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Research Article

A Systematic Feasibility Analysis of User Interfaces for Illiterate Users

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Abstract: Literacy is conventionally defined as the ability to read and write simple statements. Illiteracy and poor education are major problems in developing countries. In this digital era, computers can play a vital role in improving literacy. However, computer illiteracy is also high in developing countries and their citizens cannot understand the complex digital User Interfaces. Research shows that User Interface (UI) design should be different for illiterate, semi-illiterate and literate users. Furthermore, the design should also consider the cultural context like language, culturally relevant images, etc. The researchers of Human Computer Interaction for Development (HCI4D) face challenges to improve literacy to design effective and usable interfaces. HCI4D researchers have designed such interfaces for illiterate users over the years. Their major findings were to use non-textual designs over text-based interfaces. In the non-textual designs, they further considered artifacts like sounds, images, icons, backgrounds etc. This paper systematically reviews the work carried out by HCI4D researchers in four different domains i.e. health, agriculture, e-commerce, and education. We have extracted User Interface (UI) design recommendations from the related literature for UI designers of these domains. We believe this could help designers to create effective design interfaces for illiterate population in the domains considered for review.

Keywords: Illiteracy, Illiterate Users, User Interfaces, Semi-illiterate, Human Computer Interaction (HCI).

1. INTRODUCTION

Literacy is conventionally defined as the ability to read and write simple statements about everyday life with understanding [1]. According to UNESCO, "Literacy is the ability to identify, understand, interpret, create, communicate and compute, using printed and written materials associated with varying contexts" [2]. The Experimental World Literacy Program defines functional literates as those persons who can participate in all those activities in which literacy is required for: 1) effective functioning of their group and community and 2) for allowing them to continue utilizing their skills of reading, writing and calculation for themselves and the development of their community [3]. Cordes (2009) further expands the notion of literacy by introducing Multimodal literacy as a variety of terms such as visual literacy, digital literacy, media literacy and multi-literacies [4]. Literacy skills are required for finding, selecting, interpreting, analyzing and

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producing relevant information [5]. People need enhanced literacy skills to search and select relevant information for themselves, analyzed and interpret that information accurately [6]. Therefore, in the context of complex societies, illiterate people are not as effective as literate ones [7]. Individuals struggle with employability issues because of their low level of knowledge and expertise [8].

Computers have integrated in every field of life and therefore digital skills and basic computer concepts are essential life skills especially for young people [9]. Information Communication Technology (ICT) provides solution to improve literacy and awareness among illiterate users. ICTs offer opportunities to young people for learning and developing skills and a chance of employment [10]. In the knowledge era, continuous education and training is the only way to job security. Using ICT, traditional services are being reformed on how they are produced, traded and delivered [10]. However, a major obstacle in providing such services is the large number of illiterate people (781 million i.e. two third of the world's population). Furthermore, a large portion of those classified as literate also have great difficulty in reading/writing [11]. Research shows that illiterate populations avoid complex functions. They primarily use phones for synchronous voice communication only [12]. These hurdles could be solved by better designed user interfaces for illiterate users. Cognitive science researchers showed that low-literate people with limited education differ from people with good educations in their performance [13]. The cognitive skills including: language processing, visual organization and visual memory, mental spatial orientation, speed of cognitive processing, vigilance, divided attention and perceived self-efficacy, are some of the skills where differences were noted. In addition, there are differences in literate and illiterate populations in the same regions of developing nations in terms of life experiences, expectations, difficulties, needs and coping mechanisms. It will not be beneficial to replicate western-centric concepts, interfaces, symbols, and features, without detailed analysis of the requirements of the illiterate population of the developing countries. Further, it could result in discomfort, resistance in adoption of technology and further marginalize these groups from access to Information and Communication services [14]. Fortunately, HCI4D researchers have already realized the need for better design and provided various solutions. One of our recent works [15] is also focused on investigating the use of mobile applications in illiterate people and we found that people prefer voice-instructions and clear photos instead of text for using emails. Fig. 1 and 2 depict the user interface of the developed email application for illiterate users.

In this paper, a review is provided on the work done by HCI4D researchers to help illiterate population in four selected domains discussed below i.e. Health, Agriculture, E-Commerce, and Education. In addition, solutions provided to enhance usability of the software systems for illiterate users are discussed and the design recommendations given for better and effective UI designs are highlighted. Researchers have identified three distinct levels of literacy based on which the users could either be termed as literate, semi-literate, and illiterate. The paper discusses why these three categories should be treated differently for a better and usable software system.

The paper also discusses hardware and software related challenges for illiterate people. Finally, the paper discusses design solutions provided by the researchers in the found domain. At the end of each section, we have summarized the work done in tables along with the design recommendations.

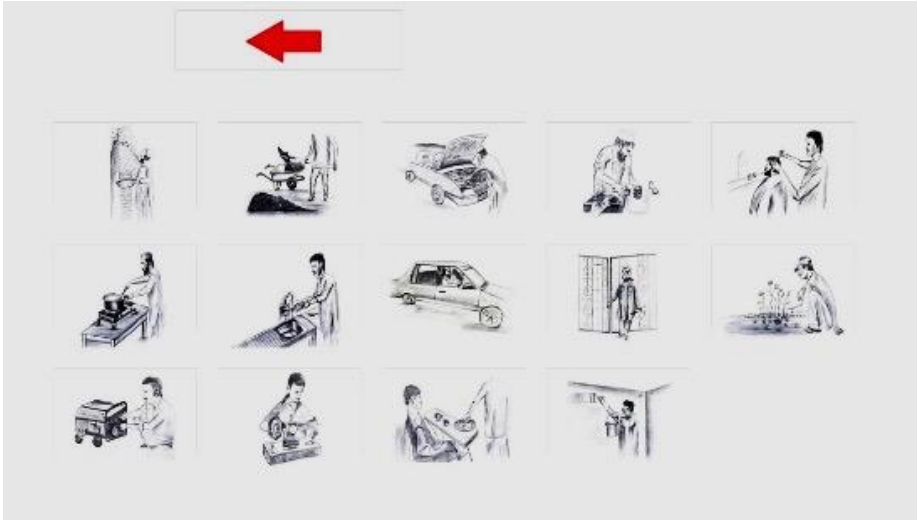

Fig. 1. Profession Selection Screen in Email Application for illiterate people [15].

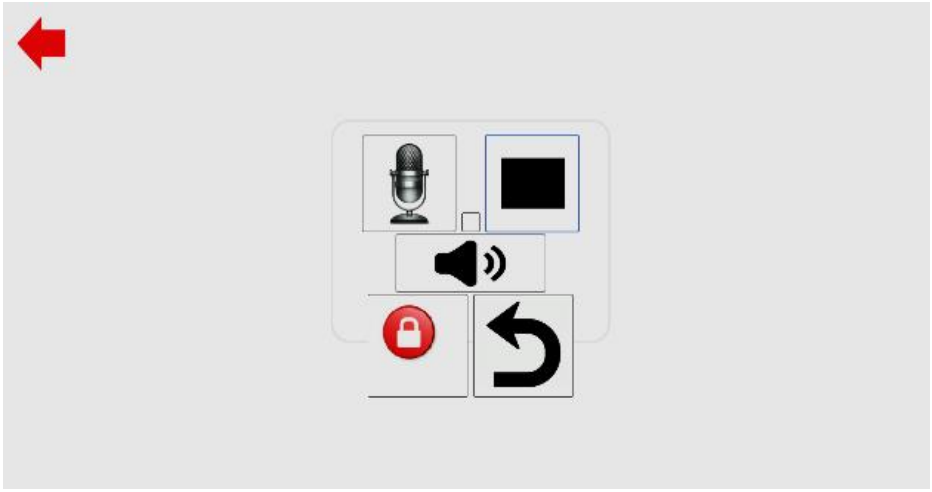

Fig. 2. Email listening page in Email Application for illiterate people [15]

2. CHALLENGES FACED IN UI DESIGNING

According to several research works [13, 16, 17], the lack of education and inability to process text are the major challenges faced by designers during the design of user-friendly UIs for illiterates. They usually design interfaces having too much text and are not suitable for illiterate people. This indicates that to design a system that achieves our goal to get most out of the illiterate our interface has to be somewhat more graphical and able to guide the no literate population which on the designer's end is a hectic challenge.

In Pakistan, the overall literacy rate is 58% [18]. Education is often used as a means for textual literacy.

However, research shows that textual literacy may not be dependent on the level of education. For example, one such project in Africa, called Vai [16], found that textual literacy is deeply linked with cognitive science and not necessarily with education. The educational level of a person, therefore, depends upon various factors which include the school one has attended, the teaching quality at that institution, family support and environment, amount of effort one has invested in learning, genetics, food and attendance etc. However, these factors are not easily understandable which works in a very complex way. Therefore, measuring the cause and effect of each of them is impractical. To solve this problem, researchers have used textual literacy as a proxy for literacy. A person is called textual literate if he/she can read and write text. Research confirms that textual literacy reflects the educational level better than the other methods [13]. For measuring the quality of education of the participants, researchers have used level of textual literacy as a proxy. Low-literate users were found to have reading and writing skills equivalent to or less than those of Grade VII textbooks. They also found that those who were unable to pass Grade-I test were unable to recognize basic alphabets while those who passed Grade-VII tests were able to read short passages. Apart from textual illiteracy, certain cognitive skills, which illiterate users experience difficulties with, were found linked with basic ICT use. Though ICT technologies, particularly the mobile phones, are widely penetrating the illiterate segments of the society, yet they are still unable to use most of its functionalities. Majority of them can only use it for basic functions like voice calls etc. [13]. The objective of HCI4D designs is to create usable and enjoyable end products; however, because of the broadness of the discipline, different value systems and different experiences, expectations, and background of users, it becomes a very tough job to fulfil this objective. That is why people often complain about bad design experiences, particularly in mobile phone industry. Kuo-Ying Huang [17] has also identified challenges related to hardware and software in his study.

3. UI DESIGN SOLUTIONS AND RECOMMENDATIONS

As stated earlier, illiteracy negatively affects citizens of a country. As shown in Fig. 3, the impact can be classified into four domains: 1) Health, 2) Agriculture, 3), E-commerce, and 4), Education.

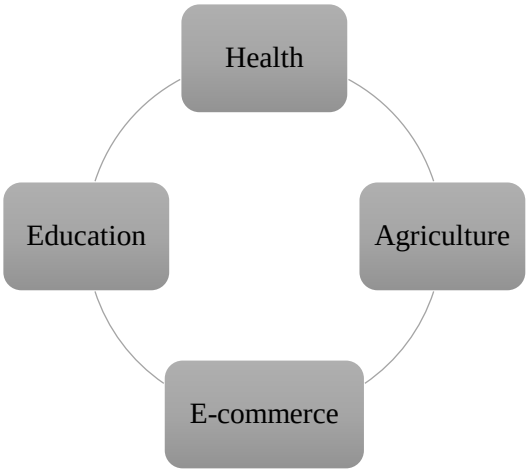

Fig. 3. Classification of Domains for UI Designs

Related to health, studies show that illiterate individuals, particularly women, struggle to understand health care messages and critical knowledge about one's life. That is why the mortality rate is higher among illiterate women, particularly during pregnancy. Infant's mortality rate is also comparatively higher in developing countries because of low literacy. Similarly, regarding education, illiterate parents fail to support their kids in their studies. They tend to have lower

educational expectations from them. This family background limits the educational success of most of these struggling students [8]. The reason most of these kids show behavioral problems and underperform in grades is because their parents are not involved in their studies. Many such students often repeat their school years and even, sometimes, discontinue schooling. If economy is concerned, literacy and schooling are directly proportional to the family income of individuals and economic success of a country. In developed societies, like Latin America, the income of an individual is directly proportional to his/her schooling. Low literate individuals find it extremely hard to compete in the job market. They are less likely to obtain good jobs [8, 19]. Moreover, illiterate individuals are often denied of their social status. They are not recognized socially, that is why they suffer from low self-esteem. Because they are not fully integrated into the society, they often lack social skills and rational thinking. They could easily be deceived and manipulated [20].

Illiteracy has a huge impact on agricultural production of a country as well. Illiterate farmers are, most often, less productive as compared to literate and modern farmers. They have no awareness and agricultural knowledge regarding new technology and farming methods [21]. It is therefore inevitable that we develop solutions pertinent to each domain to minimize the impact of illiteracy. Fortunately, researchers have addressed various issues relating to illiteracy in different domains. We, therefore, categorized the work done by HCI4D researchers in four domains i.e., health, education, e-commerce and agriculture. While every application that addresses self-development i.e., social integration and cohesion is part of educating the masses, thus included in education domain.

3.1 Health

Though healthcare is the fundamental right and basic need of every human, it is often neglected in underdeveloped countries. That is why these countries have a high mortality rate. Such countries, including Pakistan, have a lot of issues to deal with regarding healthcare infrastructure and health service providers [22]. For example, in tribal areas of Pakistan, the healthcare infrastructure is rusted, and healthcare professionals are not easily accessible. Many governments across the world have, therefore, started community health worker programs to train people from the same communities that can provide healthcare services once their basic healthcare training program is completed. This approach is useful in terms of saving cost and abundant human resources as these parts have very low number of medical schools and the cost of training doctors is very high. However, these Community Health Workers (CHWs) need better information and it is widely acceptable providing them access to reliable information will not only improve their performance but save the lives of millions of people. The problem, however, is that accessing relevant information for low-literate is a very challenging job. To address this issue, Sherwani et al. [22] proposed a spoken language interface prototype, tested with CHWs in Pakistan, for low-literate users. Their results show that well designed speech interfaces, contrary to the previous literature, perform better than touchtone for literate and low-literate users. Moreover, they found that literacy has a huge impact on “task success” for both literate as well as low-literate users. Apart from community health workers, researchers

have also tried to provide solutions for people with disabilities.

For healthcare applications, a live operator is not only cost effective but can also achieve up better accuracy than text-based interfaces. Researchers in HCI4D have also suggested using textless interface for healthcare applications [23, 24]. This suggestion is well taken by designers in health domain. Related to this, Christer Nordberg in 2010 designed an icon-based prototype for mobile phones. He found that icon-based textless interfaces are extremely effective for illiterate users [23]. In another study, Anita et al. [25] studied the best and beneficial interfaces for ATM machines. Their objective was to find what sort of interfaces is beneficial and easier to use for both semi-illiterate and illiterate users. Results showed that textless interfaces consisting of icons and speech-based interfaces are better. Another study [26] followed a user centered approach to design a mobile application for illiterate and semi-illiterate pregnant women.

In rural areas, end users are, oftentimes, illiterates and inexperienced in using computer technology. That's why interacting with normal text-based interfaces are always a headache for them. But because personal computers are immobile, requires uninterrupted power supply and expensive, a more preferred solution is to use small display devices. If icons and/or images are selected carefully based on geographic information, and speech output provides feedback in local language, human computer interaction in these areas will be considerably improved and technology will find its way into the society. The input is usually taken in text form. However, such input interfaces are not recommended for low-literate users. Input can be taken with the help of form-based interaction by speech and touch interfaces. Numerical interfaces are also comparatively better than text-based interfaces for input purposes. However, touch screens and/or buttons should be implemented in such a way to maintain accuracy when interacting with them. Also, since the users are inexperienced, interaction with computer for them is usually not comfortable. To address this issue of interaction, graphical elements, e.g., shapes should be used in UI designs. In addition, such user interfaces may also be used effectively by disable people [27].

In Pakistan, researchers have conducted various studies to determine how low-literate users can be benefited from specially designed user interfaces. One such study was carried out by Ahmed et al. [28] in 2014. They studied usability improvement for an online internship program designed for semi-illiterate users. Apart from this, researchers have also recommended multi-modal interfaces for low-literate users, meaning that interfaces should adapt to one's likes and dislikes and how one interacts with the computer system [29]. The summary of UI recommendations for the health domain is given in Table 1.

3.2 Agriculture

It is very challenging to design ICT systems for users living in rural areas in a developing country. Usually there are a variety of spoken languages in developing countries. In addition, users are illiterate or low-literate and are not exposed to digital technologies. Research has been carried out on using graphical interfaces and audio applications to address the problems related to language and literacy of people in developing countries. There are pros and cons of each of the two approaches; however they can be used together. One of

the much related researches in this area is performed by Sebastian et al. [30] where they developed an application named Video Kheti for low-literate farmers in rural areas of India. The application uses speech, graphics and touch-based technology to help farmers in searching for and watching agricultural related videos in their own language/dialect. In addition to the description of the application design/development, their paper also contains conducted with 20 farmers in rural India where the participants were asked to browse videos on particular scenario. According to their results, the participants were able to use the application; however the success was dependent on their literacy. The multimodal interfaces could not completely resolve the issues of low-literate users in using such applications.

Table 1. UI Recommendations for Health Domain

Interfaces	Recommendations
Representations(10):Text, Static Drawing, Static Photograph, Hand Drawn Animation, Video with & without voice annotation	Voice annotation are helpful while bimodal audio-visual information can be confusing [56] Richer information should be avoided [56].
Icon base, text free	Icon are effective in UI for illiterate [23].
Icon & Speech	Iconic UI and speech interfaces are recommended [25].
Speech, audio, touch screen, icon, images	Suitable input and output channels include speech interaction, audio feedback, visual display and speech interaction [27].
Icon base only, text only, icon and text	Icon base is effective [57].
Icon	Icons are effective [58].
Speech input	Effective for rapid development [59].
Online assistance	Helpful for Semi-illiterate [28].
Assistive Technologies, UI from communities	Effective in software application used by deaf and functional illiterate [60]
Multimodal interfaces, smart interfaces	Play effective role in rural area development [29]

Table 2. UI Recommendations for Agriculture Domain

Interface	Recommendations
Visual Imagery mnemonic, Complementing mnemonic, Passfaces	All are recommended for illiterate UI [61]
Speech, Dialogue Interaction, Non Linguistic Graphics	Useful in design approach for illiterate [62]
E-boards, mobile phones	Overcome the gap by using HCI techniques [32]
Speech, graphics, and touch interaction	Can be used by farmers but the success is dependent on their education level. Multimodal interface is not the perfect solution as it could not overcome many obstacles for low-literates [30]
Iconic interface, speech-based interaction in Indian languages	Effective UI for agriculture field [63]
Iconic interface	Iconic interface works better [31]

Mittal et al. [31] studied what sort of UI is effective for digitally illiterate farmers to identify disease in their crops. An interface model was presented for users who have difficulty in using digital technology, especially farmers for retrieving information through internet efficiently. It helps farmers to identify the disease in their crop along with its cause and symptoms using digital image processing and pattern recognition instantly without waiting for an expert to visit the farms and identify the disease. Experimental results prove the effectiveness of the proposed research. Their results showed that iconic interfaces work better. Besides India work has been done in Pakistan as well. For example, Kokhar et al. [32] studied how to reduce the digital divide in agriculture sector of Pakistan through ICT4D. They found that eboards and mobile phone in a simple way to overcome the gap by using HCI techniques. Similarly, Sheikh et al. [33] provided a model for illiterate farmers in Pakistan using heuristic evaluation to enhance the usability. Table 2 lists the recommendations for the agriculture domain.

3.3 E-commerce

Medhi et al. [34] in 2009 carried out a research study to investigate the type of UI that is best for semi & illiterate users in a mobile money transfer system. 90 Subjects were Interviewed having 8-Grade Schooling at max and having zero experience with PC. Text, Text Free, Rich multimedia and Voice interfaces were used in the system. They recommended text free user interfaces. Their proposed solution consists of using text-based, audio dialog, and multimedia without text. They concluded that graphical (non-text) UI designs are much preferred over text-based designs and rich multimedia UI helps in achieving faster task completion rates. In addition, they found that audio dialog systems help in achieving high speed without requiring much assistance [34]. Similarly, Medhi et al. [35] in the year 2009 in the states of India, Kenya, South Africa and Philippine conducted a research study on 90- Illiterate, Semi-illiterate's subjects. They observed variations in adoption and usage across locations and potential factors responsible for the same. The variations were along several parameters: household type, key service adopted, pace of uptake, frequency of usage, and ease of use. They found that low literate cannot take benefit from mobile banking service. Ethnographic exploration involving interviews and qualitative observations were done to find the solutions [35]. In another study Parikh et al. [36] suggested that touch input facility should be included in interface design, while development financial management system for functionally illiterate or semi-illiterate users. Another major concern for illiterate users of e-commerce applications is correlated with cybersecurity and privacy. In this digital era, our financial data is critically important. In other words, it is the new digital currency. Many government institutions are thinking about providing personalized touch services, which would give rise to the issue of security and privacy.

For mobile banking sector, graphical interfaces achieve higher task complete rates, however speech-based dialog system are more effective if the spoken dialogs are understandable by the users. Studies found that text-based interfaces adversely affect usability while other interfaces (spoken dialog system, graphical and live operator) achieve better usability [37, 38]. The

UI recommendations for E-commerce domain are listed in Table 3.

3.4 Education

The core components of a literacy program are reading, writing and innumeracy. These are the needs of a person for navigating his way in society. In addition to this, computer literacy is becoming a must have skill for a person to function well in society. Therefore, a literacy program should include computer literacy aspect. For this reason, Mohamad Adnan Al-Alaoui et al. [39] suggested an approach to utilize ICT to enable the illiterate people for having computer literacy. Their approach consists of interactive learning, self-paced and autonomous learning, entertainment learning, ease of information updating, ease of entry and exit, and ease of application to E-Learning. The hallmark of the proposed approach is the integration of speech and handwriting recognition, as well as audio and visual aids into the flow [39].

Table 3. UI Recommendations for E-commerce Domain

Interfaces	Recommendations
Text, Text Free, Rich multimedia, Voice	Text free UI is Recommended. Task completion rate is better in case of rich multimedia. Voice is Effective in term of Accuracy & Task completion time [34]
Touch input facility	Recommended [36]
Photographs of bill, coin (same color, images, and denominations), communicating languages, dragging, and dropping facility, audio etc.	Photographic, audio, images work better for digital representation of money [64]
AUI designed	Specially designed AUIs that are tailored for developing countries to help provide universal access, in particular to the illiterate and semi-literate communities. [50]
Spoken Dialog System, Graphical Interface, Electronic Forms, SMS, USSD	Spoken dialog system and speech work better. Rest are error prone. [37]
Icon & Speech	Recommended [25]
Icon base only, text only, icon and text	Icon base is effective [57]

The heavy use of text on everything from menus to document content means that those who are illiterate or semi-illiterate are not able to access functions and services implemented on most computer software. Medhi et al. in 2009 conducted a study to find that what sort of UI is required so that these illiterates and semi-illiterate users can get benefit. In their study, they developed two applications, one for job search and the other for map navigation using text free user interfaces. The results showed that text free UI is strongly recommended while voice feedback & abstracted graphics is also good for illiterate & Semi illiterate. Prasad et al. [41] designed and evaluated a prototype asynchronous communication application built on standard email protocols. They considered different message formats including text, freeform ink, audio, and video + audio – and via iterative usage and design sessions. They studied how email facilities can be made accessible to illiterate users and what sort of prototype is required. Results showed that audio video was the most viable solution.

Toyama et al. [6] suggested that cursor/hover plus enlargement facility, help with voice function

facility will work better for illiterates and near to illiterate users. They recommended Iconic Pictures for patents. Their results showed that voice function is also effective for illiterates. In another study in 2004, Deo et al. [42] developed a digital web application for giving digital library access to illiterate users. Their findings showed that Audio Clips are effective for target population. They recommended replacing textual labels with audio clips. Ávila et al. [43] focused on using icons to help in the interactions of low-literate users with computational interfaces and with citizen services through the Internet. In their study, they concluded that even though the use of photographs lends more credibility to the iconic representations, the intelligibility of drawings is not significantly lower than that of photos. The authors recommend the use of either type of image, with a preference for photos whenever the emphasis is put on the credibility or in establishing a direct connection with an entity, and a preference for drawings whenever we represent a general concept or need to be flexible for drawing concepts for which no photographic register is available. Results also showed that the use of icons could reinforce and scaffold the reading skills of semi-literate users [43]. Table 4 lists the UI recommendations for the education sector.

Table 4. UI Recommendations for Education Domain

Interfaces	**Recommendations**
Voice, Text multimodal	Multimodal interfaces are effective for semi-non-literate users [65]
Text, Free Form, Ink, audio video, Audio	video audio was the most viable solution for non-literate [41]
Text Free, Text Based, voice feedback, semi abstracted graphics	Text free UI is strongly recommended while voice feedback and abstracted graphics is also good for non-literate & Semi-illiterate [40]
Audio Clips, Textual Labels	Audio Clips are effective for target population [42]
Iconic pictures, voice function, Text	Iconic Pictures are recommended for patents and voice function is also effective for non-literate. [6]
Video and touch screen kiosk	Effective for non-literate citizens
Speech technology	Effective for non-literate citizens [45]
Touch screen, text, audio, visuals icons	All are effective [46]
Icon base, text free	Icon are effective in UI for non-literate [23, 67]
Touch input facility	Recommended [36]
Automatic Speech Recognition (ASR) and Automatic Handwriting Recognition (AHR) techniques	Work effectively for mobile non-literate education [66]
Metaphoric icons, idiomatic icon	Can benefit semi-literate users by significantly effecting users' intrinsic and extrinsic motivation [55]

3.5 Combined Work in Health, Agriculture, E-commerce, and Education Domains

In this section, we discuss the research work that is related to more than one of our identified domains at the same time. For example, Kettani et al. [44] conducted their research on developing an E-government system for Fez city in Morocco that can be accessed by all citizens including illiterate. They used video and touch screen kiosk which resulted in a user-friendly interface for both literate and illiterate people. The problems associated with illiteracy and difficulties in accessing information in developing

countries, it is a general belief that speech-based technology can play a vital role to improve the quality of life in such areas of the world. The authors in [45] investigated the reasons of the lack of such impact till date and recommend voice-search systems for illiterate people.

Many illiterate people (800 million worldwide) are currently excluded from the benefits of asynchronous and cheap communication through text messages also known as SMS. Smart phones with touch screen will soon be in financial reach of illiterate people in developing countries. The application Easy Texting allows illiterate users to listen to received SMS and composes text messages by augmenting words with touch-initiated text-to-speech support, icons for frequent phrases and by re-using words from previous messages [46]. Sherwani et al. [47] have conducted a research study to study what sort of prototype is required when providing health information access to low-literate health workers. They have recommended speech recognition and dialogue systems. In their study a speech based health information community system is provided using speech recognition and dialogue systems. This group also include Un-educated people often referred to as the "Information Poor". Zainab et al. [48] conducted a research study to determine how information could be made accessible to illiterate users. Literature suggested to used pictures, audio, voice, icon and menus, auditory interface, sensor based interface, acoustically with sound or spoken Language considering regional languages in the web application. Mandl et al. [49] have performed a review of the literature about tangile user interface for social interactions of elderly people.

In 2012 Takayedzwa Gavaza [50] conducted a research study to discover how illiterate and semi-illiterate users intuitively understand interaction with a computer. The challenge was to provide guidelines for developers of augmented user interfaces that can be used by illiterate and semi-illiterate users. In the first Wizard of Oz study, users were presented with a standard desktop computer, fitted with several input devices to determine how they assume interaction should occur.

This study found that the users preferred the use of speech and gestures which mirrored findings from other researchers. The study also found that users struggled to understand the tab metaphor which is used frequently in applications. From these findings, a localised culturally relevant tab interface was developed to determine the feasibility of localised Graphical User Interface components. A second study was undertaken to compare the localised tab interface with the traditional tabbed interface. This study collected both quantitative and qualitative data from the participants. It found that users could interact with a localised tabbed interface faster and more accurately than with the traditional counterparts. More importantly, users stated that they intuitively understood the localised interface component, whereas they did not understand the traditional tab metaphor [50].

Similarly, Indrani et al. in 2013 [51] investigated how limited education appears to impact the ability to navigate a hierarchical UI, even when it has no text. They found that low education has impact on hierarchal UI, which include text and text free UI. Their results confirmed that textual literacy is correlated with scores

on the Raven's test. In addition, they found that performances on both instruments are predictive of performance in navigating UI hierarchies, even when the UI is text-free.

Health		Agriculture		E-commerce		Education	
Interfaces	**Recommendation**	**Interfaces**	**Recommendation**	**Interfaces**	**Recommendation**	**Interfaces**	**Recommendation**
Text based	Not recommended[58, 59]	Visual Imagery mnemonic	Recommended [54]	Text	Not recommended[67]	Voice and Text multimodal	Multimodal interfaces are effective for semi-non-literate users[22]
Representation	Recommended but richer information should be avoided [58]	Mnemonic Complementing	Recommended [54]	Text Free,	Recommended [67]	Free Form Ink vs audio+video vs Audio	video+audio was the most viable solution.[75]
Video with and without voice annotation	Voice annotation are helpful [58]	Passfaces	Recommended [54]	Rich multimedia	Task completion rate is better[67]	Text Free, Text Based, voice feedback, semi abstracted graphics	Text free UI is strongly recommended, voice feedback and abstracted graphics is also good [74]
Text free icon based	Icon based are effective [51]	Speech, graphics, and touch interaction	Farmers could use it. But not effective enough. [61]	Voice	Effective [67]	Audio Clips ,Textual Labels	Audio Clips are effective for target population[76]
Icon and speech	Recommended [52]	Iconic interface,	Effective [63]	Spoken Dialog System,	Work better [72]	Iconic pictures, voice function, Text	Iconic Pictures are recommended for patents and voice function is also effective for non-literate.[6]
Audio	Suitable [53]	Speech-based interaction in Indian languages	Effective [62]	Icon & Speech	Recommended [52]	Video and touch screen kiosk	Effective[83]
Touch	Suitable [53]	Dialogue Interaction,	Useful [66]	Icon base only, text only, icon and text	Icon base is effective [59]	Speech technology	Effective[78]
Icon and text vs icon base only	Icon base is effective [59]	Non Linguistic Graphics	Useful [66]	Photographs of bill, coin, communicating languages, dragging and dropping facility, audio assistance.	Work better for digital representation of money [70]	Touch screen, text, audio, visuals icons	All are effective[79]
Text only	Not recommended [59]	E-boards	Overcome the gap by using HCI [65]	AUI designed	Recommended specially designed AUIs [71]	Icon base, text free	Icon are effective in UI for non-literates[51]

Fig. 4. Summary of UI Recommendations for the four domains

In one of our previous work [15], we have investigated the use of email application in illiterate and semi-illiterate people. We designed an email application based on pictures and voice instead of text for user interfaces. The application was tested on a large group of people and the results showed that people prefer precise voice instructions, less text and clear photos in email applications. The rapid development of technology has caused the emergence of various sophisticated information and communication technologies much cheaper than in previous years. Therefore, the penetration of technology is not only into every aspect of highly developed societies but also into developing countries such as Indonesia, as more and more people can afford to buy a variety of technologies. However, to use the technologies, many of the users in developing countries need to make a rapid technology leap; hence many of them are having difficulty in using the technologies. This paper looks at the cellular phone which is one of the technologies widely used in developing countries. Many people can afford to have cell phones but experience difficulties in making full use of them, such that they only operate the basic functions. One of the reasons for this is the low comprehension level of icons being used in the interface. Their results showed that the use of the right metaphor can improve users understanding of an icon to empower low literacy through ICTD and mobile technology [52]. Various mobile apps are not much used as they are not literate. Voice communication with graphical interfaces could be used effectively in reducing the barrier of illiteracy. Voice-based telecom information systems and graphical interfaces break the barrier of illiteracy [53]. Li and his co-authors studied how HCI can be used to contribute towards eradication of illiteracy by improving the usability of web browsers. The objective was to determine what should be used in web services for these illiterate communities. Results showed that usability can be increased by introducing human factor. The authors recommended that web services should be designed considering human factor as well [54]. Sengupta et al. [55] studied effects of icon styles on Cognitive Absorption and Behavioural Intention of Low-Literate Users. They found that icon styles (Metaphoric icon, Idiomatic icon) affect cognitive absorption and behavioural intention of low literate people. So, icon styles (Metaphoric icon, Idiomatic icon) should be introduced in web pages. The summary of all these recommendations is depicted in Fig. 4.

4. CONCLUSIONS

Illiteracy is one of the biggest problems the modern world is facing these days. Computer illiteracy is another prime problem that is increasing the digital divide significantly. While designing UI, illiterates, semi-illiterates, and literates should be treated separately. Designing for illiterate is not an easy task. Research studies identify two biggest challenges in UI design for illiterate users, i.e., lack of education and difficulties in certain cognitive skills relevant for ICT use that low literate users experience. To cope with the problem of illiteracy, HCI4D researchers have conducted studies in four different domains which include health, e-commerce, agriculture, and education. Researchers have proposed to avoid texts and instead, use text-less interfaces.

In health, researchers have recommended voice annotations, icons, speech interfaces, audio feedback, visual display, assistive technology, voice biometric

and voice-based data entry, Modern Voice recognition and touchscreens. Similarly, in the agriculture sector researchers have proposed Visual Imagery mnemonic, complementing mnemonic, Passfaces, eboards, mobile phones, iconic interface, speech-based interaction in native languages, Dialogue Interaction and Non-Linguistic Graphics.

In the e-commerce sector, Text free UI is recommended. Researchers have found that the task completion rate is better in case of rich multimedia. Voice is Effective in term of Accuracy & Task completion time**.** Photographic, audio, images work better for digital representation of money. Spoken dialog system and speech work better. AUIs have been designed specifically adapted for developing countries for providing universal access to both illiterate and semi-literate populations. Icon base and touch input facilities are recommended.

In the education sector, researchers have found that Multimodal interfaces are effective for semi-illiterate users. Video plus audio is the most viable solution for illiterates. Video and touch screen kiosk is effective for illiterate users. Touch screen, text, audio, visuals icons and speech technology are effective for illiterate users. Metaphoric icons, idiomatic icons can benefit semi-illiterate users by significantly affecting users' intrinsic and extrinsic motivation. Text free UI is strongly recommended while voice feedback and abstracted graphics is also good for illiterates & semi-illiterate. Audio Clips are effective for the target population. Iconic Pictures are recommended for patents and voice function is also effective for illiterates. Researchers have also recommended Automatic Speech Recognition (ASR) and Automatic Handwriting Recognition (AHR) techniques.

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