3.1 *Who?*—The Study Population

As defined by our keywords, all the papers studied various nuances of low-literate population. Different authors adopted different operational definitions for the semi-literate and low-literate groups depending on the scope of their study. For example, there were studies which used standardized scales like REALMS [21] and National Skills for Life Survey [69] to measure their literacy levels. In another study [7], the authors interchangeably used the terms low-literate and semi-literate for their study population. However, no other work clearly articulated the difference in the operational definition of semi-literate and low-literate groups, thus treating them as a cohort while proposing the recommendations. Given the lack of universal definition in our primary literature, we would like to emphasize that our framework should be practised as guidelines and not "laws" when working with or for the low-literate population. In other words, our framework generalizes the recommendation for the low-literate target audience; which can be built upon to draw recommendation for a group sharing similar characteristics.

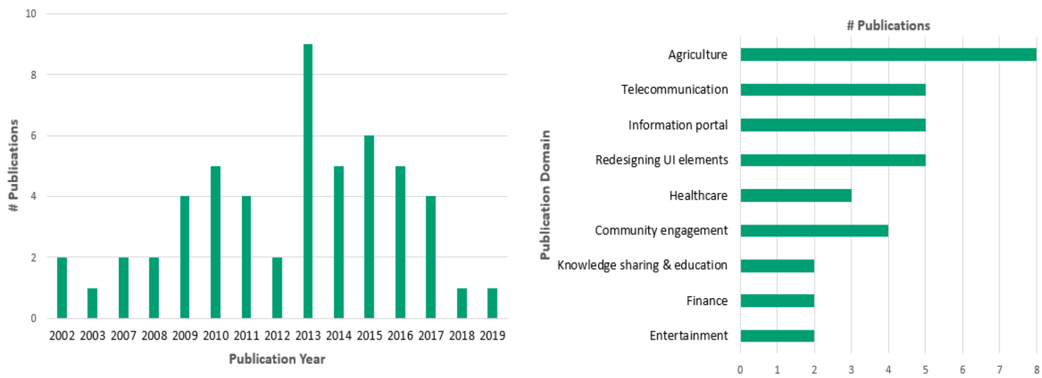


Fig. 2. Our dataset reflects the publication numbers along the timeline (2000-2019) and the research trends in terms of the type of contributions and the application domains. The left graph shows a sudden decline in the #publication from 2017 to 2019. The right graph shows a majority of the papers (36/53) focused on the design, development, and deployment of interventions across domains.

3.2 *When?*—The Time Window

We collected the relevant work published in the past nineteen years, from 2000 up to and including May 2019 (see figure 2). We recognize the advancement and transition in mobile technology from processing power, wireless network support, screen size, button keypad to touch screen input, gesture input, and more. This advancement led to a world of affordable smartphones, contributing to increased smartphone penetration [55], which in turn contributes to ever-evolving challenges in adoption and use of such technology. Since our framework builds on articles published across different generations of mobile technology, we took extra care to eliminate recommendations which pertain to obsolete technology. Our framework provides a baseline for researchers and practitioners to speculate future technologies for the low-literate population and also be used as a source to further built or derive new recommendations.

3.3 *Where?*—The Context and the Venue

Our main dataset includes studies from four continents: Africa, Asia, Europe, and North America. As shown in figure 3, the Global South is a hub for studying the low-literate population. Within Asia, 23/31 studies were situated in India, 4/31 in Bangladesh, and 4/31 in Pakistan. As presented in our finding later, the studies acknowledged the value and impact of cultural context and argued for culturally responsive design [16, 101]. Our framework presents guidelines synthesized independently of the cultural context. Thus, researchers and practitioners should be mindful of the cultural context where their research is situated and interpret and use the proposed guidelines accordingly.

Furthermore, our analysis showed that top four publishing venues included CHI (12) and regional CHI (e.g., AfriCHI, IndiaHCI, NordiCHI) with 11 papers, followed by ICTD (9), and DEV (6). Among, regional CHIs, IndiaHCI published the majority (6/11) of the work. Acceptance of the work at these popular HCI and ICTD venues establishes the quality and relevance of our dataset.

3.4 *What?*—Research Trends

In this section, we present the research trends with respect to the type of contributions and the corresponding application domains. Our data revealed that out of 53 publications, five projects

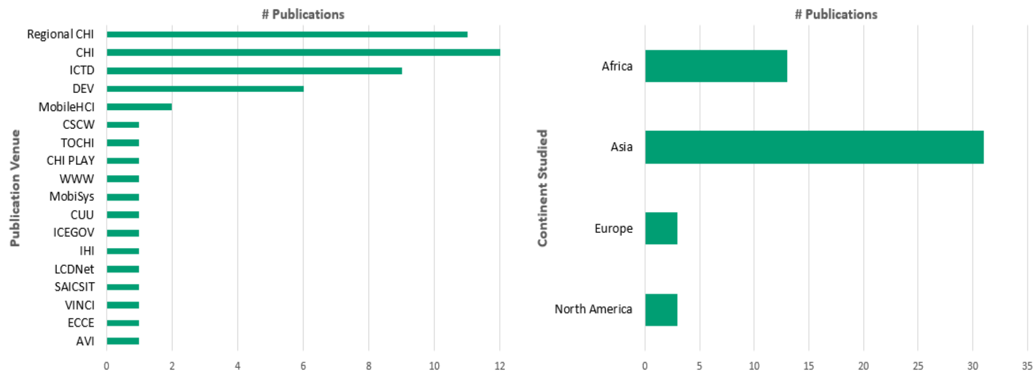


Fig. 3. Publication trend of UI design studies engaging with low-literate populations between 2000 and May 2019 at each publication venue (left graph) and across regions (right graph). The majority of our primary studies are situated in the Global South, where 22 studies are from India. Among regional CHIs, IndiaHCI published the majority (6/11) of the work.

contributed to two publications each [43, 105], [68, 69], [83, 86], [56, 57], [7, 9] thus leaving us with a database of 48 unique projects.

Multiple studies [6, 8, 35, 69, 85] focused on developing a better understanding of the user group and their interaction with the technology. For example, studies have evaluated the preferences of graphical representations and their correlation with the literacy level [114]. The adoption of visual metaphors is correlated with the cultural context [52]. Further, researchers have extensively studied, compared, and contrasted the needs and aspirations of illiterate and semi-literate individuals from the technology [37].

We observed that 36/53 papers focused on the design, development, and deployment of interventions in the domain of agriculture (e.g., [26, 65, 77, 101]), information portals [18, 42, 56, 117, 124], telecommunication [39, 97, 101, 107, 118], redesigning UI elements [33, 44, 60, 79, 96], and more (see figure 2). In addition, 17 papers within our database explicitly studied different elements of a user interface for low-literate individuals. For instance, Medhi et al. have done extensive work, from studying the impact of culturally embedded icons [88] to synthesising the recommendations for improving the usability of mobile interfaces [83, 86]. The observed trend where most studies took the “interventionist approach” is similar to the trend identified by Dell and Kumar across HCI4D literature [29].

4 *DESIGNING SARAL:* THE FRAMEWORK

In this section, we present our framework—*designing SARAL*[3] (Smartphone Applications embRAcing Low-literate users)—for developing mobile applications for low-literate users. The framework comprises 13 guidelines categorized into five themes: *Input/Output Model, Visual Design, Content and Information Architecture, Help Menu, Human in the loop*. We now present each theme in detail, where we summarize the synthesized guidelines at the end of each subsection.

[3]We specifically chose to call our framework SARAL, a Hindi word meaning easy/effortless, which best captures our vision of designing easy to use smartphone apps for people with low literacy.

Theme		Actionable Guidelines	Examples
Input/Output Model	G1	**Utilize multiple modes of interaction:** Support the application with multiple (input/output) mediums - text, audio, video, etc. *for easy comprehension* [4, 6, 7, 9, 15, 16, 22, 26, 37, 40, 43, 56, 57, 77, 83, 88, 89, 93, 108, 114, 117, 121, 128, 133].	*"It supports both voice typing and sending audio messages along with text and emojis" (P18, WhatsApp).*
	G2	**Leverage numerical literacy:** Utilize numbers (wherever applicable) to convey information and receive input *as low-literate users are comfortable with numbers* [43, 43, 89, 104, 105].	*"It gives examples of RC number/DL number right below the search box to ease interpretation of input" (P11, mParivahan).*
Visual Design	G3	**Keep a minimalist, clean interface:** Minimize the use of text and visual components in each screen to optimize the whitespace *to reduce interface complexity and feature overload* [9, 14, 18, 37, 39, 51, 56, 64, 77, 88, 89, 92, 93, 97, 114, 115, 118, 120, 121].	*"There is a lot of text on the main screen itself, with text not even fitting their text boxes. The text overlaps the visuals" (P11, mParivahan).*
	G4	**Incorporate visual cues:** Introduce bold text, highlighting, colour-coding as visual cues *to draw users' attention* [4, 14, 34, 51, 60, 68, 93, 105, 108, 117, 125].	*"The nine buttons have a different color from the background to set them apart. The login button is also at an awkward place on the screen and does not get enough attention" (P01, Ayushman Bharat).*
Content & Information Architecture	G5	**Avoid jargon:** Use understandable (everyday) words and minimize domain-specific and technical jargon *as they are difficult for low-literate users to understand* [10, 14, 20, 28, 39, 51, 68, 69, 86, 111, 128].	*"While the word group is quite self-explanatory, the term broadcast is confusing to semi-literate people, and often confused with group" (P18, WhatsApp).*
	G6	**Break down information within and across screens:** Limit information on a page to reduce scrolling *to improve visual readability.* Present information in a concise format using small paragraphs, or bullet points wherever applicable [10, 15, 34, 66, 68, 106, 122].	*"Almost everything the app has to offer is on one screen. But it has broken down some features into sub-points like FAQs" (P01, Ayushman Bharat).*
	G7	**Simplify navigation structure:** Minimize menu hierarchies. Prefer linear navigation or flatten menu hierarchies *to reduce navigation complexity* [6, 10, 15, 21, 31, 47, 57, 67, 68, 74, 86, 87, 92, 118, 128].	*"The chats, status and calls are all displayed in linear hierarchy" (P18, WhatsApp).*
Integrate Help	G8	**Provide assistance in using the application:** Make the help option easily accessible from every screen and incorporate well-designed feedback mechanisms *to facilitate more autonomous use* [10, 15, 38, 89, 93, 94, 108, 116, 118, 125, 128].	*"No help or onloading provided, FAQ section contains info on programme and not app" (P02, Ayushman Bharat).*
	G9	**Include short, simple instructions in Help menu:** Make the instructions short, gradual and simple, and avoid instructions with multiple steps *as users might not pay attention in the first go* [39, 108, 111, 116, 118, 124].	*"There are no instructions given beyond the initial tutorial, which users may forget over time" (P18, WhatsApp).*
	G10	**Adopt audio and video help tutorials:** Prefer audio or video tutorials over textual instructions in the Help menu *to make help content easily accessible* [10, 14, 21, 68, 70, 72, 88, 89, 118, 124, 132].	*"No help option available for audio and video only forwarding to either FAQ or website" (P06, WhatsApp).*
Human in the Loop	G11	**Adopt culturally responsive design:** Incorporate local language support and culturally-driven UI elements like icons, graphics, colour scheme, etc. *It is cultural identity that shapes users' perception, comprehension, and preferences* [5, 7, 10, 15, 16, 22, 36, 37, 51, 52, 63, 74, 80, 86, 88, 93, 105, 111, 112, 117, 118, 128, 131].	*"Use of rupee symbol, hand for request money, various local language support" (P06, BHIM).*
	G12	**Leverage human facilitators:** Integrate human mediators (family, peers, community, designated professionals, etc.) into the overall system design to familiarize users with potential scenarios and UIs *to help overcome usage barriers easily* [5, 7, 20, 39, 53, 86, 108, 124, 128].	*"Helpline number given, no other apparent integration" (P02, Ayushman Bharat).*
	G13	**Enable customization:** Save users' preferences about the content, layout and other settings for the application *as it makes the space more human, familiar, and pleasant to be in* [25, 111, 117].	*"WhatsApp remembers users' preferences like chat background and saves it to an extent by allowing blocking messages from certain senders" (P17, WhatsApp).*

Table 4. The *designing SARAL* framework containing 13 guidelines, their actionable definitions and examples, categorized within 5 themes. We have included participant (evaluator) reported supporting examples for each guideline across applications during our user study.

4.1 Input/Output Model

4.1.1 Utilize multiple modes of interaction. Existing work has called for a stronger focus on designing user interfaces with multiple modes of interaction, which incorporate one or more textual, graphical, and audio components as different modalities offer different kinds of support [16, 56, 57, 117, 121].

Pictorial representations are an intuitive and concise way to present information and prior work also substantiates the belief that icon-based interfaces are highly effective [43, 89, 93, 117]. Research has placed a high value on imagery and incorporation of graphical icons, compared to entirely text-based interfaces [4, 6, 7, 26, 77]. Nonetheless, while iconic support may aid a textually non-literate user, Chipchase has suggested that icons by themselves are not the solution [22]. Many tasks are so abstracted from a user's real-world experiences that it is implausible for icon-only interfaces to solve the problem. Especially for those with some levels of literacy, the meaning of icons is best understood with textual definitions [133].

Similarly, audio provides an effective and natural means for information presentation. Gaver created auditory icons in an attempt to *"use sounds in a way which is analogous to the use of visual icons to present information"* [40]. Auditory icons introduce everyday sounds to represent the actions and objects of computing for providing organized information to its users in an intuitive way. Augmenting a text-based interface with audio [37], or including audio annotations [83, 88, 108] is essential, especially for low-literate users and is easier than developing a new, separate interface. Moreover, the addition of audio helps to declutter visual interfaces or amplify visual components [41]. For instance, Medhi et al. designed a text-free interface for a job search application with abundant use of graphics, and audio to convey information that is typically done using text [89]. Similarly, Idrees et al. exemplified that a combination of visual aid with audio as an optimal means to disseminate weather forecasts to farmers [56].

Researchers have also investigated the difference in needs of semi-literate and illiterate users [16, 37]. Findlater et al. studied the transition of their participants from audio + text to text-only interfaces and observed that with time, semi-literate users became much less reliant on audio [37]. Similarly, Blake et al. have demonstrated through their work that semi-literate users may use text to disambiguate images over a few sessions [16]. Thus, semi-literate users must be treated differently than fully illiterate users while designing user interfaces.

Prior work [9, 83, 114] has examined the singular use of graphical, voice, and text-based interfaces and illustrated their advantages and disadvantages. Medhi et al. [83] compared illiterate and semi-literate users on text-based, rich multimedia, and spoken dialog systems. They found that text-free designs were preferred over text-based ones. For text-free designs, users performed the tasks faster and required less assistance with spoken dialog systems. However, task completion rates were higher for rich multimedia systems. In contrast, much research has been conducted to explore a combination of more than two modalities [56, 57, 117]. Cuendet et al. [26] explored a combination of touch interactions with text-free graphical interfaces and spoken dialog to develop a mobile system VideoKheti and determined that the system's usability was greatly dependent on the user's education level. Industry reports [15, 128] describe the ways in which presenting content with appropriate choice of modalities increases possibilities for user engagement, enables confidence, and allows flexibility of understanding the content by relying on the modality with which users feel most comfortable.

4.1.2 Leverage Numerical Literacy. Prior work has also noted that low-literate users may have numeracy skills [43, 89, 104, 105], so designers can utilize numbers to communicate actions and receive input. Using their design studies for a financial management system, researchers have demonstrated that users were familiar with number-based tools such as calendars, calculators, and phones [43, 105]. However, it is essential to acknowledge that some users had difficulty associating numbers with actions/navigation-based tasks.

Guidelines: It is important to *utilize multiple modalities* (G1) into the interface because a combination of text, graphics, videos, animations, and drawings introduces several interaction mechanisms which are flexible, efficient and mimic natural environments of its users. Designers can *incorporate numbers* (G2) in the interface to make the content more accessible.

4.2 Visual Design

While color is sometimes thought of as an aesthetic choice, it is, in fact, a key element of the psychological impact of design on users. Joshi et al. [60] proposed a phonebook Rangoli in which each contact is associated with an icon and a color. They observed that color and icons are an effective way of grouping contacts. Numerous studies indicate that color can be used to group and highlight information and to encode relationships in the menu hierarchy [51, 68, 105, 108, 125]. Color can bring the user's attention to unusual data [105], and indicate some change in the app activity [4] such as screen transitions or red flags[93]. In essence, highlighting text by making it bold [34], varying font sizes or color-coding [14, 117] provides the necessary visual cues to draw the user's attention and makes the content easier to understand.

Several studies attempt to identify the number of icons, amount of text or the density of other UI elements in an interface for low-literate users [37, 39, 56, 77, 88, 93]. Many researchers have advocated using text-free UIs in mobile applications for illiterate users [77, 89, 92, 97, 118, 120, 121]. On the other hand, literate users prefer at least some text on the screen as the text is considered an accurate mode of communication [115]. Instead of replacing text, the focus should be on incorporating minimal amounts of text [14] and augmenting it with other modalities [64]. For low-literate users, unnecessary visual elements may create confusion, which is why Ahmed et al. implemented only two icons in the interface for Suhrid—a collaborative mobile phone interface [9].

Researchers have also tried to identify the best way to illustrate an idea [18, 51, 77, 93, 114]. For instance, Medhi et al. conducted a study to determine the comprehensibility of different representations of a concept by providing each participant with a randomly selected representation of health symptoms [88]. These representations include text, static drawings, photographs, videos, animations. They learned that static drawings are more accurately understood than realistic photographs. However, when it comes to representing actions using static drawings, Medhi et al. observed that they may be misunderstood [89]. For example, in their job search application, with a simple icon demonstrating utensils, users misinterpreted the action of cleaning dishes as the kitchen.

Guidelines: It is important to *incorporate visual cues into the interface* (G4) such as colors, text highlighting, animated messages to draw the user's attention to noteworthy concepts. While visual cues can help garner their attention, it is equally imperative to have a *minimalist and clean interface* (G3) which doesn't contain a lot of text or visual elements such as icons or graphics.

4.3 Content and Information Architecture

Earlier work [68, 69] has repeatedly emphasized the need to use simple text with plain words for low-literate users [10, 51, 128]. The text should be easy to comprehend because the use of difficult, technical terminology is confusing for low-literate users, even if it is presented in the local language [86]. As demonstrated by multiple studies [20, 28, 39], users faced problems with the vocabulary and concepts associated with the computing environment due to their unfamiliarity with these terms. The prompts should have an everyday language so that a majority of low-literate users can understand them [14, 111].

Apart from the content, several studies explore the organization of information [34, 66, 68, 106]. Doak et al. [34] suggest improving visual readability by limiting the number of concepts on a page. After studying the information-seeking behavior for low and high-literate users, Kodagoda et al. [68] advise designers to avoid duplicate information and to present it as simple sentences, in manageable chunks or as bullet points to reduce the cognitive load [10, 15]. Summers et al. [122] observed that low-literacy users scan the content word by word, and with this narrow field of view, it becomes imperative to have meaningful contextual headings and pages which make sense independently. Kodagoda et al. [68] recommend presenting further details and sub-classifications in visual or auditory modalities.

Moving between different pages/screens and keeping track of the interface forms an integral part of using any application. Navigation includes the interactions that allow users to navigate different content and functionalities within an application. Previous work [10, 15, 47, 57, 87, 92, 118, 128] has promoted the use of easy, ultra-simplified navigability. Kodagoda et al. [68] have argued that the interface should allow the user to navigate forward or backward. Chaudry et al. [21] have recommended smaller path lengths and lesser depths to reduce overall complexity. There is ample evidence [31, 86] to support the use of linear navigation over hierarchical navigation. Studies show that listing items on a page instead of adopting multi-level hierarchies [74] makes it easier for users to identify the correct function since they tend to lose focus in the latter [6, 67]. Chaudry et al. [21] have suggested cross-linked or hybrid navigation as an alternative to linear or hierarchical navigation. In hybrid navigation, the navigation bar gives the users access to the initial steps of each task.

Researchers [4, 21, 53, 86] have also warned against the use of any scroll bars in the interface. Hill et al. [53] developed an educational application 'Capital Words' to improve its users' literacy skills. They used a guided linear design and learned that horizontal and vertical scrolling is less intuitive for low-literacy users.

Guidelines: Information presented to low-literate users should have *simple, understandable words and minimal technical and domain-specific jargon* (G5). Furthermore, the information should be *broken down within and across screens* (G6) to improve comprehensibility. Navigating between different parts of an application can become a tedious task for users, especially if they are unfamiliar with the computing environment. Thus, it is necessary to *simplify the navigation structure* (G7) and incorporate linear or hybrid structures over hierarchical menu-based interfaces. Similarly, it is crucial to *reduce the need for scroll bars* (G6) or other abstract gestures because these gestures may not come naturally to people with diverse backgrounds.

4.4 Help Menu

Past work has pointed out the significance of providing a consistent help feature that is easily accessible throughout the application [10, 15, 89, 108, 128]. Besides having a help option as part of the interface, users should also be given initial guidance before they start using the application [118, 125]. The application should also provide incremental tutorials, videos, demos, and instructions for users to comprehend and learn [38, 94, 116]. Other forms of support can be through help pages, FAQs, tooltips, and tutorials [128]. Studies have shown that users don't pay attention to multiple linear instructions [39, 108], so instructions should appear in context, when necessary [10] and should aid the users for the *next steps* [15]. Researchers have thus, suggested that instructions should be short and simple [111, 116, 118, 124]. They have also pointed out that users should be given a simple step-by-step guide for assistance [118].

To overcome barriers of literacy, research has suggested the use of (interactive) audio instructions [10, 14, 70, 88, 89, 124]. Smyth et al. [118] studied the user reactions for an interactive kiosk system called MOSES. Their study concluded that voice instructions and greetings based on such an animated agent helped users to develop a deep affinity towards the system. Another study concluded that an on-screen character allowed the users to easily relate the system's voice to a visual personality [68]. Researchers have also highlighted how such interaction can serve as a feedback mechanism so that the users know whether they are using the interface correctly and taking the right actions or not [21, 72, 132]. Well-designed feedback mechanisms (reporting technical/design errors vis-a-vis human errors) and providing clear, jargon-free resolutions for errors may reduce user frustration and aid in building their confidence in using the application [10, 14, 93]. For example, for a text box requiring phone number input, possible feedback could be for the user to enter 10 digits (not more or less), or in the case of mobile wallets, an audio-based mechanism to validate a send amount by repeating out-loud the value entered by the user [93].

Guidelines: With the increasing complexity of smartphone applications, the need for a *consistent and easily accessible help* (G8) has become even more crucial. For users to synthesize information and follow through the tutorial, the *instructions should be short, simple, and gradual* (G9). Also, *providing audio and video help* (G10) can help overcome the struggles due to low literacy levels.

4.5 Human in the loop

The literature emphasizes on and serves as evidence for the importance of engaging the target population, various stakeholders, and leveraging their context in the design process [9, 60, 101, 105, 108]. We now present the factors that affect the ease of adoption and engagement with the technology.

4.5.1 Adopt a culturally-responsive design. Several studies agree that users' cultural identities play an important role in shaping their perceptions, preferences, and the ability to understand different aspects of computing environments [36, 52, 80, 112]. For example, at the structural level, many users may not be familiar with the concepts and objects in an Office, such as files, folders, envelopes, clipboards. When we transfer these objects as metaphors to UI components, it compromises the comprehensibility of these elements. In one instance, Heukelman et al. [52] proposed the African village metaphor as an alternative to the office metaphor. Research has pointed out that culture-specific user interfaces may improve usability [52]. Lalji and Good [74] observed that users mistook musical notes (meant to denote the radio) as birds. Thus, it is crucial to adapt icons according to the culture of target users [16, 22, 37, 74, 88, 118], instead of assuming them to be universally recognizable. Kim and Lee [63] have demonstrated through their work that semi-concrete icons are preferred over concrete icons because concrete icons may link to real-world objects whose interpretation varies depending on the different cultures. Not just icons, meanings of other UI elements such as colors [105], graphics, classification taxonomies [131] are often culturally situated. Several reports discuss the significance of using culturally relevant content to aid in building the trust of low-literate users with technology and improve its adoption [10, 15, 51, 128]. Similarly, all users of an application might not have reading and writing ability in a common language, such as English, so it becomes imperative to provide local language support [5, 7, 86, 93, 105, 111, 117] for textual and audio interfaces.

4.5.2 Enable Customization. Users of an application with similar demographics, cultural, and linguistic backgrounds may have remarkably diverse needs [111]. Customization makes the spaces in which we operate more human, familiar, and pleasant. Singh et al. [117] created an Early Warning System for fishers in Maharashtra, India, where users' could save their preferences, and customized content was disseminated to them as per their needs. Thus, giving users the ability to decorate their applications is both fun and useful as a navigational aide [25].

4.5.3 Leverage Human Facilitators. Most studies [39, 53, 108, 124] have designed user interfaces for low-literate users by considering mobile phone usage as an individual act. Ahmed et al. [7] present an alternative to this by reinforcing that the interactions of people with technology are embedded within an 'ecological' model. Their design facilitates collaboration among people, enabling them to draw on their ecological resources to overcome the struggles due to illiteracy. Users rely on friends, family members [5], external networks [20], and resources [124] to circumvent issues that non-literacy poses. The integration of a human mediator into the overall system could familiarize potential users with scenarios [86], user interfaces, and help them overcome the initial hesitation and barriers while using a new application or device [128].

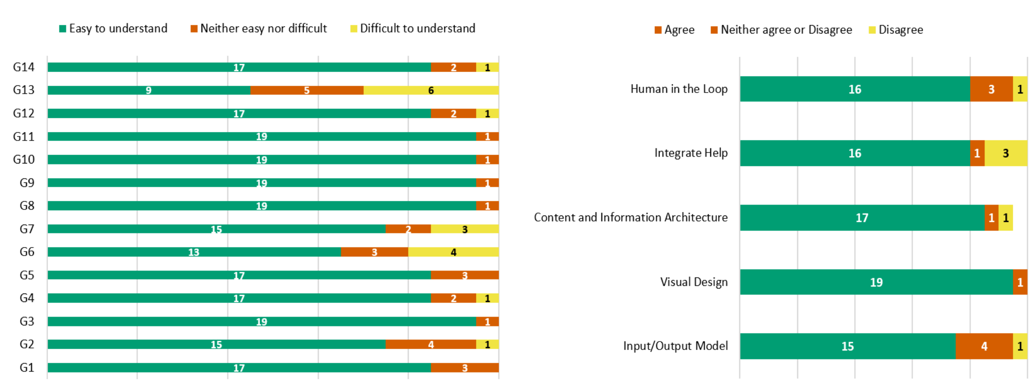
Guidelines: Applications should incorporate their users' preferences by considering their *cultural identities* (G11), literacy levels, and technological exposure. Users should be *allowed to customize* (G13) the content, layout of the interface, and general functionalities of the application according to their needs. Finally, intimidation due to app complexity can be reduced by *integrating human facilitators* (G12) into the overall system who can assist those with lower literacy levels.

5 LEARNINGS: USER STUDY & INDUSTRY REPORTS

This section presents our learnings from the preliminary evaluation of the framework, where we primarily focused on gauging the *clarity*. That is, are the participants able to understand and differentiate among the guidelines? We also inquired about the *perceived usefulness* and collected data on the *applicability* of the guidelines against a set of smartphone applications. Those are examples where the guidelines are and could be implemented to design applications effective for people with low-literacy. We also elaborate on instances where the content analysis findings helped us cater to the challenges identified from and feedback received in the user study.

5.1 Clarity

The majority of our guidelines, except G6 (formerly, *"Limit concepts per page")*, definition of G7 (*"Simplify navigation structure")*, and explanation of G13 (formerly, *"Leverage human facilitators")*, were reported to be understandable (see figure 4). We observed that although most of the phrased



(a) (b)

Fig. 4. Our participants evaluated the framework for clarity (i.e., the participant was able to understand and differentiate among guidelines) on a 3-pointer Likert Scale. Figure (a) shows reported data for Guidelines (labeled G #) and figure (b) indicates agreement over the themes representing subsets of these guidelines.

guidelines were clear to understand, the participants expressed a need for supporting examples. For example,

> *"Please provide examples if possible"* (P16)
> *"I could not think of any example of the app leveraging human facilitators."* (P08)

Further, our participants struggled with technical terms like "modalities" (G1), "jargon" (G5), and "linear, hierarchical, and hybrid navigation" (G7). One of our participant expressed, *"Linear/Hybrid/ Hierarchical Navigation [G6]. I don't really know what the terms mean, so I had to google them, and still it was not very clear"* (P08). Our data raises critical questions: are these terms too academic? Or does it point to a deeper problem that the framework should be in a colloquial language? Our observations from the content analysis of industry reports saliently point towards the former being the case, where 3/6 reports use simpler vocabulary to articulate the recommendation: *"flatten menu hierarchy"* [10], *" minimize menu hierarchies"* [128], and *" reduce nesting and avoid complex navigation"* [15]. Thus, we updated the definition of G7 from *"Prefer linear or hybrid navigation over hierarchical navigation"* to *"Minimize menu hierarchies. Prefer linear navigation or flatten menu hierarchies to reduce navigation complexity."* Similarly, taking inspiration from the industry reports we replaced the term *"modalities"* in G1 (*"Utilize multiple modalities"*) with *"modes of interaction,"* added *" everyday language"* in G5 (*"Avoid jargon"*), and included *"incorporate well-designed feedback mechanisms"* in G8 (*"Provide assistance in using the application"*). To ensure clarity, in addition to rephrasing the guidelines using parallel language, we updated the structure of the framework table to include supporting examples (see figure 5).

At multiple instances (e.g., G3, G6), the participants' suggestions helped us to rephrase our guidelines for improved clarity. For example, P03 rephrased G3 (initially, *"keep a minimalist, clean interface"*) as *"optimize white space"* to balance design elements, which guided us to append the word "white space" in the current guideline. In another instance, we incorporated P14's suggestion to rephrase the current G6 (*"break down information within and acrossscreens"*) by combining it with G8: *" 'reduce the need for scrolling' [previously G8] might be redundant if 'limit concepts per page' [G6] is properly adhered."* Also, in a few suggestions, our participants articulated the guidelines in the question form. For example, *"does the application support multiple forms of input and output like text, audio, video etc"* (P01). However, prior work shows that actionable guidelines are better adopted, hence we retained our articulation style [11, 24].

Figure 5 shows the structural evolution of the framework. Initially, the framework table consisted of 5 themes with 14 guidelines structured in a three columns: *Themes*, *Guidelines* and *Actionable Definition*. The guidelines were grouped in sets of 2-4 under each theme, accompanied by an in-depth explanation. The Actionable Definition was to be viewed as a detailed description of how the guideline can be integrated into the interface design. The analysis of qualitative data revealed that our participants incorporated the actionable definitions while rephrasing the guidelines. For example, P20 stated, *"The explanation is short enough and should be the guideline [G1] itself."* To ensure clarity, we combined the *Guidelines*, and *Actionable Definition* to synthesize the current version of the framework. The suggestions and revisions resulted in a framework with a set of 13 guidelines presented in table 4.

5.2 Applicability

The analysis of industry reports revealed an overlap with the proposed framework. The framework covers all the core UI design guidelines from across the industry reports (except domain-specific recommendations, e.g., pertaining to bank transactions in financial apps). Additionally, it also promotes leveraging the assets of numerical literacy (G2) and power of customization (G13), thus highlighting the comprehensiveness of the framework. For each guideline in our framework, we

Themes		Guidelines	Actionable definitions
INPUT/OUTPUT MODEL	G1	Utilize multiple modalities	Support the application with multiple (input/output) mediums - text, audio, video, etc.
	G2	Leverage numerical literacy	Utilize numbers (wherever applicable) to convey information and receive input

(a)

Th.		Actionable Guidelines	Examples
Input/Output Model	G1	**Utilize multiple modes of interaction:** Support the application with multiple (input/output) mediums - text, audio, video, etc. *for easy comprehension.*	*"It supports both voice typing and sending audio messages along with text and emojis." (P18, WhatsApp)*
	G2	**Leverage numerical literacy:** Utilize numbers (wherever applicable) to convey information and receive input *as low-literate users are comfortable with numbers.*	*"It gives examples of RC number/DL number right below the search box to ease interpretation of input" (P11, mParivahan)*

(b)

Fig. 5. Structural evolution of the framework. Figure (a) shows the structure used for user study and figure (b) is the updated framework post revisions and incorporating learnings from the user study and the content analysis of industry reports.

asked our participants *"Do you think [X] application follows the recommendation [Y]?"* Here, *[X]* indicates the application assigned to the participant, and *[Y]* indicates each guideline. Although our primary goal of assigning smartphone applications to participants was to enable them to engage and evaluate the framework, the collected data helped us understand the utility of the framework. We observed that most of our participants provided precise supporting instances for the extent to which the assigned application implemented guideline(s). For instance, except one, 12/20 participants reported their assigned application aligning with G5 *"Avoid jargon"* and 6/20 to believe that the application somewhat follows the guideline:

> *"[App] follows most of it [G5], however words such as empaneled even grievances may not be suitable, could be replaced with more easier to understand complaints etc"* (P02).

On the other hand, participants reported that most of the applications did not adhere to G9 (*"Provide assistance in using the application"*) and G11 (*"Adopt culturally responsive design"*). For example, for G9 (within the theme 'Integrate Help'), 2/20 participants shared that their assigned application follows the guideline, 4/20 believe that the application somewhat follows the guideline, and 14/20 participants shared that their assigned application does not follow the guideline at all. For example, P12 expressed, *"I could not find a dedicated help button and believe this feature is split amongst contact and about us."* Our analysis showed that our participants were able to identify gaps and opportunities for improving the UIs of existing smartphone applications to ensure improved user experience for low-literate users.

Thus, the findings serve as a testament of comprehensiveness of the framework, clarity of the guidelines, and the potential of our framework to help practitioners, designers, and researchers to critique existing interface designs.

5.3 Perceived Usefulness

Our data revealed that most participants (17/19) believed the framework would be helpful in designing smartphone applications for low-literate users as *"a good starting point"* (P06). One of our participant shared,

> *"Framework could be helpful when designing for inclusive user base as it aims to bring to notice the application features/characteristics for which trade-off needs to be determined so that the application is neither too simple for literate users nor too complex for low-literate users. For designing applications purely for low-literate users, framework provides a nice set of introductory guidelines to be kept in mind while designing the app"* (P17).

Although a majority of our participants considered the framework to be helpful, three participants pointed out the overlap between our framework and HCI usability guidelines: *"[...] A lot of the design recommendations were generic UI/UX design principles"* (P06). This speaks to the tendency to dismiss guidelines as being *too obvious*, however, as we demonstrate in the previous subsection, a majority of the applications that our participants studied did not follow some/most of these recommendations. Further, we noted instances where participants were unable to comprehend the reasoning behind a guideline. For example, for G12 (*"Leverage human facilitators"*) a participant shared, *"Why do we need human facilitator? Focus should be on learnability instead of human dependency"* (P05). Thus, we augmented our framework with the purpose behind a recommendation to help researchers and practitioners using this framework understand the *challenges faced by low-literate users* and how a recommendation attempts to overcome them (see table 4). The following quote by P10 verifies our inference,

> *"A little details in the guideline with it's (sic) purpose, (say) Incorporate visual cues to catch user's attention, so that it conveys what is the guideline and what will it lead to when implemented."*

Out of the 6 studied industry reports, 4 focus on designing financial applications for low-literate people (see table 3). We observed a pattern where specific recommendations (e.g., around privacy and secure online financial transaction) stemmed from the nature of the application domain. Evident across industry reports, our data from the evaluation study further reaffirmed the need to emphasize some guidelines in our framework more than others, primarily based on the application's domain. For example, P16 shared, *"some guidelines are more important than others, depending on the apps. Such as for social and networking apps, some themes are essential, whereas, for payment-related applications, some other guidelines are essential."* Further, our participants weighed an explicit focus on some recommendations such as *"simpler visual and navigational UI"* (P04) and support for regional languages:

> *"[...] focus more on elements specific points targeted with low-literate users in mind like 'Does app support regional language and functionalities like search in local language ?', 'Does app provide relevant keypad since biggest challenge in target audience is Keypad', etc"* (P05).

The designers, researchers, practitioners, and implementers must acknowledge that our framework containing 13 guidelines is derived from the learnings from a variety of domains (see figure 3), with an attempt to keep our framework as generalizable as possible. However, these recommendations impact the usability of a smartphone application for a low-literate user to different degrees. These guidelines stem from diverse challenges that low-literate users face and missing out on some of these recommendations can have a larger (potentially, adverse) impact on usability than others [82]. Readers must also note that these guidelines in our framework hold varying importance for different application domains. Consider, for instance, for high-stakes scenarios such as digital payments, *leveraging human facilitators* (G12) is critical to build trust and improve usability of the application [123]. We emphasise that users of the framework must engage with their target population to understand their context and needs, to establish priorities in the implementation of these features.

6 DISCUSSION

We performed a systematic review to synthesize recommendations proposed in the HCI literature, over the past two decades, into a framework of 13 actionable guidelines for designing smartphone apps inclusive of low-literate users. We refer our framework as *designing SARAL* (Smartphone Applications embRAcing Low-literate users). We improved the synthesized framework by incorporating the learnings from the content analysis of six industry reports and preliminary evaluation study with 20 researchers and practitioners. Our data from the literature review, preliminary evaluation, and content analysis highlighted a *research practitioner gap* and *evolutionary nature* of the proposed framework. We now unpack these themes in detail.

6.1 Research and Practice Gap

Our research provides yet another example of the research-practice gap [27, 45]. The breadth of HCI research in the field has great potential in facilitating the design of more usable products for low-literate users. However, a recurring theme that we observed through our user study was that several of the (research-proposed) recommendations were not implemented in the smartphone applications that the participants used to evaluate our framework. There could be a variety of reasons for why these recommendations are not being realized in smartphone apps, including but not limited to, a lack of awareness of these recommendations, or inaccessibility to this breadth of research [102]. Nevertheless, content analysis of industry reports revealed a few instances of practitioners leveraging a subset of research literature to guide their tools [15, 110] and recommendations [15, 128]. Future work may be required to investigate how often these industry reports are being utilized by practitioners responsible for creating smartphone applications. Arguably, technical, financial, and policy-level constraints could also affect the implementation of such guidelines [24, 46, 102].

Culosso et al. [24] discuss barriers to the use of academic research and how translational resources could help reduce the gap between research and practice. The most common barriers to the use of research are related to the content of and access to publications. It has been observed that developers have difficulty accessing scientific literature, which is often behind institute walls or available with paid subscriptions [19]. If accessible, it can be time-consuming to determine which resources merit attention and to synthesize their findings [12, 24]. Further, practitioners find HCI publications' content often too complex and abstract, which hinders the utilization of their findings [24]. To alleviate this problem, Culosso et al. [24] suggest incorporating actionable recommendations and data for advocacy. Taking inspiration from their work and feedback from our user study participants, we have created a framework that contains *actionable guidelines* with their *purpose* and supporting *examples* from our user study. As researchers in the HCI field, we, too, believe that the knowledge we produce as a community should be accessible to a broader audience, including practitioners so that we can benefit from a symbiotic relationship.

For research to become truly translational, researchers may have to adopt additional dissemination strategies, e.g., blogs/websites/social media, to support their research and have a positive impact [23, 71]. The Design-based Implementation Research (DBIR) framework portal[4] is an excellent example to follow. The website provides open access to articles and case studies to learn or

[4]www.learndbir.org

implement DBIR. Such a translational resource could also address a lack of resources that often hinder the implementation of a recommendation. For example, for a recommendation (G11 in our case) to use culturally-appropriate icons, designers could contribute to repositories to help the development of applications that are easy and understandable for everyone to use [93]. Similarly, designers, practitioners, researchers, and implementers could build and contribute to a repertoire of tools, artefacts, and assets of translational resources (e.g., printable cards and worksheets [15]) for others in the community. We want to emphasise that translational resources could be led by the researcher (e.g., seminars), co-produced (e.g., trajectory cards for scenarios) or led by the UX practitioner (e.g., pamphlets that translate concepts for UX designers) [129].

Other translational resources could be directly integrated into practitioner workflows, such as tools that provide just-in-time best practices within existing systems for designers or developers. For instance, the development of mobile applications is done primarily using integrated development environments (IDEs), e.g., Android Studio. These IDEs come with basic functionalities of compiling, testing, evaluating a program, and making deployable packages. IDEs also provide mechanisms to extend their core functionality through plugins. Li et al. [75] have investigated the use of an IDE plugin that helps developers create privacy-friendly apps by engaging them to think about privacy during the development process and providing real-time feedback on potential issues. Similarly, plugins could be created to integrate recommendations on designing for low-literate users into commonly used design/development tools. The plugin may suggest improving the current design by adhering to a particular guideline while providing supporting implementing resources (e.g., examples, icons, and more).

We have discussed a future of designing *new* smartphone applications with a focus on being inclusive of the low-literate population while bridging the research-practice gap. What about the available smartphone applications (e.g., Paytm, Google Maps, Uber, and more), offering enabling services, and being consumed by people of varying literacy levels? While the framework can serve as a baseline when designing applications from scratch, updating, testing, and improving existing applications can be more challenging. *"Layer-on-top"* translational solutions could be explored for existing smartphone applications to make them inclusive for people with low-literacy. For example, Navana Tech [110] have built illustrative iconography, contextual voice assistant, and a software development kit (SDK) to implement a text-independent, visual and voice-driven user experience in existing applications. Future work may investigate how translational resources might diverge for different starting points in the project lifecycle.

6.2 Evolutionary Nature of Framework

The systematic review resulted in a corpus of recommendations, including technology which has become obsolete over the years (e.g., cross-shaped arrangement of active widgets to facilitate smooth navigation using the central button of the feature phone [125]). This highlights the temporal nature of recommendations, implying the need to evolve the framework as new modalities of interactions appear. In this section, we discuss the fundamental yet evolutionary nature of our framework and the components that contribute to this nature - *Users* and *UI Elements*.

6.2.1 Evolving Nature of Users. We derived our framework from the studies proposing smartphone UI design recommendations for low-literate users. There are recommendations that factor in additional variable attributes apart from the literacy of the 'user' like cognitive difficulties, technology exposure, age, and motivation that affects the adoption of UIs by our target stakeholders [32, 61, 81, 90]. For example, interaction techniques like scrollbars (G6) have been considered less intuitive tasks for low-literacy users (initially) but have shown to be highly learnable with time and usage [53]. Another study exemplifies how motivation derived the consumption of entertainment media by low-income, novice technology users even when it required to traverse multiple levels of complex UI navigation [119]. Similarly, a recent study by Ismail and Kumar serves evidence of community health workers adapting and learning WhatsApp when it became essential to their work [59]. These findings corroborate the evolving nature of users with experience and motivation. We re-emphasise that the framework, like the one presented here, should not be viewed as a replacement of contextual studies. Instead, given the evolutionary nature of users, it should be used as a supplementary tool alongside in-depth contextual studies to meet low-literate users and their needs in their situated context.

6.2.2 Evolving Nature of UI Elements. The UI components and functionalities have evolved with the introduction of new modalities of interactions. For example, one time passwords (OTP) have recently become a de facto authorisation mechanism for many mobile applications, including smartphone apps targeted for low-literate populations (also observed in our set of apps including mParivahan, BHIM, and Ayushman Bharat). Further, with smartphones gaining new capabilities, the possibilities for applications will also grow. For example, integrating new services on the existing apps is also seen as an emerging trend. For instance, the Delhi Metro (DMRC)[5] mobile application has integrated Google Maps, and WhatsApp is working to integrate payment service [126]. It becomes imperative to study how the integration of applications with different usability, impacts the overall usability of an application for a low-literate user. The rigorous user studies to understand the impact of evolving UI elements will bring new insights into low-literate users' engagement patterns, giving rise to new recommendations.

6.3 Framework in the Wild: Usability & Scope

It is important to note that low-literacy often does not occur in isolation and might be influenced by the users' socio-economic background, gender, age, and more. For example, low-literate children may require additional novel interactions to keep them engaged [113]. Similarly, individuals with hearing impairment may need textual prompts translated into sign language videos [95], and people with visual impairment may prefer a haptic interface with vibrations as the core feedback mechanism [130]. However, it requires additional research and contextual studies in understanding and designing a suitable interface for groups at these intersections. Thus, we see a three-fold use of the proposed framework:

- During the early stages of design, the framework could serve as *a starting point* towards aiding designers to inform designs of future smartphone applications' interface features for the low-literate population, including people at the intersections of low-literacy. Additionally, including this framework within pedagogy elements for design or engineering, students could serve to be a helpful *learning tool.*
- The framework may also serve as *a critiquing tool* for existing UIs, and if they are fit to cater to the low-literate population.
- Additionally, the framework can be used as *a skeletal source* to expand itself and/or synthesise different flavours by further deriving new recommendations to accommodate the advancement of technology and user capabilities and the groups at the intersections of low-literacy — *thus making the framework evolutionary.*

6.4 Limitations & the Road Ahead

The proposed framework's intended audience includes researchers, designers, practitioners, and implementers across industry and academia. While a majority of our study participants were design

[5]http://www.delhimetrorail.com/mobile-app.aspx

students, we allowed for a mix of experience in our sample to gauge the perceived usefulness of the framework by the research community. Due to the impact of the COVID-19 pandemic, we were limited by the research methods we could utilize and the participants we could recruit for our study. Most participants had 1-5 years of experience working on HCI/UX, and are currently or will be involved in product design and application development for low-literate users, and thus, should be sensitized to designing for low-literate users. We acknowledge that a broader sample with diverse vantage points could lend more insights into the framework.

We identified relevant papers by searching the Association for Computing Machinery (ACM) Digital Library, which is one of the most comprehensive databases of research in the fields of computing and HCI. However, our corpus is by no means exhaustive, limited by our record selection criteria and search methodology, and new work continues to emerge. By focusing on low-literacy as the primary parameter to build the core framework, we see this work as a first step in the direction of creating a stack of customised translational resources for building smartphone apps inclusive of low-literate users.

With that said, we describe this work as a preliminary evaluation of the framework and a large-scale follow-up study with industry practitioners and implementers is the next step. Going forward, we will be following in the footsteps of the DBIR framework portal[6] and make our framework available on *https://designingsaral.com* as an open resource that can be accessed, extended, and evolved by the community (across academia and industry). We emphasize our framework is evolutionary and encourage further research on extending this to population groups at the intersections and with unique needs.

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