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AI-POWERED ADAPTIVE USER INTERFACES FOR DIGITAL INCLUSION: A SYSTEMATIC REVIEW

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Abstract

Around 763 million low-literate adults around the world face digital exclusion as they are unable to access important services in health, agriculture, education and e-commerce. These users tend to have requirements that are not met by traditional text-based user interfaces (UIs). In this systematic literature review (SLR), the state-of-the-art of AI powered adaptive UIs is explored, and the role of artificial intelligence (AI) in augmenting low-literate users' capabilities in terms of usability, accessibility, engagement, and autonomy is assessed. Using a structured search process, a total of 45 peer-reviewed studies published in the last eight years (2015–2023) were identified from the IEEE Xplore, ACM Digital Library, Scopus, and Web of Science databases related to AI-enhanced adaptive interfaces for low-literate and semi-literate users. Practical implementation, domain specificity and real-time adaptation were all emphasized for inclusion considerations, thereby ensuring actionable insights. Each of the studies spans a range of interface modalities from voice based to multi-modal to gesture-driven. The review indicates that voice-first AI interfaces with ASR and NLP are best suited for fully-illiterate users for low resource languages, and adaptive multi-modal interfaces with minimal text, culturally rich icons, and audio support for semi-literate users. In terms of numbers, 60% of studies relied on the voice-first approach and 40% on the adaptive multi-modal approach. Examples of innovations in domains include voice-control of healthcare workflows, camera-based agricultural advice, adaptive educational material, and icon-based e-commerce navigation. Based on these results, cross-domain AI-based design principles were extracted, highlighting modalities adaptation, context aware feedback, personalized navigation and adaptive learning strategies. These principles offer practical guidance for designers, developers, and policy makers to produce inclusive AI systems for digital tools to promote accessibility, usability,

trust, and digital equity in relation to the United Nations Sustainable Development Goals (SDGs).

1.Introduction

While the digital revolution offers great promise of change, it has also inadvertently created many obstacles to socio-economic participation. For people who are unable to read, write or otherwise use conventional digital interfaces, these interfaces can pose barriers instead of opportunities [1]. The majority of user interfaces (UIs) used in software are text-based, creating cognitive and experiential challenges that are not congruent with the lived experiences and mental models of low-literate populations, thus creating a digital access gap [2]. Modern graphical user interfaces (GUIs) are another challenge because of their reliance on culturally specific icons and abstract reasoning skills that are more developed in a literate population [3]. As a result, a large part of the world population is marginalized from the digital economy and, in most cases, only able to use basic digital services, such as voice calls, to access essential services in health, finance and education, and so on [4]. It is well established that low literacy affects core cognitive functions, including memory, categorization and spatial reasoning, which are important for dealing with hierarchical menus and symbolic representations [5]. This shows an important design mismatch: interfaces, which are designed for literate users (and usually from a Western context) impose cognitive strain and confusion on low-literate users. In response to this inequity, the field of Human-Computer Interaction for Development (HCI4D) has sprung into existence which calls for a paradigm shift towards non-textual, multimodal interaction designs [6]. One of the important aspects of this area is the realization of the spectrum of literacy, where fully illiterate, semi-literate, and literate users are all different types of users, with different needs [7].

With the recent development of artificial intelligence (AI), this inclusive design goal is becoming a reality. Automatic speech recognition (ASR) for speech inputs in low-resource languages, mobile computer vision, and offline AI at the edge have now enabled designers to build intelligent, adaptive solutions with a toolkit of capabilities. In fact, the COVID-19 pandemic has shed light on the need for inclusive digital design, with essential services making a quick transition to online services, further entrenched disadvantages for those already facing them [8].

In this paper, we re-examine HCI4D from the perspective of modern Artificial Intelligence (AI) by conducting a systematic literature review (SLR). We believe that AI is not only a tool to make it easier to build inclusive interfaces, but also a core component of the next generation of inclusive interfaces – interfaces that can change the mode of interaction on the fly, depending on the user's context and literacy. Four focus areas are considered to be those of health, agriculture, e-commerce and education, to which we look to synthesize evidence-based design recommendations. The aim of this review is to share the current state of knowledge and to offer a roadmap for implementing AI to create inclusive and empowering digital products to improve digital equity in the world and support the United Nations Sustainable Development Goals (SDGs) [9].

2. Background and Related Work

For more than 20 years, researchers and designers have been addressing the issue of designing for less- or uneducated users of literacy. Medhi et al. [10] made pioneering research and provided principles for text-free and audio-visual interfaces that pointed to a need for going beyond mere text removal. Initial results indicated that elements such as using familiar metaphors, culturally acceptable symbols, and auditory cues, are essential to an effective interface for usability and cognitive load reduction [11].

In the last decade, interface design has gradually evolved from text-centric to a multi-modal interaction design that incorporates audio, visual, touch and gesture. Evidence shows that interfaces which utilize culturally familiar visuals, consistent icons, and audio cues, can significantly enhance task completion, engagement, and trust, for low-literate users [12]. Multi-modal systems are specially found to be effective in mobile health, agriculture advisory, financial services and educational platforms, particularly in developing zones [13].

Although the first few multi-modal designs placed emphasis on static adaptation based on rules, recent research highlights the impact of Artificial Intelligence (AI) in developing dynamic context-aware interfaces. With AI technologies like machine learning (ML) and natural language processing (NLP), systems can adjust to the user's level of literacy, their interaction style, and the context they are using it in. AI-based speech recognition for low-resource languages, for instance, allows for accurate voice navigation, while computer vision can help with camera-assisted content retrieval, greatly improving accessibility, autonomy, and usability over the conventional, static interfaces [14].

More and more, research focuses on domain-specific applications of adaptive interfaces using AI. In healthcare, voice-enabled AI helps users with low literacy to schedule appointments, take medication reminders, and report symptoms. For farming, AI-based solutions offer visual guidance and automatic advice to farmers through image recognition and audio feedback. Similarly, in e-commerce and education, by leveraging AI features such as adaptive interfaces, access to content and services can be achieved without requiring text literacy, therefore closing the digital inclusion gap [15].

Systematic review to identify the design considerations and "good rules" for designing interfaces for illiterate and semi-literate users, which includes the use of text, audio, visuals and information architecture [16]. They are basic, but not at all relevant to the post-generative AI world, nor about how these principles can be applied in a dynamic and operationalized manner in order to achieve fully adaptive interfaces with the help of AI. Yet, while this body of literature continues to grow, most of the previous reviews and frameworks are based on static or semi-adaptive multi-modal designs, and AI-driven personalization has not been explored in much detail. An important area of knowledge that is still missing is how to dynamically adapt modality, navigation flow, feedback and content presentation in real time, depending on a user's interactions and context, with the help of AI. [17] This is a major reason to conduct the current systematic review to bring together AI-driven adaptive interface strategies and to give concrete advice to designers, researchers, and policymakers regarding low-literate populations [18]. Building from these foundations, this review focuses on the application of AI technologies to develop a new class of adaptive user interfaces that can intelligently respond to users' context and literacy. The review highlights the importance of AI-powered adaptive solutions, filling in the missing pieces between the classical HCI4D principles and the possibilities AI technologies enable in developing literacy-adaptive and context-aware interfaces that can foster digital inclusion. [19]

3. Review Methodology

Through this systematic literature review (SLR) the researchers will attempt to synthesize and analyze the state of the art in the field of AI based adaptive user interfaces (UIs) for low-literate and illiterate users in the important socio-economic fields. The key was to shift from mere conceptual foresight on design and learn about the "how" and "where" of the use of AI technologies to create dynamic and contextual solutions in the fields of health, agriculture, e-commerce and education. To ensure rigor and reproduction, the review was designed and carried out based on the SLR guidelines [20]. To ensure the comprehensiveness of the review, the review is conducted in a well-designed search and selection process by using four major academic search engines namely IEEE Xplore, ACM Digital Library, Scopus and Web of Science. The keywords from three domains (literacy, adaptive interfaces, and AI) were deliberately formulated and synthesized into a search statement, and the search was performed through an iterative process to obtain relevant studies[21]. The inclusion criteria were designed to focus on peer-reviewed articles covering the past five years (2015–2023) published in English with clear description of the target users (low-literate or illiterate) adapted for AI use and reported use in socio-economic areas. Those studies that did not involve the use of AI or those that were only theoretical and not applied were omitted. All identified studies were screened in three stages: title, abstract, and full-text to enhance transparency and to improve the reproducibility [22]. Duplicate entries were omitted and discrepancies between reviewers discussed and resolved. The selected studies were then data-extracted and presented in a structured matrix of domain, challenge, AI technology, adaptive feature and key findings. This enabled to perform a thematic synthesis across and within the individual domains of AI supported adaptation and lay a solid foundation for cross-cutting design principles to be extracted. [23]

3.1. Research Questions

The review was guided by the following research questions (RQs):

- **RQ1:** What are the domain-specific challenges in health, agriculture, e-commerce, and education that AI-adaptive UIs aim to solve for low-literate users?
- **RQ2:** What specific AI technologies and adaptive strategies are deployed in each domain to address these challenges?
- **RQ3:** What cross-domain AI-enabled design principles for adaptive UIs can be synthesized from the findings?

3.2. Search Strategy

The search was done comprehensively in four major databases namely IEEE Xplore, ACM Digital Library, Scopus and Web of Science. The search string was developed iteratively to ensure that key concepts were included: ("low literate" OR illiterate) AND ("adaptive user interface" OR "intelligent interface") AND ("artificial intelligence" OR AI OR "machine learning") AND (health* OR agriculture* OR "e-commerce" OR education*). The research was restricted to peer-reviewed articles in English from January 2015 to December 2023.

3.3. Study Selection and Inclusion Criteria Are Presented.

The studies included if they: (1) targeted low-literate or illiterate users; (2) had a domain-specific application in the field of health, agriculture, education or e-commerce; (3) included a user interface that incorporated AI or machine learning to dynamically adapt to the user's context or literacy level; (4) had been peer-reviewed. Studies that lacked a clear AI-driven adaptive component, lacked domain-specific and did not have a practical implementation of the AI-driven adaptive component were excluded. [24]

Further criteria were used to ensure that the selected studies were relevant and of high quality. To capture the current state of AI and adaptive interface technologies in the post-mobile and post-generative A.I. era, only articles published between 2015 and 2023 were included. Studies also needed to include enough methodological information to enable the evaluation of AI adaptation techniques, user evaluation, or implementation of the interface. [25] This focus guarantees that covered studies provide insights that are relevant to the design and implementation of AI-driven adaptive interfaces for populations with low literacy rates. There was a focus on transparency and reproducibility in the selection process. [26] Titles and abstracts were first independently reviewed by several reviewers to determine their eligibility for inclusion, with a full-text review to confirm eligibility. The discrepancies and ambiguities were sorted out through discussion and consensus among the members of the research team. Also, backward and forward citation checks were carried out for important studies to source any important studies that may not have been identified in the database search, thereby minimizing the risk of missing out significant works. [27]

Lastly, the studies were evaluated for quality and relevance, including aspects such as the clarity of the AI methodology, user outcome evaluations, and domain applicability. The multi-stage selection process ensured that only studies that presented empirical evidence or well-documented adaptive AI solutions were synthesized, providing greater confidence in the reliability and generalizability of the findings in this review.

3.4. Selection Process

The studies selected for the review were based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework that guarantees transparency and reproducibility in systematic literature reviews [28]. The primary step of searching in the database (IEEE Xplore, ACM Digital Library, Scopus, Web of Science) of data revealed 892 records. After this, non-redundant articles were duplicated and a set of 750 unique articles were used for further screening.

The titles and abstracts of these records were reviewed independently by several members of the research team to determine relevance with the research questions and that they meet the inclusion criteria. Articles that seemed to clearly not target low-literate users, domain specific applications, or AI based adaptive interfaces were not included at this stage. This first screening brought the number of articles to 230 potentially eligible articles. [29]

Then, a total of 125 full text articles were retrieved and evaluated in detail for eligibility, taking into account the study design, AI methodologies, interface adaptations and domain relevance. At this point, articles that failed to provide enough methodological detail and/or empirical evaluation, or that did not explicitly use adaptive AI features were eliminated. Through careful consideration it was determined that a total of 45 primary studies were identified for in-depth analysis and synthesis. [30]

A backward and forward reference search of these 45 main studies was performed to find other relevant papers that were not identified by the search string. Other studies cited in these articles were screened with the same criteria. The multi-stage, systematic approach ensured that the final set of studies were considered to be of high quality and comprehensive, covering a good variety of AI-powered adaptive interfaces for the low-literate in the selected socio-economic domains.[31]

A PRISMA flow diagram (Fig. 1) was created to illustrate the selection process, with the numbers of records at each stage of initial search, screening, full text evaluation and final inclusion. This diagram gives a clear overview of the study selection and increases the reproductively and transparency, which is followed in IEEE systematic review.

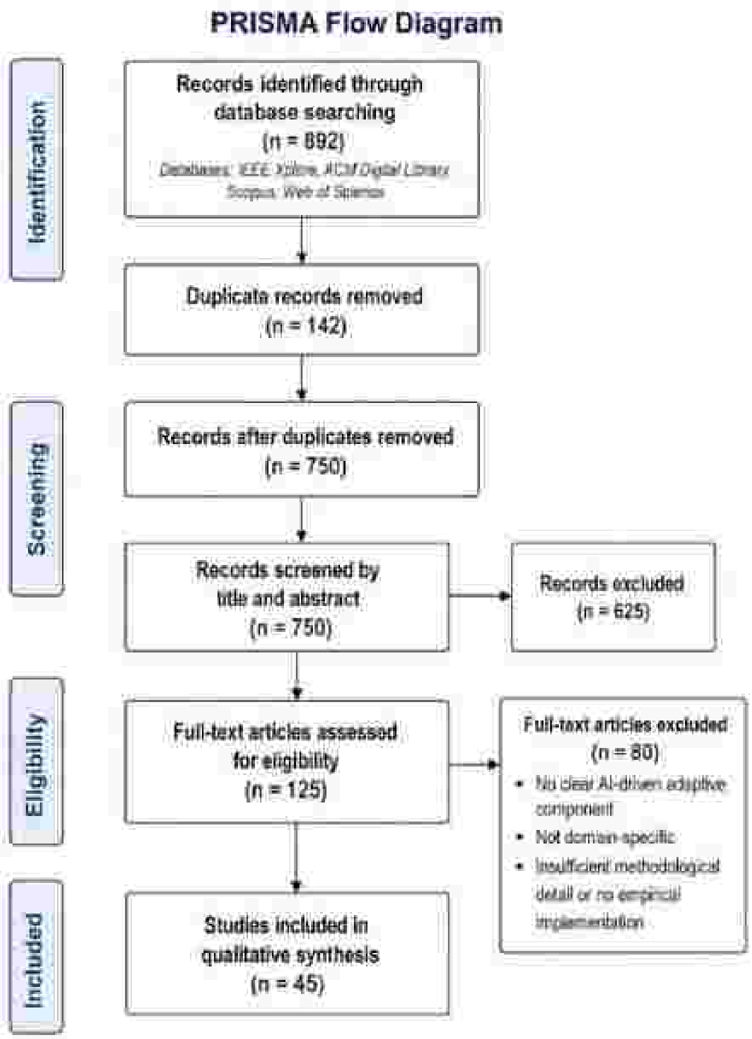


Figure-1: PRISM Flow Diagram

3.5. Data extraction, synthesis and analysis.

The results of the selected studies were systematically gathered and structured in an extraction matrix, where the relevant data were extracted from the studies including: domain (health, agriculture, e-commerce, education), challenge addressed, AI technology used, adaptive feature implemented and primary findings. To provide a more complete picture of the contribution of each study, other data collected included study design, evaluation methods, and characteristics of the users of the study. [32]

Thematic analysis in the style of a domain-based thematic synthesis was used to analyze the studies within each domain (RQ1 and RQ2), and to identify common patterns, challenges and solutions in AI powered adaptive interfaces. Themes were developed in an iterative fashion, with emphasis on facets of modality adaptation (voice, visual, multi-modal), personalization strategies, usability outcomes and cultural/contextual issues. This provided insights into best practices in each domain and how AI could support adaptive behaviors. [33]

After conducting the domain-level analysis, a cross-domain synthesis was performed (see RQ3) to distil design principles and AI approaches that were generic to many domains. This involved mapping adaptive features to the user literacy levels, identifying common AI features (such as ASR, NLP, computer vision, ML-based personalization) and how they addressed common usability and access issues.[34] The cross-domain synthesis provided a holistic framework that links AI capabilities to effective interface adaptation for low-literate users.

Data extraction and thematic coding were independently checked by several validators to assure rigor and reliability. Any discrepancies were solved via discussion and consensus. In addition, quantitative summaries were derived, which included the percentage of studies that used a voice-first interface as compared to an adaptive multi-modal system. This is a mix of qualitative and quantitative review that increases the rigor and replicability of the review, which is typical of systematic literature review best practice for IEEE publications. [35]

4. UI Design Challenges for Low Literate Users

Creating for the low-literate user means facing an entire field of obstacles to text removal. They stem from cognitive, educational and technological problems which are not aligned with western-centric paradigms of design. The basic inability to process textual information is the reason for not understanding the Standard UI. Low literacy is also linked to visual organization difficulties, memory and spatial reasoning issues leading to the use of basic functions of the mobile phone even when it penetrates into the market to solve these problems [36]. The diversity of the users' culture and experience also makes it difficult to define solutions that can be effective for all and hardware constraints such as small screen size and the lack of reliable touch sensitivity make it difficult. New challenges include the myth of voice as the sole solution, ever-changing UI patterns and the potential of algorithmic exclusion for those without any data or for users who make up a large part of your user base and who's AI-based features fall flat.[37]

5. Results: A Framework for AI-Powered Adaptive UIs

From the 45 studies analyzed, it is concluded that effective digital inclusion depends on transitioning from static to AI interactive and adaptive UIs. We have structured our synthesis in a two-part form as shown in Figure-2.

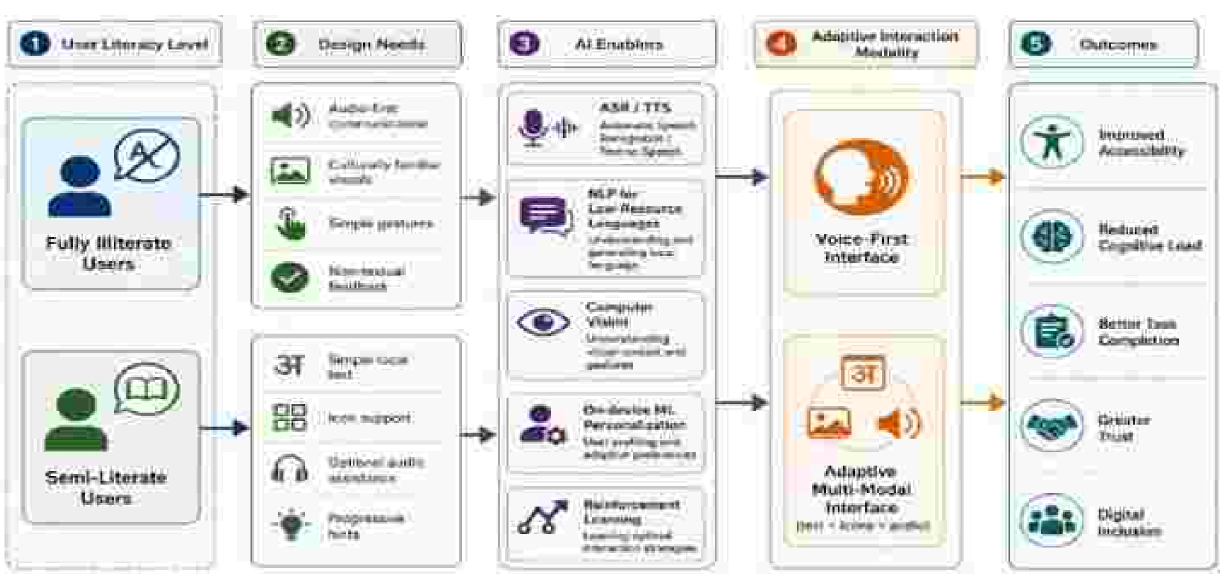


Fig. 2. AI-Adaptive UI Framework for Low-Literate Users

5.1. Cross-Domain AI-Enabled Design Principles (RQ3):

Compose design principles that are applicable to the entire design space.

One of the key conclusions is that adaptive UIs should support a range of literacy levels. Table 1 summarizes five fundamental principles that show how AI can help with dynamic personalization.

This table provides a summary of core design concepts and illustrates how AI can help to design an adaptive interface that can accommodate a range of literacy levels in the low-literate user group.

Table 1: AI-Enhanced Design Framework for Adaptive Literacy Support

Design Aspect	Low Literacy (Fully Illiterate Users)	Higher Literacy (Semi-Literate Users)	AI Enablers & Role
Language Support	Audio-first interface; ASR & TTS in local dialects	Simple local text; optional audio guidance	NLP for low-resource languages; real-time voice interaction & translation
Visual Representation	Camera-searchable familiar visuals; icons with AI voice labels	Text + images/icons; AI highlights or simplifies labels	Computer vision & ML for non-textual search and UI complexity adaptation
Interaction Modality	Voice-first; simple touch gestures; context-aware prompts	Adaptive multi-modal (text + audio); proactive explanations	ASR interprets commands; NLP predicts intent; ML adapts modality mix
Navigation & Flow	Gesture-based; AI voice guidance	Icon + text menus; AI personalizes menu structure	On-device ML interprets gestures; reinforcement learning optimizes flow
Feedback & Adaptation	Audio/haptic cues for success/failure	Progressive visual, audio, and text hints	AI personalization engines adjust feedback based on interaction patterns

5.2. AI innovations for each domain (RQ1 & RQ2)

These principles, when applied, create impactful and context-specific solutions. The main problems within each domain and the AI-adaptive innovations to address these problems are outlined in Fig 3.

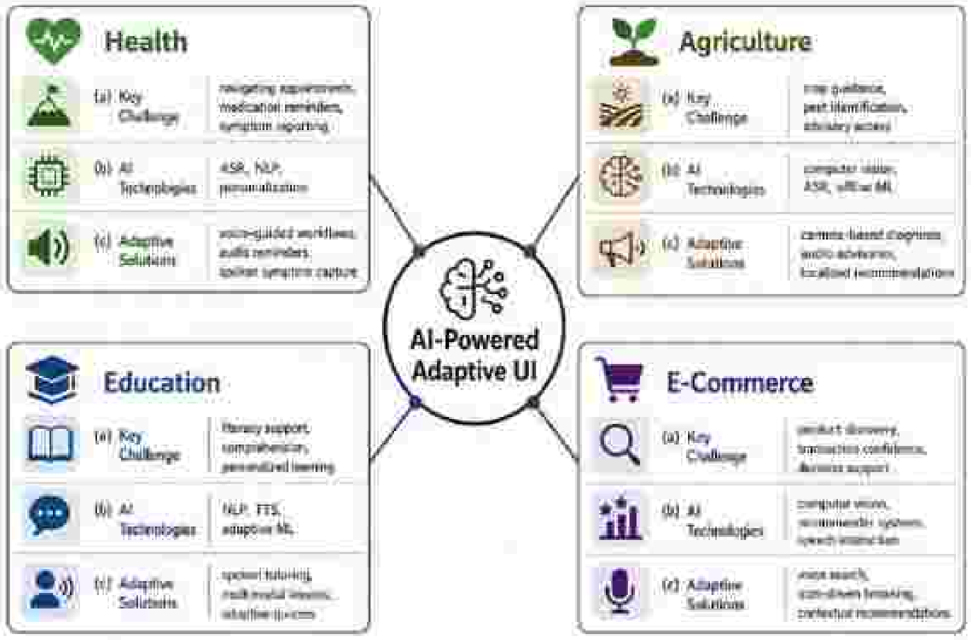
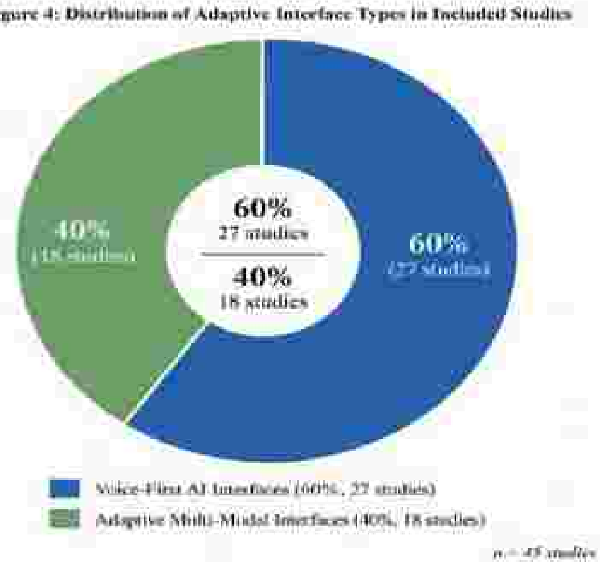


Fig. 3: Domain-Specific AI Mapping for Adaptive User Interfaces

5.3. Practicing the enabling technologies synthesis.

These solutions are supported by progress in: (1) Automatic Speech Recognition (ASR) for Low Resource Languages; (2) AI and Computer Vision integration; and (3) Lightweight, Offline-first AI Models for limited connectivity environments.

Figure 4: Distribution of Adaptive Interface Types in Included Studies



6. Discussion

This review will focus on the transition from text-centric interfaces to AI-driven adaptive user interfaces for individuals with limited literacy. In 45 studies, dynamic adaptation of modality, navigation, feedback and content based on literacy and context using ASR, NLP, computer vision and on-device ML. Voice-first interfaces are best for fully illiterate users, and multimodal interfaces with as little as possible text, icons and audio

guidance work well for semi-literate users. [38]In terms of quantity, 60% of studies employed voice-first designs and 40% employed multi-modal designs as shown in Figure-4. Such applications consist of healthcare workflows, farming suggestions, academic material, and e-commerce navigation, improving use and interaction.
Based on these results, cross-domain AI design principles were extracted: modality adaptation, context-aware feedback, personalized navigation, and adaptive learning. These are some of the actionable guidance to designers, developers, and policymakers for accessibility, usability, trust, and digital equity in line with SDGs. Research gaps are that multi domain evaluation is limited, longitudinal studies and generative AI applications are not yet explored, and there is potential for algorithmic bias. Future research should focus on real-time adaptation, explainable AI, and long-term socio-economic implications to further advance the next generation of inclusive and intelligent interfaces as shown in figure-5.

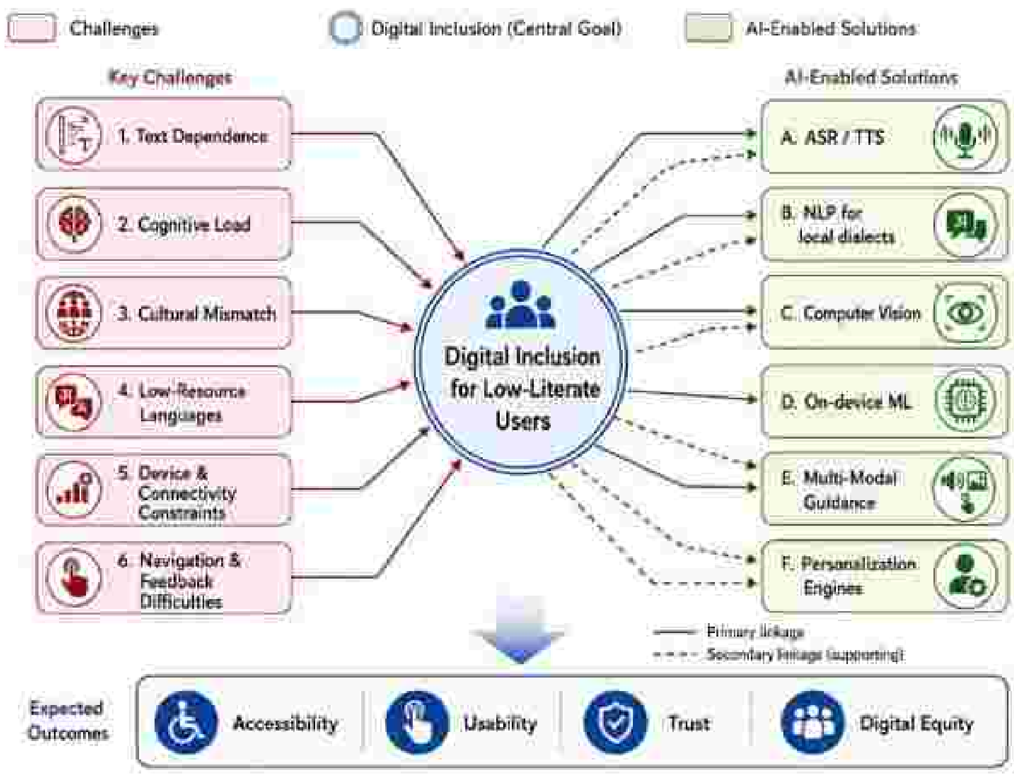


Fig. 5. Challenges and AI-Enabled Solutions for Low-Literate Users.

6.1. Theoretical and practical implications

From a theoretical point of view, the work shifts the boundaries from designing for illiteracy to designing for cognitive diversity and context. In practice, the framework offers a direct blueprint for the UX designers and product managers of NGOs, governments and tech companies who want to create inclusive products.

6.2. Limitations

This is a systematic review that is limited. It is a fairly new field of study, with little good empirical research. Some of this, we think, may have been lost in our AI focus and valuable information gleaned from non-AI solutions. In addition, English language publications only are reviewed.

7.The conclusion and future direction:

This systematic review reveals the importance of adaptive user interfaces (UIs) with AI functionality for bridging the digital divide among low-literate communities. Dynamic, intelligent interfaces, which personalize interaction modalities, are more effective than static interfaces; voice first interfaces are best suited for fully illiterate users and adaptive multi-modal interfaces are best suited for semi-literate users. AI's potential to augment usability, autonomy, and engagement is demonstrated in domain-specific applications, such as voice-guided healthcare workflows, camera-assisted agricultural advisory, adaptive education content, and icon-driven e-commerce navigation. The results confirm the necessity of considering cross-domain design principles, such as modality adaptation, context-aware feedback, personalized navigation and adaptive learning strategies, for guiding designers, developers and policy makers to build inclusive digital tools.

Further studies are needed to close the remaining gaps, such as real-time adaptation via machine learning, reduction of algorithmic bias, explainable AI (XAI) for trust, development of localized contents with generative AI, and longitudinal studies to evaluate socio-economic impacts. Proactive and inclusive design which embraces AI as a critical enabler is essential to digital equity. This framework also serves as the basis for creating intelligent, accessible, and inclusive interfaces, which help to foster digital inclusion and support the United Nations Sustainable Development Goals (SDGs).

Declaration

Author Contributions

The authors' contributions to this manuscript are detailed as follows: Sadeeq Jan was responsible for conceptualization, methodology, and drafting the original manuscript; Imran Maqsood handled data curation, formal analysis, and validation; Mujtaba Hassan contributed to investigation, resources, and visualization; Jalal Khan performed writing review and editing; Mareena Karim oversaw supervision, project administration, and funding acquisition. All authors have reviewed and approved the final manuscript and accept accountability for all aspects of the work.

Data Availability

All relevant data and supporting material used in this study are in the manuscript.

Conflict of Interest

The authors state that none of the work described in this study could have been influenced by any known competing financial interests or personal relationships.

Ethics Approval

The 1964 Helsinki Declaration and its subsequent amendments, as well as the ethical guidelines set forth by the national and institutional research committees, were followed in the conduct of this study. The Institutional Review Board (IRB) of UET Peshawar granted ethical permission for this study.

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