Highlights

User-Centred Design with End Users from Low Socioeconomic Backgrounds: A Case Study with Fisherfolk in Bangladesh

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- A full UCD cycle with end users from low socioeconomic backgrounds
- A set of specified requirements for several digital applications
- A set of developed personas to represent the end users
- Two application prototypes
- A set of guidelines for research and development with similar end-users
- General recommendations on UCD with diverse end users

User-Centred Design with End Users from Low Socioeconomic Backgrounds: A Case Study with Fisherfolk in Bangladesh

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Abstract

Context: User-Centred Design (UCD) advocates for high user engagement in the designing and developing of applications. Since applications are developed based on end-user expectations and address the context of use, UCD enhances the usability of the applications for the particular end users. However, UCD, with diverse end users, such as end users from low socioeconomic status, is challenging due to several reasons, such as communication, low digital literacy, and sensitivity. **Objectives:** This study aims to investigate the application of User-Centred Design (UCD) with low socio-economic status end-users in order to identify the challenges that emerge in this context and derive recommendations for more inclusive future design initiatives. **Method:** We followed a research through design approach. As part of the process, we surveyed 520 fisherfolk in Bangladesh, and conducted 16 focus group discussions to understand the context of use and to specify the requirements for several software applications, and conducted eight workshops for prototype development. **Results:** In this article, we present our experience of UCD with fisherfolk in Bangladesh, representing low socioeconomic status. We documented requirements for multiple software applications, developed personas to represent the end users, and iteratively designed two application prototypes through interactive workshops. **Conclusion:** Based on our experience, we recommend guidelines for future developers who intend to develop software with fisherfolk in Bangladesh, as well as for researchers and developers who plan to work with diverse end users.

Keywords: User Centred Design, Requirements, Persona, Prototype

1. Introduction

User-Centred Design (UCD) is an iterative process of design and development ensuring a better understanding of end users' characteristics, needs, and expectations [1]. UCD advocates for higher involvement of the end-users in four suggested phases - understanding the context of use, specifying requirements, developing design solutions, and evaluating those. UCD offers many benefits, including higher chances of designs meeting end users' expectations and requirements, less possibility of human errors since designs are developed for specific contexts, higher empathy between the developers and the end users, and a better understanding of diverse cultures and human values leading to developing sustainable business solutions [2, 3]. Understanding the context and developing empathy is particularly crucial for end users with diverse characteristics, such as the elderly, those with low digital literacy, end users from low socio-economic status, different cultural contexts, and so on. Diverse end users are very different from most software engineers; as such, understanding them is crucial to developing empathy [4]. However, in reality, conducting UCD with diverse end users is challenging, as end-user participation through conventional user research methods (e.g., surveys, interviews, focus groups, brainstorming) is affected by the sensitivity of the end users. This article presents our exploratory research to follow UCD with one diverse end-user group: low socioeconomic status population represented by fisherfolk in Bangladesh.

Bangladesh is a developing country that is home to thousands of rivers and has the Bay of Bengal on one side of the country. Over 18 million people in Bangladesh directly or indirectly earn their livelihood from fishing, and collectively are referred to as 'fisherfolk' [5]. The majority of the fisherfolk in Bangladesh belong to low socio-economic status, and as a result, they get very limited opportunities for formal education. This has led to both low literacy and very low to almost no digital literacy in this community. With the extensive digital transformation goals of the government and the availability of cheaper digital devices in the local markets, many fisherfolk now have access to digital technology. However, most software applications on those digital devices become unusable for them as those are not designed keeping their diverse user characteristics and needs in mind. They need

different software customized to serve their purposes. The software should be designed following a UCD process involving them to ensure their unique needs, expectations, and requirements are understood and met, to align with their level of digital literacy, and to ensure a user-friendly interface. This approach is essential for encouraging their adoption of the software. However, UCD with fisherfolk in Bangladesh is challenging for several reasons [6, 7]. These include: 1) **Communication**- they mostly live in remote rural locations where telecommunications services remain limited, and 2) **Low digital literacy and Sensitivity**- livelihood under extreme conditions, such as natural calamities, high risk, and exploitation, make them very hesitant to share information.

As part of our ongoing research on a large Information and Communication Technology for Development (ICT4D) program, we have successfully developed a trusting relationship with the representatives of the fisherfolk community in Bangladesh as well as with local volunteers [8, 6]. This ICT4D program is a multi-year, interdisciplinary research and development initiative focused on supporting marginalized communities in Bangladesh through participatory and digitally enabled interventions. The program aims to improve livelihoods, enhance climate resilience, and strengthen access to information and services by co-designing contextually appropriate digital solutions with community members. A core emphasis of the initiative is on participatory engagement, local capacity building, and fostering community ownership to ensure the long-term sustainability of developed solutions.

The program comprises multiple interrelated projects addressing domains such as livelihood support, disaster preparedness, information access, and social inclusion. The present study contributes to this broader initiative by applying a UCD approach to engage fisherfolk in understanding their needs, specifying requirements, and co-developing prototype applications. In this way, the UCD work reported in this paper forms part of a larger development strategy that seeks to translate participatory research into practical, scalable digital interventions for vulnerable populations.

Around 80% of fisherfolk engaged in the program possess mobile phones; however, around 40% of them need some assistance to use those devices [6]. We followed the UCD process to understand the expectations, needs, and requirements of fisherfolk in Bangladesh to develop different digital applications. To understand the context of use, their characteristics, digital literacy, livelihood practice, challenges, expectations, and needs, we conducted a broad-scale survey and 16 focus groups at two different locations in

Bangladesh. Based on the understanding we specified the requirements for multiple software and designed prototypes. We conducted eight workshops to evaluate the prototypes. As part of the UCD process, we also developed personas, a user model of the fisherfolk as end users, documented requirements of multiple digital applications, and developed two evolutionary prototypes that we refined with them.

Our findings serve as an initial guideline to help software developers better understand the ICT needs of fisherfolk in Bangladesh as end users and to **specify their requirements**. Moreover, the developed **personas** can be used to design and develop software for fisherfolk in the future e.g. access to fishing information, resources, government services, etc [8]. Based on our experience with UCD among fisherfolk in Bangladesh, we propose several **guidelines for research and development with similar end-users**, such as fisherfolk. We also present more **general recommendations** on how UCD should be planned and conducted with diverse end users of **varying socioeconomic status**. These recommendations will guide future researchers and developers in planning user research with similarly disadvantaged communities.

It is noted that partial survey results (319 responses) and a tacit knowledge transfer prototype were discussed in our previous publication [6]. However, this article reports the analysis of a full survey (520 responses), focus groups, and workshops. Moreover, this article discusses the design and development of two different application prototypes.

The rest of the article is organized as follows: Section 2 presents some background on UCD concepts and existing literature on research with fisherfolk in Bangladesh, Section 3 describes the survey, focus group and workshop designs, Section 4 presents the findings of UCD process in each phase, Section 5 describes trustworthiness and limitations of the research, Section **??** discusses the implications of the research, Section 7 presents UCD guidelines based on our findings and finally Section 8 concludes the article with future research directions.

2. Background

In this section, we outline key UCD concepts, focusing on user modeling with personas and prototyping, introduce the Bangladeshi fisherfolk community from the literature, and review challenges in applying UCD to develop digital solutions for them.

2.1. User-Centred Design

User-Centred Design (UCD) is a philosophy that ensures end-user participation in the design process [9], incorporating principles and methods to guide design decisions. Introduced and refined by Donald Norman in the 1980s [10, 1], UCD originated from human-computer interaction (HCI), and places end users at the center of software development [11]. Involvement of users fosters ownership, satisfaction, and adoption [2, 3]. Guiding principles include Norman's seven principles [1], Shneiderman's eight golden rules [12], and Nielsen's heuristics [13, 14], emphasizing simplicity, visibility, learnability, and clear action-feedback mapping [9]. UCD typically involves four steps: understanding context, specifying requirements, designing solutions, and evaluating against requirements. ISO-9241-210 provides standards for UCD, defining these phases and recommending iterative feedback.

Understanding the context of use involves studying factors such as the physical and social environment, user abilities, preferences, expectations, and cultural influences to identify key influences and answer where, how, and why users engage with the application. Based on this understanding, requirements are specified using modeling techniques like use case scenarios, user stories, and personas. Design solutions are iteratively developed and reviewed by end users, ranging from sketches to interactive mid- or high-fidelity prototypes, with the prototype type determined by user preferences and engagement.

2.1.1. User Modeling: Persona

A persona is a fictional character representing a specific group of real end users [15], typically capturing their background, goals, interests, and frustrations [16] and often presented with names, images, and demographic details [17]. Although no standard method exists for developing personas, researchers have proposed various approaches, generally grouped into qualitative, quantitative, and mixed methods [18].

The qualitative methods of developing personas rely on exploratory qualitative research on end-users with a medium sample size, involving end-users in all design stages, emphasizing and analyzing their behaviors, and developing personas with multiple iterations [19]. Some examples of qualitative methods include 1. the UCD method (collecting information through user research and evaluating personas in all development stages), 2. the eliciting and visualizing differences between the trust method (analyzing the trust import behaviors of the users and contextualizing personas), and 3. Cooper's version of the persona technique involves five stages: identify user variables,

envision problems, brainstorm, set persona expectations, and perform requirement analysis [20, 21, 22].

The quantitative methods of persona development center on leveraging a large pool of user data gathered from different sources. The data collection method usually includes surveys, online data sources, and algorithmic analysis [23]. In this process, core users are identified as the primary persona, and they are extracted from a pool of multiple personas. These personas, derived through quantitative analysis, are valuable tools for shaping service designs within organizations [24]. Some examples of quantitative methods include the Persona-centric Service Design method and the Hanako method [22, 25, 26].

The mixed methods of persona development integrate several elements of the quantitative and qualitative approaches, and they frequently target particular user groups, such as age-related user groups [27]. Despite their differences, all persona development methods serve the purpose of using personas, and enhance personas with elements such as name, photo, goals, and so on.

Nielsen (2004) proposed a ten-step mixed-method process for persona development [28], grounded in three areas: data material, engagement in persona descriptions, and organizational buy-in. The process begins with gathering data from multiple sources to understand target end users and selecting appropriate methods for data collection and storage. Afterward, an initial hypothesis about user groups is formed and refined through data analysis. The data is then verified—considered the most challenging step—as it requires checking whether it supports the hypothesized needs, attitudes, and values of different user groups. Emerging patterns allow users to be grouped and personas constructed with defined bodies, backgrounds, and traits. These personas are then placed in specific situations and validated with real users, initiating scenario creation. Once validated, the personas are shared with organizations to support developers, and a narrative or scenario is created for each persona, providing context and enabling ongoing refinement.

2.1.2. Design Solution: Prototypes

A prototype is an early design simulating an application's look and function [29], providing a tangible artifact to facilitate discussion and feedback from end-users and developers. Camburn et al. identify four objectives of prototyping: refinement, communication, exploration, and active learning

[30]. Prototypes can be iterative, gradually refining a design, or parallel, comparing multiple designs [31]. Evolutionary prototyping iteratively transitions to the final product [32], while competitive prototyping has separate teams develop divergent solutions [33]. Prototypes often use a subset of requirements to balance accuracy and cost, known as relaxed requirement prototyping, reducing early-stage risk and refining requirements [34, 35, 36, 37]. Requirement selection must prioritize essentials to avoid adverse effects [38]. Low-fidelity prototypes help progress designs and gather conceptual feedback without focusing on details [39, 40].

2.2. Fisherfolk In Bangladesh

2.2.1. Livelihood

Literature on fisherfolk in Bangladesh shows extensive research on fishing locations and livelihood challenges, but few studies propose solutions. Research near the Brahmaputra River highlights fisherfolk's dependence on local investors ("Arotdar/Mahajan") for credit, and identifies challenges such as insufficient credit, poor marketing, lack of fishing knowledge and equipment, disturbances by extortionists and robbers, poverty, illiteracy, and child labor [41, 42]. Similar issues—low education, poor sanitation, inadequate housing, health problems, and low income—are reported near the Paira River [43]. Seasonal floodplain beels in northern Bangladesh support short-term fishing livelihoods, and income can be increased through measures like alternating rice-fish culture [44]. Jakariya et al. also propose a mobile application displaying fisherfolk vulnerability indices to aid policymakers in improving livelihoods and ensuring sustainable development [45].

2.2.2. Information Sharing Practices

Research on fisherfolk information-sharing in Bangladesh indicates a need to improve information services. Shuva et al. [46] reported that fisherfolk rely on family and friends for information and recommended changes to provide equal access, including better radio signals, mobile networks, and government services, noting that Bay of Bengal fisherfolk are information-poor due to illiteracy and poverty. Conversely, Salam and Arman found a small community on Kutubdia Island using the Internet for weather, fish locations, and maps [47]. Blanchard et al. [48] reported that weather information is often shared by word of mouth and suggested user-friendly online messages, noting growing Internet access. Barua et al. [49] recommended mass awareness cam-

paigns as effective for disaster risk reduction and early climate adaptation through broadcast information.

2.3. Challenges of UCD with Fiherfolk in Bangladesh

Like much of software engineering, UCD has adopted agile characteristics, with incrementally elicited requirements [50, 51], frequent end-user involvement, and iterative feedback [52]. Empirical studies also examined integrating UX design with agile development [53]. However, applying these practices in the Bangladeshi fisherfolk context presents challenges.

A major difficulty is the diverse linguistic landscape [6]. Fisherfolk speak various dialects, making communication and requirement elicitation challenging [54]. Since agile practices depend on continuous, clear communication, language barriers can cause misunderstandings. Translators or locally knowledgeable intermediaries are therefore important for accurate information exchange.

Another challenge concerns limited educational and technical skills. Many fisherfolk work in traditional occupations and may struggle to participate in requirement engineering. Software must accommodate low technical proficiency. Prior research identified varying digital literacy levels and recommended involving fisherfolk in incremental development—ideally as product owners in a scrum team [6]. However, this is difficult in practice, as additional digital literacy support is needed for meaningful participation.

Technical constraints also affect software development. Connectivity and infrastructure cannot be assumed in remote fishing areas [55], and many fisherfolk rely on low-end or non-smartphones [56]. Software must therefore be lightweight, device-compatible, and resilient to intermittent power.

Finally, understanding fisherfolk's operational context is essential for effective requirement engineering. Their socio-economic and environmental conditions differ significantly from urban settings [57]. High-engagement methods such as ethnographic research and participatory design can capture these realities, ensuring that solutions match community needs and support user acceptance and adoption.

2.4. Design and Development for Low Socio-Economic Status (SES) End Users

A growing body of research examines the design and development of interventions for low socio-economic status (SES) end users, delivered through web or mobile applications, Facebook, email, and similar platforms [58].

Most interventions aim to improve health, offering health-related or dietary guidance. In a review of e-health interventions for low SES groups, Al-Dhahir et al. found that involving users early in the design process can be time-consuming and costly, and more work is needed to determine the optimal stage for user involvement [58]. They also recommend drawing on behavioural theories and ensuring collaboration among researchers, developers, and end users throughout development, evaluation, and implementation.

Khan et al. similarly advocate an iterative user-centred design process. While "price" initially appeared important for healthy snack decisions, their evaluation showed that participants no longer considered price useful, underscoring the need for users to revisit and reassess requirements [59]. Regarding SES end-user involvement in health interventions, Radunz recommends clearly explaining the purpose and benefits of the intervention, presenting consent information in simple language, and keeping questionnaires short [60].

Faber et al. introduced an "Inclusive eHealth Guide," categorizing essential information for developers and health professionals into development, reach, adherence, evaluation, and implementation. Although the guide stresses usability and evaluation with the target audience, it remains high-level and does not specify how to follow the UCD cycle. Other studies (e.g., [61], [62], [63]) have assessed mobile applications for low SES communities, but their insights are limited to specific case studies and do not yield general UCD guidelines. Consequently, a dedicated guideline for the UCD process for low SES end users is needed.

3. Methodology

We reviewed different approaches of combining "Design" and "Research", and selected "Research Through Design" as most appropriate for this research [64, 65]. "Research Through Design" is a design activity that operates as research [64] and if replicated may not produce the same outcome as two designers may produce different designs for the same problem [65]. The selection of data collection strategy was guided by Denscombe's criteria of suitability, feasibility, and ethical considerations [66], which led to the selection of surveys and focus groups to understand the context of use and specify requirements, and workshops to evaluate designs with fisherfolk in Bangladesh. Moreover, the selection of data collection approaches was also guided by similar interventions reported in HCI research, which recommend

Figure 1: UCD Journey

that a communal approach is important as opposed to an individual approach followed in the Global North [67, 68].

The survey and focus group discussions were not designed towards particular software solutions; instead were aimed at understanding the needs and challenges. The software solutions were designed from the exploratory data collected from survey and focus group discussions and were evaluated in the workshops. The full journey is depicted in Figure 1 and detailed in the following subsections. Human research ethics approval was obtained from the relevant committee (Project ID: 35456) prior to data collection to ensure ethical compliance.

3.1. Survey

For the survey, clustered random sampling [66] was employed to select fisherfolk household members. This technique involves randomly selecting participants from naturally occurring groups or geographical areas, known as "clusters", with homogeneous characteristics [66]. In this case, the selected clusters were two districts with differentiated geographical characteristics, including Chadpur (downstream) and Kurigram (upstream).

The preliminary survey was conducted from 28 November to 14 December in 2021, with the fisherfolk. The survey questions included demographic and socioeconomic attributes, as well as access to and ownership of digital technology, information availability, and digital capacity. There were also questions around the most and least important issues communities experience in fishing to identify their challenges and future scopes for interventions (See Appendix). There were a total of 30 questions in the survey, four of which were open-ended. Local partner organizations played a crucial role in participant recruitment. Trained research assistants facilitated data collection, including providing explanatory statements, obtaining consent, reading

survey questions, and recording responses. The survey targeted fisherfolk household members from two districts, ensuring equal representation of men and women for a comprehensive gender perspective. In Bangladesh, men primarily engage in direct fishing activities from open water sources, whereas women are predominantly involved in various other aspects of the fisheries supply chain in Bangladesh [69]. It is noted that, for the ease of understanding as well as to ensure efficient exchange of information, the explanatory statements were simplified. This is in line with the suggestions of Radunz et al. [60]. The simplified explanatory statement script was reviewed and approved by the Human Research Ethics Committee.

3.2. Focus groups

Utilizing the survey findings around the primary challenges and key information sources within the fisherfolk community, we subsequently conducted focus groups from June to December in 2022, engaging fisherfolk household members from Chadpur and Kurigram districts. The survey gave us a landscape view of the demographics, roles, and challenges. The objective of the focus group was to explore the challenges the communities mentioned in the survey questions. Besides, the focus group also aimed to uncover the decision-making process, knowledge ownership, and the transfer process within the community. To ensure a range of perspectives, we formed four distinct groupings: young adult males (aged 18-35 years), young adult females, older adult males (aged 35 years and above), and older adult females. Purposive sampling [70] was employed to identify fisherfolk communities in those selected districts where researchers had access to the community to ensure a representative sample. Focus group discussions contained qualitative data. Similar to the surveys, the explanatory statements were simplified and approved by the Human Research Ethics Committee. The audio recordings of the focus group discussions were transcribed into Bangla text and then translated into English. The transcriptions and translations were performed by two research assistants, closely supervised by one of the authors.

3.3. Workshops

Workshops were conducted in July 2023, and September and October 2024 with groups of fisherfolk in the same two districts. The objective of the workshop was to understand community experiences with the prototype. Communities were asked to provide usability feedback as well as their experience with the interface and functionality of the prototype. It also aimed to

refine the prototype based on community reflections. The workshops were designed as free-from-discussion sessions where the prototypes were demonstrated to the participants either on mobile phones or simulators on laptops. Participants were given a description of the prototype application and a demonstration of major functionalities. The participants asked questions to clarify things and gave feedback during the demonstration. One developer, two research assistants and two community volunteers facilitated the sessions. The community volunteers were given a detailed demonstration of the prototype application before the session. During demonstrating each functionality, we asked specific questions such as "Can you tell us from the list what the price of "xyz" fish was yesterday?". The questions were asked not only to get feedback on the prototype but also to assess their understanding of the interface and functionality. The fisherfolk were grouped for the workshops as follows: adult males, adult females, a mixed group with adult males and females, and boat captains. We attempted to recruit the same participants for the workshops as the focus groups; however, this was not always possible.

3.4. Data Analysis

Qualitative data from the survey and focus group discussions were analyzed using content analysis [66]. The steps we followed while applying content analysis were (1) **Identifying the units of data:** Each response to the particular question being analyzed was considered a unit, (2) **Form categories:** The units of data were read multiple times and possible categories of responses were formed, (3) **Coding units with categories:** The units of data were then associated with a category, (4) **Analyse the text:** The categories were analyzed to find relationships. The full data coding is presented in Figure 2 (right side). For readability, we highlighted a snippet of the coding on the left side of Figure 2.

The quantitative data responses from the survey were stored in the "Kobo" platform. A quantitative analysis of the survey responses was conducted using the Kobo Toolbox and reported with descriptive statistics in this article. The quantitative data laid the foundation of our understanding of this particular cohort and helped differentiate among the roles/user groups within the fisherfolk community - such as boat captains, senior women fisherfolk, small fish business owners, and so on.

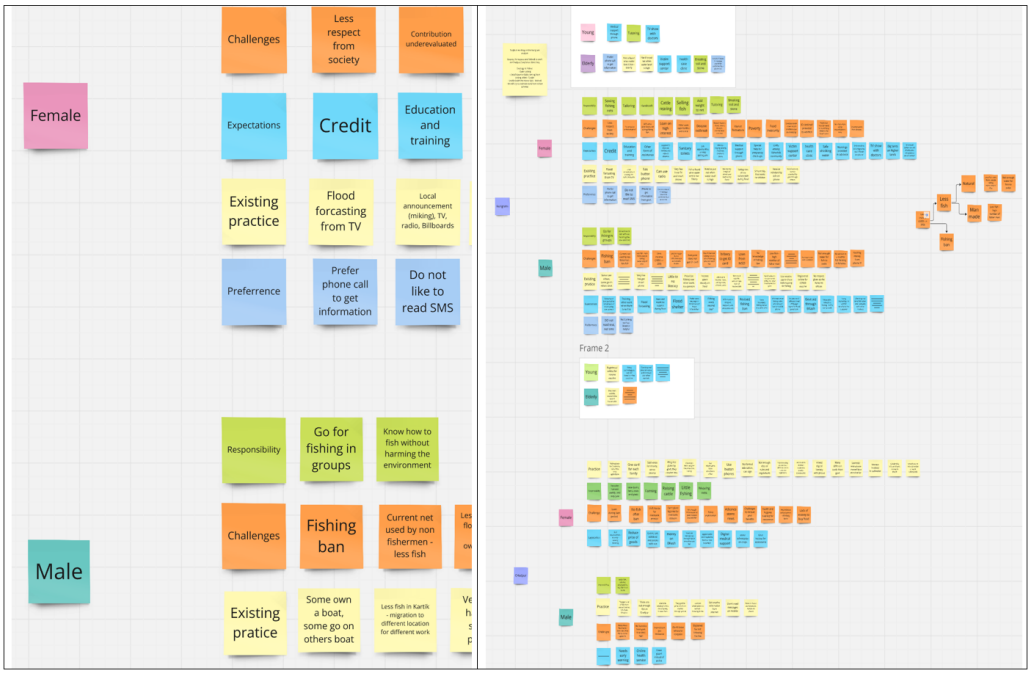

Figure 2: Left Side: A snippet of coding and grouping, Right Side: Full view of coding and grouping

3.5. Persona Development

We applied a mixed approach to developing a persona from the collected data, inspired by Jansen et al., who found that this method is the most robust form of persona development, combining the strengths of both quantitative and qualitative methods [23]. However, the authors also noted the time and cost challenges involved in the process. Since we conducted the research over almost four years and managed to collect many responses, we overcame the difficulties mentioned by the authors.

We followed Nielsen's ten-step [28] approach to develop personas. From the analysis of large survey data, we identified different stakeholders and got an initial idea of the different roles they play. We determined the user groups at this stage. The user groups were then verified and complemented in the subsequent focus group discussions, resulting in rich qualitative data. Based on the focus group data, we decided the number of personas needed for each identified user group. The persona descriptions were added mostly from qualitative data.

3.6. Prototype Development

From the understanding of the context of use, persona, and specified requirements, we developed prototypes. The objective of the prototype development was to communicate design ideas as well as to refine them together with the fisherfolk themselves. We developed evolutionary prototypes and adopted a collaborative approach to refine those together with the fisherfolk.

4. Results

We surveyed 520 fisherfolk, conducted 16 focus groups and eight workshops at two different locations in Bangladesh: Chadpur and Kurigram. The focus group size ranged from five to twelve participants, and the workshop size ranged from seven to thirteen participants. Over 100 fisherfolk participated in the focus groups, and a total of 65 (49 men, 26 women) participants attended the workshops. Some fisherfolk participated in all activities - the survey, a focus group, and a workshop.

4.1. Demographic Information

4.1.1. Survey

Among the respondents, 40% were between 18 and 29 years of age, 55.6% were between 30 and 59 years of age, and 4.5% were more than 60 years

of age. Around 36% didn't get any opportunity for formal education, 45% had a primary level of education, and around 15% and around 4.6% had a secondary and higher secondary level of education, respectively. Around 0.4% had completed a graduate level of study, with 0.2% completing post-graduation. Around 12% said their monthly household income is less than 5000 Taka (approximately $50 USD), around 38% earned between 5000 – 10000 Taka (approximately $50 - $100 USD), Around 40% earned 10000 – 20000 Taka (approximately $100 - $200 USD) and around 11% earned more than 20000 Taka (approximately $200 USD). Around 9% expended less than 5000 Taka (approximately $50 USD), around 46% expended between 5000 -1000 (approximately $50 - $100 USD), around 34% expended 10000 – 20000 Taka (approximately $100 - $200 USD), and only 11% could expend more than 20000 Taka (approximately $200 USD).

4.1.2. Focus Groups

Focus group participants were from 20 to above 50 years old. All men participants were engaged in fishing, and a majority of them used to go fishing in groups. Two of the men participants were involved in the fish business. All of them said they started fishing in early childhood. All men participants said they didn't go to school. However, almost all of them could sign their names (except four who couldn't). On the other hand, the majority of women participants said they went to school, although half of them dropped out between grades one to three. The highest level of education was higher secondary school, mentioned by three women participants.

4.1.3. Workshops

Workshop participants were from 18 to above 60 years old. The majority of the participants were engaged in direct fishing activities or were boat captains. One participant was engaged in the fishing business, and three participants changed their profession to furniture crafting; however, they were fisherfolk before. Almost all the men participants of the workshops went to primary schools. The majority of the women participants in the workshops had a secondary level of education. It is noted that several participants did not provide enough information on their demographics.

4.2. Understanding the Context of Use

4.2.1. Roles and Responsibilities

In the survey, about 48% of participants reported involvement in manufacturing and/or maintaining fishing equipment, while around 28% identified as boat owners, share-fishers, or fish traders/small business owners. Approximately 15% were boat owners or day laborers. Other roles included homemaker (12%), fish processor (11%), boat renter (7%), and creditor (4%). Participants could select multiple roles.

Focus groups showed that men fisherfolk primarily perform fishing activities such as driving boats, group fishing, repairing nets, and maintaining boats. All participants relied on natural resources and practiced environmentally responsible fishing. Some men also engaged in fish trading, purchasing fish from boats and selling through retail or wholesale channels.

Women fisherfolk carried out more varied responsibilities. Alongside managing all household chores, they contributed to fishing-related tasks such as sewing nets, adding weights, selling fish to households, and catching fish in shallow water. Many were also involved in farming and agricultural work, including cattle rearing, dairy farming, and cultivation. Several participated in additional income-generating activities such as tailoring, handicrafts, tutoring, breaking hard soil and stone, harvesting paddy, and reaping jute. A summary of these roles is shown in Figure 3.

4.2.2. Digital Literacy

Among survey participants, about 85% reported owning mobile phones, primarily for communicating with family members. Of those without phones, around 8% used someone else's device, while the remainder did not use mobile phones due to financial constraints. Only 25% owned smartphones; the rest used feature phones. Among smartphone users, 18% had internet access. Overall, 63% felt confident using mobile phones, while the remainder required assistance. Reasons for phone use (N = 208) included communication (30%), mobile banking (25%), health and government service information (12%), education/online learning (10%), social media (10%), and gaming (5%). Reported challenges included economic hardship (28%), network issues (19%), internet problems (10%), and family or social barriers (5%).

Focus group data indicated that most fisherfolk had no formal education and were generally illiterate, though nearly all could sign their names. Older fisherfolk relied on feature phones, while younger users preferred smartphones. Smartphone uses included checking weather information, listening

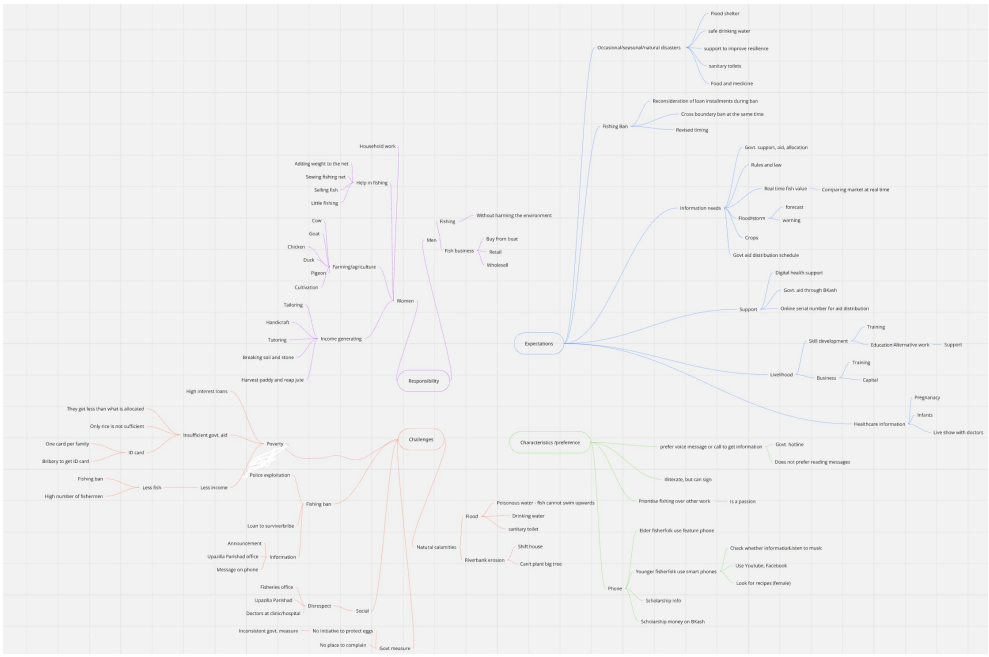

Figure 3: Responsibilities, characteristics, challenges and expectations of the fisherfolk

to music, and accessing Facebook and YouTube; some women used them to find recipes. Several fisherfolk noted that their teenage children used phones to look up scholarship information and receive funds via the mobile banking service "BKash". Key characteristics and preferences derived from the data are shown in Figure 3.

4.2.3. Challenges Faced by the Fisherfolk in Bangladesh

Survey participants listed and ranked various challenges, with the most frequent being lack of income, employment, and financial difficulties; government regulation and enforcement; limited government support and services; natural and man-made disasters; and inadequate health and education services (Figure 3).

Focus group participants echoed these challenges. They explained that poverty arises from high interest rates, insufficient government aid, and low income. Most need loans to buy or maintain fishing equipment. Government aid is limited: rice during fishing bans, incomplete allocations, and only one fishing ID per family. Income has declined due to fewer fish from bans and increased competition.

Challenges related to the fishing ban include difficulty accessing information, reliance on district office announcements, mostly sent as SMS (often unread), and exploitation by local police. High-interest loans are often needed to survive or pay fines.

Other challenges include social disrespect due to low socio-economic status at official offices or health clinics, natural calamities such as floods (poisoned water, lack of drinking water, no sanitary toilets), riverbank erosion (forcing relocation and preventing tree planting), and insufficient government initiatives (inconsistent measures, no protection for fish eggs, and no platform to raise concerns).

4.2.4. Expectations of Fisherfolk in Bangladesh

Focus group discussions revealed several expectations of fisherfolk (Figure 3). The most prominent was the need for information, including fishing rules and regulations, government support and aid schedules, flood and storm forecasts, and general crop-related information. They also sought livelihood support, such as formal education, fishing skill development, training for alternative work and business setup, and access to capital. Healthcare needs included pregnancy and infant-related information and live online doctor consultations.

Other expectations included fishing ban adjustments (timing, cross-border bans, and loan installment reconsideration), support during natural calamities (flood shelters, safe drinking water, food, medicine, sanitary toilets, and resilience measures), and general support mechanisms such as government hotlines, digital health services, and online aid distribution with serial numbers.

4.3. Development of Persona

Based on the quantitative and qualitative data we collected from the survey and focus groups, we developed nine personas for eight different types of user groups we identified. There was one persona for each of the user groups: boat owner, women fisherfolk from the boat community, association leader, boat captain, sharer, zero sharers, and small fish business owner. There were two clusters identified for the user group "women fisherfolk from fishing households", thus, two personas were developed for this role. We present two roles with a sample persona in the following subsections.

4.3.1. Boat Owner

We found that many men fisherfolk own one or multiple boats. They form small groups of fisherfolk, including one captain and multiple sharers, and go fishing. Some of them often play the role of captain, sometimes they assign the role of captain to a more senior fisherfolk who is an experienced captain. Depending on their role (whether they are captain or sharer), their income ranges from 5,000 Taka to 20,000 Taka. They often take loans from the shop owners to arrange the fishing trips. The loans often range from 20,000 Taka to 100,000 Taka. The boat owner persona is presented in Figure 4.

4.3.2. Women fisherfolk from the boat community

"Boat community" refers to the community of fisherfolk who live on boats. They do not have a fixed place on land; however, each family usually has a boat for fishing and a boat where they live with their family. They live with many livelihood challenges, such as drinking water, sanitary latrines, and so on. Almost all the members of the family go fishing. They are considered as "low cast" and are not well accepted outside of their community; as such, most of them get married to other members of the community. Figure 5 presents one persona of female fisherfolk within the boat community.

4.4. Specifying User Requirements

A number of software requirements were identified from the survey responses and focus group discussions. We describe some of the software requirements in subsequent sections.

4.4.1. Software One: Flood and Storm Warning Software

The concept of this project came from the implications of natural calamities such as flooding and sudden storms, as described by the fisherfolk. Along with the experiences of adverse effects of flooding, fisherfolk shared a lot of expectations for support during the crisis period and hope for assistance to develop resilience for such events. We envisage a real-time flood and storm warning application that the fisherfolk can directly use to help them better prepare for such crises and help reduce dependency on external support. A list of primary requirements for the software is presented in Table 1.

Table 1: Key Requirements for Software

Key Requirements for Flood and Storm Warning Software
1.1 Notification

Requirement	The software shall notify the user if a flood or storm is predicted to hit
Rationale	An automated alarm will help fisherfolk to prepare for natural calamities
Note	The software will need to be trained on historical data related to natural calamities such as floods and storms and be able to read satellite data related to present geographical conditions
Source	Fisherfolk challenges and expectations
1.2 Flood prediction	
Requirement	The software shall predict the flood based on historical data and present geographical conditions
Rationale	A flood prediction software will help the fisherfolk in making decisions for fishing as well as save their lives and assets
Note	The software will need to be trained on historical data related to floods and be able to read satellite data related to present geographical conditions
Source	Fisherfolk challenges and expectations
1.3 Storm Prediction	
Requirement	The software shall predict the storm based on historical data and present weather conditions
Rationale	A storm prediction software will help fisherfolk in taking necessary precautions during fishing
Note	The software will need to be trained on historical storm-related data and be able to read present weather conditions
Source	Fisherfolk challenges and expectations
1.4 Weather Information	
Requirement	The software shall show present weather conditions with recent future forecasts
Rationale	The real-time weather information will help fisherfolk to conduct fishing activities
Note	The software needs to collect real-time satellite data
Source	Fisherfolk challenges and expectations
Key Requirements for Fish Price Dashboard	
2.1 Real Time Fish Price Display	
Requirement	The software shall display the prices of different fish at different locations within Bangladesh
Rationale	The Market price of fish will help fisherfolk to determine the wholesale price to sell fish from the boat
Note	Fish prices vary a lot at different locations and at different stages of retail. A number of factors, such as the availability of fish and catchment status, contribute to this variation. A comprehensive framework needs to be developed for the collection and systematic display of this information as a dashboard
Source	Fisherfolk expectations
2.2 Fish Price Collection	
Requirement	The software shall facilitate entering data about the fish price
Rationale	The fisherfolk should be able to enter the price they sold the fish for from their boat
Note	The interface needs to be easy and intuitive for fisherfolk
Source	Fisherfolk expectations
Key Requirements for Voice Messages for Information	
3.1 Voice Messages	
Requirement	The software shall notify fisherfolk about important information, such as fishing ban, by audio messages
Rationale	At present, text messages are sent to fisherfolk who have ID cards. Since fisherfolk do not read text messages, they do not get the information. The software should convert the text messages to simple audio messages that are easily understandable by fisherfolk
Note	Fish prices vary a lot at different locations and at different stages of retail. A number of factors, such as the availability of fish and catchment status, contribute to this variation. A comprehensive framework needs to be developed for the collection and systematic display of this information

Source	Fisherfolk characteristics
	Key Requirements for Pregnancy and Infant Health Information
4.1 Pregnancy Guide	
Requirement	The software shall provide information about growth, diet, and general health related to pregnancy in a timely manner
Rationale	This will help the pregnant women to get information about diet and general to dos during pregnancy
Note	The information needs to be in the form of audio so that fisherfolk can listen to it, instead of reading
Source	Fisherfolk characteristics, challenges, and expectations
	Key Requirements for Pregnancy and Infant Health Information
4.2 Infant Guide	
Requirement	The software shall provide information about infant care according to age
Rationale	This will help the parents to get proper information about infant care
Note	The information needs to be in the form of audio so that fisherfolk can listen to it, instead of reading
Source	Fisherfolk characteristics, challenges, and expectations
4.3 Health and Safety Information	
Requirement	The software shall provide information on generic health and safety related to pregnant women, mothers, and infants
Rationale	This will help fisherfolk to get information about the care of pregnant women and infants
Note	The information needs to be in the form of audio so that fisherfolk can listen to it instead of reading
Source	Fisherfolk characteristics, challenges, and expectations
	Key Requirements for Skill Training Software
5.1 Training	
Requirement	The software shall provide customized training videos on different categories such as fishing, tailoring, farming, handicrafts, and so on
Rationale	This will help fisherfolk to systematically acquire the knowledge of fishing as well as other skill categories
Note	The training needs to be in the form of a video. Textual information needs to be translated into audio.
Source	Fisherfolk characteristics, challenges, and expectations

4.4.2. Software Two: Fish Price Dashboard

According to the fisherfolk stakeholder classification in [6], we collected data from primary individual stakeholders, including labourers/sharers, male and female fisherfolk, captains, shop owners, and boat owners. Labourers/sharers, fisherfolk, captains, and boat owners typically sell their catch directly from their boats to wholesale buyers. Small shop owners along the riverbanks also purchase fish from them and then resell those to wholesale buyers. Wholesale buyers subsequently transport and sell the fish to retailers at a higher price. This complex hierarchical chain leaves fisherfolk unaware of market prices. Prices for specific fish types vary across timeframes due to factors such as catchment, preservation requirements, and seasonality. Moreover, wholesale buyers exert considerable control over pricing and intentionally maintain barriers between fisherfolk, retailers, and consumers, as they capture most of the profit.

Hamid Bepari "Mahajon"

Background

Age: 60 years

Gender: Male

Hamid Bepari is a boat owner who owns 2-3 wooden boats and 4-5 types of nets. He takes a small loan locally known as "Dadon" from the fish shop owner (Aratdar) to make boats and nets, and also to hire fisherfolk who will catch fish in his boat.

For each boat, he will hire 4-5 fishermen locally known as (Bhagi) according to the boat size. Hamid Bepari has to pay 5000-6000 taka to each fisher as "dadon" to go fishing. One of them will be the boat captain, who is an experienced person in the group. He will guide the direction of the sailing and the location to throw nets. Hamid Bepari gives directions if he goes on a boat. Usually, Hamid Bepari is not the boat captain; he serves as a sharer. He often hires 15-17 sharers when he wishes to go to sea for fishing.

Family

Hamid Bepari lives with his family, including his wife, two sons, and one daughter. He wants their children to be educated and to select a different profession other than fishing.

Digital Literacy

Hamid Bepari owns a feature phone since he cannot operate a smartphone. However, he sometimes watches the news, and the prices of fish in "Arat" (big market) with the help of his son, who has a smartphone. He receives incoming calls and is capable of making calls. He can hardly read or send messages. Hamid Bepari is familiar with bkash payment system (online banking through mobile phone). It has become essential in his day-to-day life.

Figure 4: Boat Owner persona

During our discussions, fisherfolk expressed a strong interest in knowing the market prices at which their fish are sold. We argue that substantial socio-technical research is required to design software capable of informing fisherfolk about real-time fish prices across the retail chain. A preliminary

Munni

Experience

Age: 30 years

Gender: Female

Munni is a seasonal fisherfolk who lives on a boat with her family. She never went to school. During the fishing season, Munni goes fishing with other women fisherfolk from the boat community. Occasionally, her husband accompanies her. In the off-season, Munni sells cooking pots.

Digital Literacy

Munni's family owns a feature phone, which allows her to receive incoming calls; however, it has limited functionality for making calls. Additionally, Munni is unable to read Bengali messages due to her lack of formal education.

Fishing

For fishing, Munni uses "Moi" net and fish hooks with 200-1000 fishing tips attached to it. Munni and her group venture to the middle of the river in their fishing boat. She attaches shrimp fry to the fishing tips and throws them into the river. After 1-1.5 hours, she retrieves the fishing hooks.

Expectations

Due to belonging to the boat community, Munni does not get social recognition. They are not involved in other communal activities. Munni's husband is unable to join other fisherfolk outside of the boat Community for fishing. Munni aspires to have access to land, clean drinking water, and sanitation facilities. She wishes to live with dignity.

Figure 5: Female fisherfolk from boat community persona

list of requirements for such an application is presented in Table 1.

4.4.3. Software Three: Voice Messages for Information

Fisherfolk expressed significant concerns about the timing and availability of information on the "fishing ban," noting that they currently rely on local announcements and offices. Although the Government of Bangladesh disseminates important citizen information via mobile phones, these initia-

tives primarily use text messages, which fisherfolk repeatedly reported they do not read. Therefore, the proposed software would deliver "voice messages" to communicate fishing-ban updates, regulatory changes, and local fishing-related news directly to their phones.

A review of fishing-related information availability in Bangladesh shows that nine government organizations publish such information, mostly as downloadable, read-only PDF documents. We argue that an intermediary software module could convert these texts to voice and send them to phone numbers registered by fisherfolk. However, third-party development may face compatibility issues due to the inconsistent formatting of published documents. Thus, government organizations are best positioned to develop and maintain this software. Requirements are summarized in Table 1.

4.4.4. Software Four: Pregnancy and Infant Health Information Application

Fisherfolk discussed many challenges related to healthcare services, including availability and access. Some specific recommendations came from young women fisherfolk, such as having pregnancy and infant health information on the phone. Some of them also spoke about having real-time video consultations with doctors. The requirement for an application based on their suggestion is presented in Table 1.

4.4.5. Software Five: Skill Development Training

Women fisherfolk do many jobs to support their families. These include handicrafts, tuition (mostly young women fisherfolk), farming, rearing cattle, and so on. They do not get any formal training on those, and as such, they struggle to produce good quality outcomes. Men fisherfolk also communicated their interest, such as working as "drivers" during the fishing ban period when they did not have any work. However, they also illustrated their frustrations of not knowing any work other than fishing. The idea of this software came from the rationale that fisherfolk may need some other skills to help them earn a living during challenging periods, such as fishing bans and other natural disasters. The key requirements are listed in Table 1.

4.5. Developing Prototypes

We developed prototypes for software one and two, the priority is decided based on the emphasis participants provided for different software.

Both prototypes were evolutionary, following an iterative prototyping approach since we did not develop alternate or parallel designs. Two final year software engineering student teams of six developed the prototypes under the supervision of the researchers. For the first software (software one), the requirements were concise and clear, and as such, a high-fidelity prototype with all major functionalities was developed. In the second application prototype, a requirement relaxation was applied, and only features focusing on the fisherfolk, such as the display of fish prices, were prioritized. The fish price collection, verification, and other features were not considered for the evolutionary prototype, as researchers believe that socio-technical research is needed to find a proper business model. Since the overall business process was not clear at that stage, a low-fidelity prototype was deemed most appropriate. Both prototype interfaces were designed in "English" and localized in "Bangla".

4.5.1. Flood Watch Application Prototype

To address the requirements of software one - a notification software for flood and storm prediction as well as, for weather updates- we developed a mobile application interface. On the first page, the application displayed a map in the default map view (we also had an alternate screen with a satellite map view for evaluation). The map indicated different locations and a triangular icon with the latest condition of that location. The colour of the triangular icon indicated the present status, with green, yellow, and red for no, mild and severe warning, respectively. When users hover the cursor on the icons, it shows a message on whether it is safe for fishing with the same colour code as the icons, shows the present water levels, and information on when the data was last updated. Clicking on the details button on this pop-up would take the users to the next screen that showed other information on the location, including water level, rainfall, and so on, in a tabular format. Figure 6 shows the interface.

It is noted that the information on the warnings is available on the Bangladesh Government website. Thus, the main aim of the software is to present the information/warning to the fisherfolk in a user-friendly and understandable way. Therefore, instead of a low-fidelity design prototype, we developed a prototype mobile application that collected the information/warnings from existing sources and presented the information/warnings in a way that the fisherfolk could understand. With a design prototype, the evaluation of the real-time translated messages would not be possible.

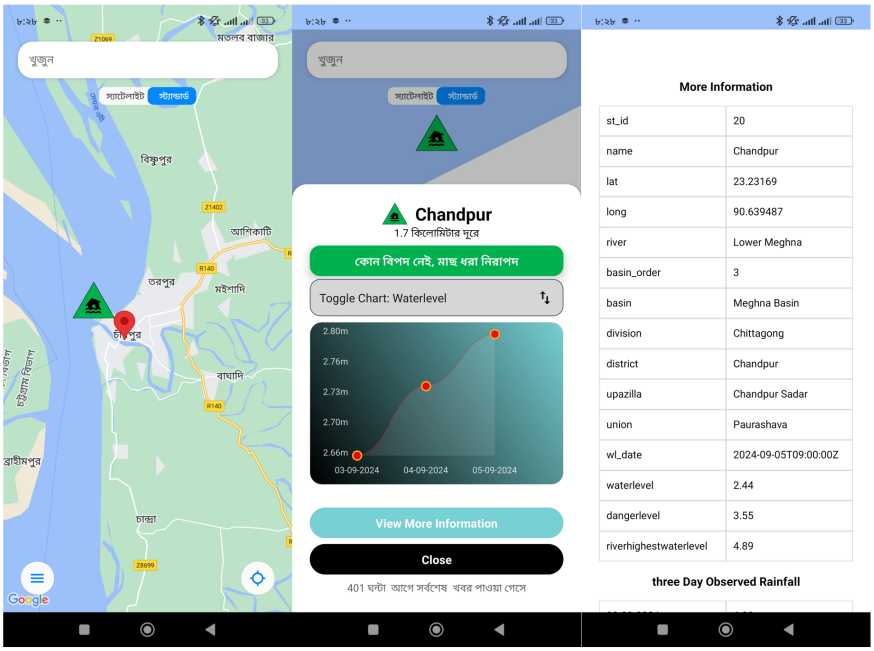

Figure 6: Flood Watch Application

4.5.2. Fish Price Dashboard Application Prototype

To address the requirements of software two- a display of fish prices- we developed a low-fidelity design prototype named Fish Price Dashboard. The prototype was developed in the "Figma" platform as illustrated in Figure 7. The first page contained an introductory note describing the purpose of the application, with a "Start" button at the bottom. Once the user clicks on "Start". They are then taken to the "Home" page, where a list of different fish with their latest price details (location and price) is displayed. The purpose of showing the list in this way is to indicate how prices change from one location to another. One of the motivations of this software was that fisherfolk wanted to know how much the fish is sold for at the market. Fisherfolk usually sell the fish at the shore or the riverbank; the price of the fish in other places will give them a better idea of the market price for each fish. The end user can click on a specific fish from the list on the "Home page" to get detailed historical information about the fish. They are then taken to the third screen, where they see all the price entries of that fish, with the time and location of price entry. They can also view the fish price

changes over time and location in a graphical format.

It is noted that a separate interface was developed for fish price entry. Based on a consultation with the partner organization, it was decided that the community volunteers would provide the fish prices during the research study. Since the fisherfolk are not involved in fish price entry, we do not discuss that part in this article.

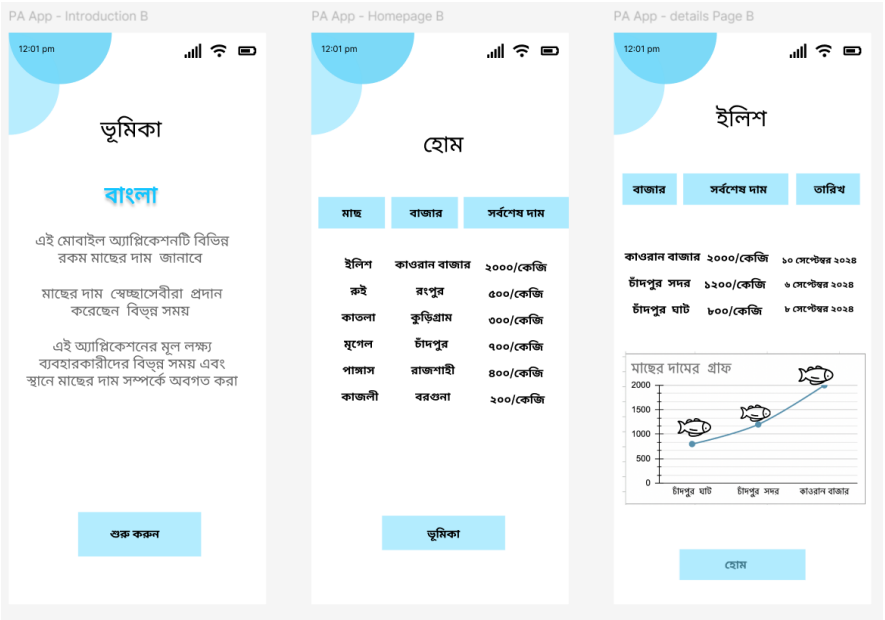

Figure 7: Fish price dashboard

4.6. Evaluating the Prototypes

We presented the application prototypes to the workshop participants. The "Flood Watch" application prototype was reviewed by all workshop participants (65) from two locations, and the "Fish Price Dashboard" prototype was reviewed by the boat captains (23) from one workshop at each location. The feedback we received, along with our reflection on those, is summarized in Table 2 and is described in the following subsections.

4.6.1. Flood Watch Application Prototype

Workshop participants preferred the default map view as the home page over the satellite view. Contrary to prior assumptions [6], fisherfolk found the

default map easier to understand, so the satellite view was discarded from the home page. The prototype included both a full Bangla interface and a mixed Bangla-English interface; most preferred Bangla, while three younger participants preferred English. The final design allows toggling between the two languages. On the second page, the tabular view included longitude and latitude, which some fisherfolk found confusing; however, they wanted that information to be displayed, so a voice description feature was added, with a speaker icon playing explanations on cursor hover. Finally, fisherfolk requested a feature to locate nearby boats on the map. While considered out of scope for this application, the requirement is noted for future research, particularly regarding privacy implications.

Table 2: Summary of evaluation

Flood Watch	
Default map screen	The application will have the default map screen on the home page as preferred by the workshop participants
Mixed response on language	The application will have a toggle language feature selected by the users
Irrelevant information	All information will be displayed on the screen, with a voice description of the different dimensions
Location of other fisherfolk nearby	Out of scope for this application; however, need more research to develop
Fish Price Dashboard	
Preference of list view of fish prices	The home page will display the fish prices in list format, we will include another column to indicate the difference in prices
Struggle with graphical representation	The graphical view will only be displayed for a selected fish; however, a voice description feature will be added to the graphs
Use of fish icon	We do not see any difference made by the fish icons; however, as suggested by the participants, we keep it
Expectation to sell fish through the application	The feature can be decided based on additional research on the context of use

4.6.2. Fish Price Dashboard Application Prototype

The main feedback on the "Fish Price Dashboard" was a preference for a list view of prices. Observations showed it took participants a few minutes to interpret the screen, while almost all struggled with the graphical view. Even after adding fish icons, participants in the second workshop still found graphs confusing. Consequently, the list was enhanced with a column showing price differences between locations, and a voice description of the graph was planned to aid interpretation.

The application's primary goal is to empower fisherfolk with up-to-date fish prices for informed selling decisions, using market price data rather than user input. Boat captains requested a feature to sell fish through the app.

While promising, this requires further research on the "context of use" before development, either within this app or as a standalone platform.

5. Trustworthiness and Limitations

Robson st al. [71] discussion calls for research quality in real-world inquiry. Given the character of this study, we discuss methodological quality in terms of trustworthiness [72].

First, credibility was strengthened through triangulation across survey data, focus groups, and prototype evaluation workshops, allowing insights from one phase to inform and validate the next. The long-term engagement of the research team and local collaborators with fisherfolk communities also supported rapport and more open participation. Opportunities for clarification were used to improve participant understanding during data collection.

Second, dependability was supported by a clearly documented multi-stage UCD process, including sampling decisions, focus group composition, workshop procedures, and content analysis. The study also provides explicit detail on how survey findings informed focus groups, how both informed persona development and requirements specification, and how prototypes were iteratively refined through workshops.

Third, confirmability was enhanced through collaborative analysis. Multiple researchers were involved in coding and discussing interpretations. Prototype development and refinement were also undertaken collaboratively, reducing reliance on a single developer's interpretation.

Fourth, transferability should be understood in analytic terms. The study focused on two districts representing upstream and downstream fishing conditions and provides rich contextual detail on fisherfolk roles, literacy, digital access, and livelihood conditions. While the findings are not intended to represent all fisherfolk communities in Bangladesh, they may inform UCD work with other low-SES and marginalised end-user groups with similar characteristics.

This study also has limitations. It does not include all types of fisheries communities, such as fish cultivators, and workshop participants were not always the same individuals who took part in earlier focus groups. In addition, some nuance may have been affected through transcription and translation, despite careful supervision. Finally, prototype evaluation prioritised qualitative feedback over standard usability instruments to better suit the study context and participants' literacy levels.

6. Discussion

In this section, we reflect on our experience of research through design with fisherfolk in Bangladesh and synthesize our findings into a set of **four key insights for the software engineering (SE) community**. While the preceding sections presented detailed results and observations, here we elevate those findings into four broader insights that have implications beyond this specific case study. These insights highlight how established UCD and SE practices need to be adapted when working with low socio-economic status (SES) end users.

6.1. Insight 1: Conventional UCD Practices Need Adaptation for Low-SES End Users

With the advancement of Information and Communication Technologies and different Government initiatives for empowerment through ICT, several similar applications/interventions already exist. For example, a search for pregnancy and infant health-related applications in Bangla in the app store returned more than 60 applications. However, as mentioned, women fisherfolk have explicitly indicated the need for such an application. A closer look at those applications reveals that the majority of those provide text-based information, which is difficult for the women fisherfolk to understand, as they indicated they are not interested in reading information.

The above scenario is an example of overlooking diverse end-user requirements and developing applications with assumptions of a "generic end-user" group. Although there are plenty of expected applications in Bangla already, the fisherfolk do not use those. Due to the unique preference of not reading text, any application developed for fisherfolk in Bangladesh needs to have a "text to voice" feature to translate the information into voice. This is also evident from the fact that a lot of information is communicated to fisherfolk in the form of short text messages; however, they do not read those messages.

Similarly, during prototype evaluation, we observed that conventional usability evaluation strategies were not suitable. Completing tasks with minimum guidance was not possible, and the fisherfolk preferred to provide qualitative feedback rather than quantitative measures such as SUS. Moreover, visual elements such as graphs were difficult for many participants to interpret.

Observation 1

Audio is an essential feature of any software developed for fisherfolk in Bangladesh. Due to their preference for not reading long text (or any text at all), information should be communicated by the software in audio format.

Observation 2

Conventional usability evaluation strategies need to be customized, consistent with the attributes of the end users. Any quantitative evaluation should be avoided where possible.

These findings suggest that standard UCD practices cannot be directly applied in such contexts. Instead, SE processes must explicitly adapt interaction design and evaluation strategies to the capabilities and preferences of low-SES end users.

6.2. Insight 2: Requirements Emerge Through Interaction with Artifacts

Another second insight is that requirements cannot be fully specified upfront when working with low digital literacy end users. Instead, they emerge progressively through interaction with prototypes and other design artifacts.

Two new requirements came in from the fisherfolk during the evaluation of the prototypes. In the "Flood Watch" application, the fisherfolk wanted to know the locations of other fisherfolk fishing nearby, and in the "Fish Price Dashboard" application, they wanted to sell fish through the application. The need for these was not realized by the fisherfolk until they reviewed the application functionalities in the workshops.

This is a common scenario while working with end users with low digital literacy. Due to their unfamiliarity with different digital applications, they do not fully understand what can be achieved with them. It is useful to present them with some examples to help guide their thinking and generate innovative ideas around the examples.

Moreover, due to marginalization and other livelihood struggles, the fisherfolk community faces many challenges. The initial focus group discussions gravitated towards describing all challenges, deviating from the discussion to understand the context of use. The researchers intervened several times to keep the discussions on the topic.

Observation 3

To specify the requirements, the data collection session should be planned very well to understand the participants' actual needs. Some examples can be helpful to guide the participants' thinking. New requirements can come up at any phase; thus, the UCD process should be iterative.

These findings reinforce the importance of iterative UCD and suggest that requirements engineering in such contexts should be artifact-driven rather than relying solely on upfront elicitation.

6.3. Insight 3: Socio-Cultural Mediation is Central to the UCD Process

A third insight is that socio-cultural factors play a central role in conducting user-centered design (UCD) with low socio-economic status (low-SES) and marginalized end users, and therefore must be treated as first-class concerns within software engineering (SE) processes. The findings from the exploratory research with fisherfolk communities demonstrate that conventional software engineering and participatory design approaches are often insufficient when working in culturally complex and socially vulnerable contexts. Instead, culturally adaptive techniques are required to ensure meaningful participation, ethical engagement, and inclusive technology design.

One major challenge identified during the study was language and communication. Although Bangla is the primary language spoken by the fisherfolk communities in Bangladesh, the language varies significantly across geographical regions through different dialects. Even though several researchers were native Bangla speakers and others had prior ICT4D experience in Bangladesh, communication barriers still frequently impeded discussions during focus groups and data collection activities. As a result, the research team relied heavily on local collaborators who could facilitate communication and bridge cultural and linguistic gaps. This finding highlights the need for culturally adaptive SE methods that incorporate local facilitators, contextual communication practices, and linguistically sensitive engagement strategies rather than assuming uniform communication norms.

Another important observation was that livelihood struggles and socio-economic hardship strongly shaped participant engagement. Many participants focused primarily on immediate survival concerns and day-to-day challenges rather than discussing abstract technological solutions. Their lived

experiences of economic vulnerability also made them cautious and sensitive during data collection processes. Participants were often reluctant to share information with outsiders and demonstrated limited trust toward unknown researchers. This finding suggests that software engineering research with marginalized communities cannot rely on short-term or transactional engagement models. Instead, culturally adaptive approaches must prioritize long-term relationship building, empathy, and community-centered participation practices.

The study further demonstrated the importance of trusted local intermediaries in enabling meaningful participation. A collaborating local partner organization played a critical role because of its long-standing relationship with the fisherfolk community. The organization's established trust enabled researchers to conduct focus group discussions in a safe and friendly environment where participants felt comfortable sharing their experiences, challenges, and perspectives. This illustrates that trust is not peripheral but foundational to inclusive SE research, particularly in underserved communities. Ongoing trust relationships are therefore essential for sustained data collection, co-design activities, and successful technology adoption.

Moreover, societal and cultural attributes, particularly gender dynamics, significantly influenced participation patterns. In mixed-gender workshop settings, women participants were notably less active and contributed less frequently to discussions. However, in women-only groups, they participated more openly and confidently. This observation demonstrates how social hierarchies and cultural norms can directly shape whose voices are heard during software design processes. Without culturally adaptive facilitation techniques, standard group-based workshops risk reinforcing existing inequalities and excluding already marginalized perspectives from system requirements and decision-making processes.

Overall, these findings emphasize that culturally adaptive software engineering techniques are necessary when designing applications for marginalized communities. Such approaches acknowledge the importance of language diversity, socio-economic realities, trust relationships, community partnerships, and gender-sensitive participation practices. By embedding these socio-cultural considerations into SE and UCD processes, researchers and practitioners can develop more inclusive, ethical, and contextually relevant technologies that better reflect the lived experiences and needs of marginalized populations.

Observation 4

Researchers need to work in collaboration with local partners who have (1) a good understanding of cultural context, (2) a trusting relationship with the community, and (3) the ability to speak the local language very well.

Observation 5

Customized training sessions should be conducted with local collaborators to ensure a thorough understanding of the interventions before facilitating data collection.

Observation 6

To understand the context of use, working with smaller participant groups is suggested, and societal attributes such as gender dynamics need to be considered while forming the participant groups.

These findings demonstrate that effective SE processes in such contexts depend on trust, cultural understanding, and appropriate mediation through local collaborators.

6.4. Insight 4: There is a Gap Between Research and Practical Deployment

Our final insight relates to the gap between existing research and its practical application for end users. Another prominent requirement we found was for a system to warn the fisherfolk about floods and storms. Although the same application was not found on the app store, we found several research publications applying machine learning models trained on historical data to predict floods in Bangladesh [73], [74], [75]. There is some research on specific locations near the river as well [76], [77]. Some of the research indicates promising results in predicting the susceptibility of flooding; however, this published research is not accessible to fisherfolk, nor is it presented in a way that will be understandable by them. These implemented models need to be developed as software that can be used by fisherfolk. This highlights a gap between research outputs and deployable systems that can create real-world impact.

Observation 6

Different applications need to be developed based on the latest research and trialed with fisherfolk. A clear gap exists between research and practice in the fisherfolk community in Bangladesh.

Observation 8

While designing prototypes, general features should be customized to address the unique needs of the end users, and iterative prototyping should be adopted.

Our findings thus suggest that SE research should place greater emphasis on translating technical advances into usable, context-appropriate applications.

6.5. Summary

These four insights demonstrate that developing software for low-SES end users requires **rethinking our key assumptions in software engineering**. Conventional UCD practices need adaptation, requirements emerge through interaction with artifacts, socio-cultural mediation is essential, and there is a need to bridge the gap between research and practice. These insights form the basis for the guidelines presented in the following section.

7. Proposed UCD Guidelines for Low SES End Users

The preliminary data from our exploratory research indicates that digital literacy, as well as the usage of digital applications, is increasing among the fisherfolk. This is apparent from the responses we got from the young fisherfolk. Almost all of them use the internet on their mobile phones for different purposes. We anticipate that in a few years, the majority of the fisherfolk will use different digital applications on their phones. As such, the applications need to be designed in a way that they are usable by the fisherfolk. The observations we made during the UCD process with fisherfolk in Bangladesh are summarized in Table 3 and discussed in detail in the following subsections.

Based on this case study, we propose general guidelines for planning and conducting an effective UCD process for low SES end users. As noted in Section 2.4, while many case studies exist, no general guidelines are available.

Table 3: Summary of Observation in different UCD phases

Phase	Experience	Recommendation
Understanding the context of use	The characteristics and environment of the end users are very different from those of the developers	It is necessary to develop a persona to describe the end users
	User groups were identified from the quantitative method, and further refined, and more information on each group was collected in the qualitative method	Mixed method of persona development is more useful
	More insightful findings from focus groups and workshops than the survey	Working with small representative groups is suggested
	More spontaneous participation by women in single-gender workshops	Consider societal attributes (such as gender dynamics) while creating participant groups
Specifying requirements	New requirements came in during the evaluation	(1) An iterative UCD process is necessary
		(2) Tentative examples can be useful to guide their thinking
	Initially, end users are too focused on describing challenges (instead of needs)	Extra emphasis should be given to identify the actual needs
Designing prototypes	Some unique preferences- such as not reading text, not understanding graphs	General designs should be customized to address unique user needs
	Prefer to keep information that they do not understand fully	Features should be designed in a way to educate end users in the case they do not understand
	Evolutionary prototypes were very useful in refinings the designs	Iterative prototyping approach should be adopted
Evaluating prototypes	Completing tasks with minimum guidance was not possible with the fisherfolk, researchers provided a brief overview and demonstrated some functionality of the application	Conventional usability evaluation strategies should be customized
	SUS could not be used, as fisherfolk preferred to provide qualitative feedback	Quantitative assessment should be avoided

These recommendations aim to assist researchers and practitioners in developing digital applications for similar communities using a UCD approach. The recommendations are detailed in the following subsections, and Table 4 compares them with existing case studies to show alignment and applicability across different low SES contexts.

7.1. General Characteristics

Evaluation of both prototypes showed that adding voice descriptions was well received. The audio feature improved ease of use and supported literacy; for example, in the Fish Price Dashboard, it helped participants interpret graphs. We therefore recommend incorporating voice input and output in interfaces for low SES users, aligning with findings that they prefer multimedia interfaces [59].

Some requirements already have supporting research or applications, such as local flood prediction or pregnancy and infant health apps. However, fo-

cus groups revealed a need for easily accessible flood and women's health applications. There is a gap in translating research into simple, usable tools. Researchers should engage communities to apply research outcomes, empowering marginalized users and increasing societal impact beyond publications.

Recommendations

- "Speech" is the preferred mode of interaction with the user interface, instead of "text"
- Existing research needs to be communicated and translated into practice

7.2. Planning UCD Process

As reported by [59], end users suggested that one feature was not needed during prototype evaluation, despite requesting the feature during requirement specification. We experienced a similar phenomenon in our case study as well, when our end users could specify the requirements more clearly during prototype evaluations. This indicates that the low SES end users are often doubtful about their expectations. Due to the low digital literacy, they struggle to visualize the features and their functionalities during initial requirement elicitation. When they see some artifacts as a form of prototype or other designs, it helps them to understand the usage and provide more specific comments on that. Based on these findings, we recommend that after initial requirement elicitation, additional sessions should be conducted with some artifacts (either initial designs or simple prototypes) to validate the requirements.

It is general wisdom that collaboration with local experts is necessary for UCD with low SES end-users. As such, no existing research discusses this aspect. However, from our experience, we noticed that the local collaborators should have an ongoing trusting relationship with the target communities. Low SES end users from developing countries are often marginalized due to many livelihood challenges; as such, they are often reluctant to open up in front of others, especially to those whom they don't know for a long time. While selecting local collaborators, researchers and practitioners should find people who have an ongoing trusting relationship with them. Due to the bonding with the participants and the comfort of sharing information, the local collaborators often need to facilitate the sessions (regardless of the researchers' presence). As such, it is important to train the local collaborators

on the UCD concepts, most importantly, different UCD phases and the iterative nature of the process. This also helps them to keep the conversation within context. Realizing the gap after the initial workshops, we conducted training workshops with the local collaborators before the actual workshops with the participants.

Recommendations

- Requirement validation sessions with the SES end users are a must and should be conducted with some design artifacts
- Local collaborators need to have a trusting ongoing relationship with the low SES end users
- Local collaborators need to be trained on the UCD artifacts

7.3. Data Collections

Effective data collection requires careful consideration of several factors. Small-scale focus groups are valuable for gaining deeper contextual insights because they allow richer engagement, detailed understanding of user needs, and provide opportunities for all participants to contribute. Recruitment should consider social attributes—such as gender dynamics in our case—as these shape group interaction and data quality, ensuring that diverse perspectives are represented. Well-designed data collection protocols help maintain focus and consistency, reducing bias and making findings more reliable. Simple consent procedures are important for better understanding and clear communication of essential information, so that participants can give informed consent more easily. For prototype evaluation, qualitative feedback is especially useful, as it captures nuanced, context-driven insights that quantitative measures may miss; as in our case, participants were often reluctant to provide quantitative values. Therefore, we used a customized evaluation instrument instead of the usual usability scales. Well-prepared data collection protocol and simple consent were also suggested by [60].

Recommendations

- Small-scale focus groups are better for understanding the context of use
- Social attributes need to be assessed for focus group recruitment
- Data collection protocols should be designed carefully to minimize deviation from the discussion
- Simple consent
- Qualitative feedback is better for prototype evaluation

7.4. Persona

To understand the different user groups within the communities and their dynamics, rigorous data collection is necessary. Findings from the quantitative and qualitative approaches complement each other and provide a comprehensive understanding. Personas can be the best tool to represent this insight and to help develop empathy, which is absolutely necessary to build software for them. Moreover, personas can contain context-specific information; however, they must include information on each user group role, goal, expectations, and challenges.

Recommendations

- Mixed method of persona development is more useful
- Persona must contain role goal, challenges, and expectations

8. Conclusion and Future Plan

We present the findings of our exploratory research as part of an ICT4D project aimed at empowering fisherfolk in Bangladesh. We applied the User-Centred Design approach to understand the context of use, specify requirements, design solutions, and evaluate those. In each phase of UCD, we reflected on our experience and proposed recommendations for the future. We found that fisherfolk in Bangladesh are a marginalized community that faces several livelihood challenges. The digital literacy level varies a lot among

Table 4: General Guideline for UCD with Low SES End Users compared to existing literature

Dimension	Recommendation	New	Present in [58]	Present in [59]	Present in [60]
General	"Speech" over "text"			✓	
	Research Translation	✓			
UCD Process	Requirement validation with artifacts			✓	
	Trusting ongoing relationships	✓			
	Training on the UCD artifacts	✓			
Data Collection	Small-scale focus groups	✓			
	Social attributes during recruitment	✓			
	Data collection protocols to minimize deviation				✓
	Simple consent				✓
	Qualitative feedback	✓			
Persona	Mixed method of persona development	✓			
	Role, goal, challenges and expectations in Persona	✓			

them. Many factors, such as gender dynamics, trust relations, and linguistic landscape, influence the overall process of UCD. Based on all these factors and the unique characteristics, such as a preference for visual content, we propose specific guidelines for the UCD process, as well as some design artifacts that need to be considered when designing software solutions for this community. We also emphasize the practical application of research findings to make an impact on the fisherfolk's daily lives.

Drawing on our experience with this specific community, we propose several recommendations for planning research and development with similar disadvantaged communities. These include collaborating with small groups of representative participants, taking social dynamics into account during recruitment, developing personas using mixed methods, and conducting qualitative evaluations of prototypes. In the future, we aim to extend the approach to other similar end users to evaluate the consistency of the recommendations. We also plan to conduct small-scale controlled experiments to justify each of the recommendations.

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Appendix

Survey Questions

- What is you age Range?
- What is your gender?
- Where do you live? (Location)
- What is the highest level of education you completed?
- What specific activities do you do as part of your profession?
- How long have you been involved in fishing? (in months)
- What is your monthly Household income? (Taka)
- What is you monthly Household expenditures?(Taka)
- How do you access information?
- How do you share information with others?
- Do you own a mobile phone?
- If you do not have a mobile phone, do you have access to other's mobile phone?
- If yes, what is your relationship with the mobile phone owner?
- What are the purposes of using a mobile phone?
- If you do not use a mobile phone, what are the reasons for not using a mobile phone?
- What type of mobile phone do you use?
- Do you have access to internet?
- Who else owns a mobile phone in your family?

- What is your relationship with family members who use a mobile phone?
- What types of phone they use?
- Do they have internet access on their mobile phone?
- What is the quality of network connection for calls at home?
- What is the quality of network connection for calls at the areas you work?
- What is the quality of the network connection for the internet at home?
- What is the quality of the network connection for the internet at areas you work?
- Do you need any help while using a mobile phone?
- Do women in your household get equal opportunity of using mobile phone?
- What are the purposes of using mobile phones by the youth group?
- What challenges do they face using a mobile phone?
- Rank the following livelihood challenges in order of their importance to be resolved:
  - Government support, and services (compensation/assistance/safety net during ban period by
  - Govt/other organization/fish card)
  - Income and employment (general, Debts and loans, alternative income during the ban period)
  - Health and Education
  - Fisheries production and management (access to rivers, waterbodies)
  - Impact of natural and men-made disaster and risk
  - Gender equality (e.g. Fisheries, access and use of technology)