Addressing Digital Exclusion via the Inter-Generational Codesign of Extended Reality, Underwater Telepresence, Social Games, and Voice AI Technologies

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***Abstract*— Older people throughout the world tend to be digitally excluded. Regional deprivation multiplies this effect with younger people in deprived regions also digitally excluded. Codesigning digital technologies, using the natural and heritage resources of such regions would address this, but is rarely done. We present our methods and preliminary results, two-thirds of the way through a 30-month project to develop novel technologies in extended reality, underwater telepresence, digital social games, and artificial intelligence voice interfaces and to use these assets to tackle digital exclusion. We are taking an intergenerational approach, working with 36 partner organizations, some to identify possible technologies and others to help with recruitment. Between August 2023 and June 2024, we ran thirty inter-generational codesign workshops for extended reality (11), underwater telepresence (10), social games (6), and voice interaction (3) with a total of 95 attendees (53 older (50+ years old) and 42 younger (16-30 years old) participants). In total we aim to recruit 120 participants (80 older, 40 younger) and codesign four new technologies. We present our experiences in recruitment and workshops. This has lessons for (i) other regions facing similar issues of digital accessibility, (ii) those codesigning novel technologies for older people, (iii) those working in extended reality, underwater telepresence, digital social games, and voice interfaces.**

Keywords- digital inclusion; codesign; coastal regions: extended reality; underwater telepresence; digital social games; artificial intelligence voice interfaces.

I. INTRODUCTION

We have presented a preliminary (halfway) report on our project entitled "Intergenerational co-creation of novel technologies to reconnect digitally excluded people with community and cultural landscapes in coastal economies (ICONIC)", funded by the UK Research and Innovation Engineering and Physical Sciences Research Council [1]. Here we expand on that report giving an update, unpublished information related to the original content, new details from a further six months' work, in particular including progress from further workshops.

Older and younger people living in coastal and rural areas, such as Devon and Cornwall (D&C) in England, face significant health inequalities [2] [3]. In other countries such as Spain it may be rural areas in the country interior that are more deprived. Although most solutions often lie with politics and economics, the codesign of human-centered digital technologies that reduce inequalities and empowers an equitable digital society, is also imperative. Three types of digital equity exist: (i) digital connection – being able to access the same digital facilities and services as everyone else; (ii) digital employability – having an equal chance for jobs in the digital economy and (iii) digital enablement – using digital to have equal chance of participating in aspects of society otherwise denied.

The benefits of a digital society are not equally distributed across different demographic and socioeconomic backgrounds. For example, older people often do not use digital technologies at all, or only minimally due to inequity in digital connectivity and enablement [4]. Furthermore, while older people's links with community, resources and meaningful activities are essential in supporting health and well-being, these links are increasingly dependent on a digital connection, often meaning Digitally Excluded Older People (DEOP) are at risk of being engulfed by an additional sphere of exclusion. For Younger People (YP), digital employability equity is of greater concern with disparities in opportunities for digital employment and career aspirations.

In England, the most disadvantaged regions are often coastal, characterized by areas of low productivity and high deprivation. Traditional industries, such as farming, mining, fishing, and port activity, have all declined, with alternative, often high-wage digital sectors struggling to emerge, resulting in an exodus of younger skilled people. Those left behind, may be from poorer backgrounds, lacking secure and well-paid jobs, or a clear sense of career ambition. Disadvantaged regions need to use the assets they have to try to address such digital inequalities. In England, many coastal regions, including D&C, have social, environmental and heritage assets. While access to such cultural and environmental assets are known to improve health and wellbeing, equitable access is not always available to older people. And the converse is also true, that digital equity is important for the economy of 'left behind' coastal regions. Digital technologies are becoming essential in presenting and connecting with local culture. The cultural landscape together with community groups makes a cultural ecosystem that gives a region its unique identity, helping to promote its economy to the outside world [5].

Technology for intergenerational connectivity is an emerging field [6]. Lack of technical support is often the main contributor to digital exclusion among older people. YP often

adopt new technology quickly so can act as 'digital champions' for DEOP. Positive benefits of intergenerational activities are also widely reported for YP, many related to educational and developmental gains and improved attitudes towards older people [7]. Work with companion robots demonstrated well how YP's design ideas for technology may be different from older people's expectations [8]. However, intergenerational codesign may bring ideas that older people had not thought of but are acceptable and useful.

Research codesign is now widely used [9] [10] and there is prior research on intergenerational digital codesign [11]. Our project learned considerably from the prior work on the Generating Older Active Lives Digitally (GOALD) project funded by the Economic and Science Research Council [12]. GOALD tried to take an intergenerational approach to digital design but had problems in recruiting younger people [13]. Nevertheless, we learned from their experience in running codesign workshops and from the guidance for developers of digital products for older people that they produced [14].

The ICONIC project is a 30-month project. We are taking an intergenerational approach to address digital exclusion in older people and digital economic and employment exclusion of younger people. It is important to know if being intergenerational is a necessary component of codesign. We need to know if and how this approach leads to differently designed more inclusive technology. We have chosen four technologies that may connect people to community and cultural landscape in our coastal region: extended reality, underwater telepresence, digital social games, and Artificial Intelligence (AI) voice interfaces.

Immersive experiences can help improve wellbeing for people unable to visit certain places due to mobility problems. This is a major issue for heritage sites, sites of special scientific interest, and coastal landscapes where there is often limited ability to modify construction. Climate change, flood and coastal erosion create additional risks and put increasing pressure on the need to facilitate novel and sustainable visitor experiences, and tourism [15]. *Extended reality* (XR) allows people to experience those spaces virtually and enjoy the wellbeing and psychological benefits. A better understanding of the importance of the marine environment enables us to take this a step further into *underwater telepresence*, celebrating the rich marine environment of D&C.

Connecting with others helps address social isolation and in that respect the importance of technologies, such as videocalls, has been demonstrated in care homes and for people unable to travel during the pandemic. But often more is required than just the opportunity to talk. *Digital social games* have been shown to be a key motivator in connecting, educating, and engaging people and more importantly keeping people engaged as well as reducing stress from prolonged isolation [16]. They offer possibilities for the communication of specific values and information while simultaneously engaging previously disconnected audiences. Digital games also have the capacity to engage hard to reach audiences and minority groups but also allow for the valorization of heritage, often a strong motivation for rural regions and marginalized groups. While more generic history-themed digital games are commercially available, the potential health and wellbeing benefits of digital games based on the specific history and historic environment related to the cultural identity of D&C had not yet been explored and so is a focus of ICONIC.

Finally, while the three technologies above can be used to engage individuals with some level of digital awareness, skills and device ownership, we need ways to engage those most digitally excluded - those without internet access or digital devices. This group, for reasons of cost, awareness, lack of skills and/or support perhaps due to isolation may never use broadband or own a digital device but nevertheless can be connected to the digital world through existing phone technology. *Voice interaction with the internet* is now commonplace through smart speakers but making that available by telephone to an older internet naïve population has had little research. Voice interaction by phone via chatbots to community and cultural resources could help re-connect DEOPs, particularly those with visual impairments.

The ICONIC project therefore aims to codesign appropriate and human-centered technologies focusing on extended reality, underwater telepresence, social games, and voice AI. The project is trying to capitalize on existing cultural and environmental assets in D&C to address challenges faced by both DEOP and YP. ICONIC is necessarily an inter-disciplinary project with a team drawing on computing science (including AI, games, robotics, vision), public health, psychology, architecture, art and design, history and heritage, marine biology, and business studies.

The rest of this paper is structured as follows. In Section II we present ICONIC's research questions and in Section III, the objectives. As this paper focuses on methods, in Section IV, we present our methods in detail. Preliminary results and discussion are in Section V. Section VI concludes our article.

II. RESEARCH QUESTIONS

The six main research questions for this 30-month project are: (i) Is intergenerational codesign of the four identified technologies feasible? (ii) Does intergenerational codesign promote an equitable digital society in coastal Britain? (iii) Which of the four technologies are more susceptible to intergenerational codesign and what preferences do DEOP and YP have in using these technologies? (iv) Which approaches lead to a sense of connection with community and cultural landscape for DEOP and help develop confidence, communication skills, and employability for YP? (v) Does intergenerational codesign lead to differently designed technology with more potential for inclusivity? (vi) What are the technical and social requirements to develop, adopt, scale-up, spread and sustain these technologies?

III. OBJECTIVES

The objectives of ICONIC include: (i) To engage with local partners who will help with recruitment and who have various digital resources related to the social, environmental, and heritage assets of the region; (ii) To recruit 120 participants (80 DEOP, 40 YP) with the help of those external partners; (iii) To codesign four novel technologies by taking an intergenerational approach in a series of workshops; (iv) To document group working by external observation and

internal reflection to assess the impact of intergenerational working between the four technologies on design; (v) To assess whether using the four codesigned technologies improves digital access and wellbeing and sense of connection for DEOP or digital involvement or digital employability of YP; (vi) To explore sustainability through opportunities of embedding these processes into curricula for further and higher education students and in the creation of a social enterprise partnering university and community groups.

IV. METHODS

A. Regional Partner Organisations

An initial stage (Objective (i)) was to recruit and meet with partners to explain ICONIC's aims and to explore their related resources and needs. By June 2024 we had met with and had the support of 36 organizations (Table 1). Some partners had both resources and experience of using digital to engage with the digitally excluded. For example, the Ocean Conservation Trust runs the 'Oceans For All' sessions, in which care home residents can view 360 degree videos recorded inside the tanks of the National Marine Aquarium (NMA) in Plymouth, and Geevor Tin Mine in Cornwall have developed a Virtual Reality (VR) tour to provide remote access to their 18th Century mine-workings heritage site. Other partners provided 'the challenge' such as remote villages Pendeen and Carnon Downs in Cornwall. In some cases, partners provide technology that needs further development. For example, to support voice AI development, we are working with a small and medium enterprise (SME) PatientCards that has a social prescribing network that can be accessed through the Help@Hand mobile application. With Pendeen village we are working with community members who provide 'Outreach Pendeen' a community newsletter containing details of local services, activities, and community groups (see Section G).

B. Recruitment of Participants

We have worked with our partners to recruit older people (aged 50 or over) and younger people (aged 16-30) (Objective (ii)). The project has ethical permission from the University of Plymouth Arts, Humanities and Business Research Ethics and Integrity Committee (09/05/23; project ID 3941). Our primary method of recruitment has involved recruitment partners (Table 1) sharing adverts of the project with potential participants. This strategy was supplemented through contacting additional groups (such as the University of the Third Age, a network that supports education for retirees) that are not partnered with the project directly, to attempt to recruit participants that are 'digitally excluded'. Partner recruitment success has been varied, with some partners unable to source interest in the project and others providing many participants. For example, prospective rural community partners reported no participation interest amongst individuals in the older, rural communities that they work with. Other partners embedded in rural communities were much more successful and contributed sufficient participants to embed a codesign workshop group with them. Further recruitment of YP was conducted through our University, to ensure an intergenerational component for the workshops. Although university students are not a good fit for 'digitally excluded', some, such as nursing students, may not be particularly digitally proficient, and given problems of recruiting younger people, we have compromised to ensure the intergenerational aspect of the project. Participants are reimbursed for their participation with vouchers, with additional vouchers available to cover costs of transport and time to travel to the workshop venue. Before their first workshop, we meet with participants either in-person or remotely (via phone or Zoom) and they are interviewed to gauge their current engagement with digital technologies, local heritage and the environment, and their local communities. By the end of June 2024, we had recruited 53 DEOP and 42 YP. Outside of networks within the University of Plymouth, recruiting YP has proven more difficult than recruiting DEOP due to workshops conflicting with working or education hours. This has been addressed through embedding asynchronous codesign workshops within work being conducted by community partners and further education (FE) providers in Cornwall that work with YP.

As participants are being recruited from diverse backgrounds, there is considerable variation in the nature of digital exclusion they report in recruitment interviews. Participants have reported barriers to accessing technologies, including lack of skills, costs, and poor local infrastructure [17]. One commonality across most participants, however, is a keen interest to learn more about the technologies being codesigned as a part of the ICONIC project. Participants have shown the greatest interest in the Underwater Telepresence technology, with XR a 'close second', as both technologies can be used to make difficult to access spaces more accessible to a wider audience. Social digital games has registered the least interest from participants, with some older participants reporting negative attitudes. The feedback, based on anecdotal evidence, seems to suggest that this negative attitude stems from the general portrayal of digital games in the media and a missing personal experience with games technology and digital games [18], linking digital games to violence and wasting time. Nevertheless, a core of 8 DEOP joined codesign workshops for the Social Games technology, taking ownership of the direction of the game design and the interpretation of the seagrass conservation theme (see below). This group can also later provide a more reflective picture of the specific games technology and games they engaged with, creating a more nuanced perception in the community which could lead to a shift of the community attitude.

C. Overview of the codesign workshops

Objective (iii) is to codesign four novel technologies by taking an intergenerational approach in a series of workshops. The iterative process of technology development we are using is like Participatory Inquiry approaches generating knowledge collaboratively and iteratively where research and action are linked through critical reflection [19]. Our approach is based on an extension of the Participatory Inquiry method called Research through Design [20]. Stakeholders are involved at all development stages of the project from initial problem-

TABLE 1. SUMMARY OF 36 PARTNER ORGANISATIONS SUPPORTING WORK ON THE ICONIC PROJECT SHOWING THEIR ROLE IN EITHER PARTICIPANT RECRUITMENT (PR) OR TECHNOLOGY CONTENT (TC).

Partner	Brief Description of Partner	Role
Abbeyfield	Charity providing housing, residential care and support to older people [21]	PR
Age UK Cornwall	Charity supporting older people (federated independent branches) [22]	PR
Age UK Plymouth	Charity supporting older people (federated independent branches) [23]	PR
Carnon Downs	Village community/hall in Carnon Downs, Cornwall [24]	PR
Centre of Pendeen	Village community/hall in Pendeen, Cornwall [25]	PR
City College Plymouth	Plymouth Further Education college, providing education for students aged 16+ [26]	PR
CN4C	Social enterprise supporting individuals in Cornwall with economic/social issues [27]	PR
Cornish Mines	World Heritage Site preserving 18th and 19th century mining sites in 10 locations [28]	TC
Cornish Mining NT	Heritage Site preserving Tin Coast mining region: 3 locations in west Cornwall [29]	TC
Cornwall AONB	National Park (Area of Outstanding Natural Beauty) covering approximately 27% of Cornwall and comprising twelve separate areas, eleven of which are coastal [30]	TC
Cornwall College	Cornwall Further Education college, providing education for students aged 16+ [31]	PR
Cornwall Digital Exclusion Network	Team embedded in Cornwall Council to support access to digital tools and services in Cornwall and the Isles of Scilly [32]	PR
Cornwall Museums Partnership	Charity that works collaboratively across museums in Cornwall to promote wider engagement with Cornish heritage [33]	TC
Cotehele National Trust	An estate with a medieval house that has been developed across the Tudor and Victorian eras additions located in the east of Cornwall run by National Trust [34]	TC
Dartmoor Nat. Park	Historic national park in south Devon with extensive Bronze Age heritage [35]	TC
Exmoor National Park	National Park located in Somerset and north Devon [36]	TC
Geevor Tin Mine	Historic 18th century mine site in west Cornwall [37]	TC
Healthwatch Torbay	Non-profit organisation supporting health and social care in Torbay, Devon [38]	PR
PatientCards	SME running the Help@Hand social prescribing mobile application used as information sources by the ICONIC Voice AI technology [39]	TC
Hi9	SME specialised in voice AI interfaces [40]	TC
iSight Cornwall	Charity supporting individuals with sight impairments in Cornwall [41]	PR
Made Open	SME that runs Cornwall Link and Devon Connect directory websites used as information sources by the ICONIC Voice AI technology [42]	TC
Minack Theatre	Historic open-air theatre in west Cornwall, with views over Porthcurno Bay [43]	TC
Mount Edgcumbe	Historic Park and stately home in south-east Cornwall [44]	TC
Newquay Orchard	Community group in Newquay, Cornwall [45]	PR
Nudge	Community group in Plymouth [46]	PR
Ocean Conservation Trust	Charity focused on ocean conservation, that runs the National Marine Aquarium, Plymouth [47]	TC
Plymouth CH	Plymouth Community Homes (PCH) - Large housing association [48]	PR
Plymouth Digital Exclusion Network	Team embedded in Plymouth City Council to support access to digital tools and services in Plymouth [49]	PR
Plymouth Sound National Marine Park	The UK's first national marine park, based in Plymouth Sound [50]	TC
Saltram National Trust	Park and Georgian stately home near Plymouth run by National Trust [51]	TC
South Devon AONB	'Area of Outstanding National Beauty' National Park located in south Devon [52]	TC
South Devon College	Further Education college in Torbay, providing education for students aged 16+ [53]	PR
St Austell Healthcare	GP practice serving St Austell and surrounding areas, working with PatientCards [54]	PR
The Eden Project	Attraction in Cornwall comprising domes housing emulations of natural biomes [55]	TC
Torbay Community Development Trust	Charity supporting community development in Torbay, South Devon [56]	PR

framing to the later development stages (for example, designing interactions). To accommodate the iterative nature of the codesign process, we have set up monthly time-boxed development windows and each technology will have between 7 to 10 workshops. From the technical point, this setup provides a suitable timeframe to plan, develop the technology, deliver the workshop, and analyze the results of the workshop to generate knowledge (Figure 1). One of the main benefits of the monthly workshops is repeated, consistent interaction with the participants: a key ingredient for building a productive collaborative relationship.

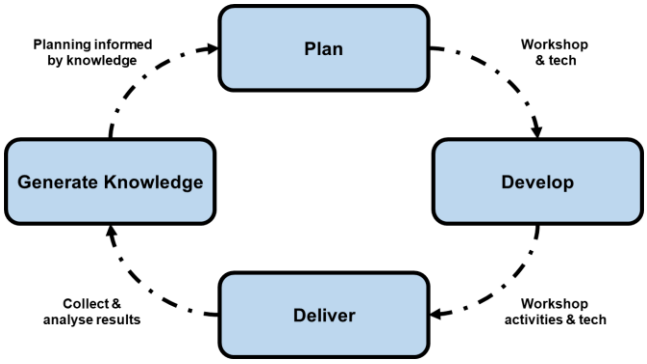

Figure 1. Monthly iterative process used to extract knowledge from the codesign process. The outcome of each process is being used to inform the planning and delivery of the next workshop.

D. Extended Reality (XR)

Our work with XR technologies aims to give older people with mobility impairments access to experiences in sites of cultural and historical significance, addressing the limitations of commercially available VR systems while creating bonds with specific places and communities. For example, older adults may have needs related to physical impairments such as visual (use of glasses with the VR headset) and aural (VR headsets interference with hearing aid devices) [57]. Current VR systems have a strong emphasis on the gaming aspect of the VR market, highlighted by the design of the individual controllers, which at the core is a gaming controller split in two. This can present challenges to the users with limited dexterity in their thumbs and fingers. In addition to technology adaption, content tailored to the older adults' interest is crucial to providing an experience that leads to acceptability and adoption [57].

This builds upon previous work on the development of XR systems for digital heritage, which focused on Powderham Castle and the Higher Uppacott medieval site in Dartmoor National Park [60]. We are focusing on Cotehele (Table 1), a site managed by the National Trust which preserves a series of medieval buildings and historic garden in Cornwall. Despite the best efforts of its local team to improve accessibility and the visitor experience, the site includes buildings with accessibility issues, such as narrow corridors and steep steps, and limited public transport.

Between August and December 2023, we ran five XR workshops. An introductory codesign workshop was held asynchronously with one rural workshop group in March 2024 and three further workshops were held with a group of students at a partner FE provider in June 2024, making ten workshops in total (Table 2). We used a Meta Quest 2 headset to give participants a VR immersive experience (Figure 2). Activities included multiple methods of documenting, experiencing, and speculating about historical sites and their potential to elicit wellbeing principles such as social cohesion and intergenerational interactions. These included 360 video demonstrations, persona-based experience design workshops, and activities to test ergonomics of XR hardware for older users.

Figure 2. Participant trying out a virtual reality environment via a head mounted display in one of the codesign workshops.

E. Underwater Telepresence

We want to give people the feeling of being underwater while onshore and to see an environment they have never seen before. Our initial codesign workshops revealed several barriers to engaging with the underwater world, such as financial constraints, time commitments, physical fitness requirements, and discomfort due to cold water. While initially, we intended to deliver the experience via a remotely operated vehicle, through a scoping review [60] we identified other potential technological implementations of underwater telepresence characterized by the trade-offs between accessibility, interactivity, as well as the complexity of installation and maintenance. Between September 2023 and February 2024, in partnership with the NMA, we ran five workshops. Activities included problem-framing, physical prototyping and educational technology demo sessions. As with the XR track, we also ran an introductory codesign workshop asynchronously with a rural workshop group in April 2024 and a further three extended codesign workshops were held with a group of students at a partner FE provider in June 2024, making nine workshops in total (Table 2). The Underwater Telepresence introductory workshop took place at the NMA and focused on identifying problem statements

and identifying participant preferences for the technology following immersive demos. The extended codesign workshops for the YP mirrored the activities first completed by the original intergenerational codesign group, but also included digital prototyping of UI elements for stimulating and relaxing underwater experiences.

F. Digital Social Games

Games may be a key technology for engaging with younger user groups that are often otherwise hard to reach as they offer interactive engaging experiences. As people get older, the technology they use will often stay with them, affecting future generations of older people, playing games using digital technology. Traditional games and play [61], including chess, board games or storytelling, have a rich history and background in learning and shared exploration of knowledge with a strong social focus, which is often overlooked in the current debate on games. Social games add a stronger social emphasis and a social component into the mix, which allows the formation or retention of communities. How can we help them keep both older and younger people engaged and contributing? One approach we envisioned is the development of a new digital social game creation framework inspired by casual game creation apps [62] such as Wevva [63] that will provide co-creation groups with the technology for understanding, exploring, and creating games while not having access to more expensive computing hard and software. As games can be quite divisive, codesign is a crucial aspect of designing the framework along with the community to cater to the needs of the entire intergenerational group.

In discussion with project partners NMA "Blue Meadow team" we decided to focus development on the topic of seagrass and its growing process. The beneficial role of seagrass as part of the local ecosystem and its ability to combat the effects of climate change identifies with the ethos and beliefs of the local coastal community. The topic also provides links to another ICONIC technology namely underwater telepresence and builds on local strengths. The codesign process for social games started in February 2024 and has been working with two groups (i) the main workshop group completing five workshops and (ii) an asynchronous group embedded within a partner completing two workshops, making seven workshops in total (Table 2). As all workshops they followed the iterative approach to knowledge generation (Figure 1) enabling the capture and integration of the codesign team's feedback and suggestions into the game development process. Game development, in general, is mainly concerned with the "construction" of the game and it is focused on bringing together elements such as game design, programming, art creation, sound design, level design and more [64] [65]. Game development for our Social Game, follows a similar approach, with most work being carried out by the development team with input from the codesign participants. The codesign team's primary role is conceiving and creating the way the game works, with a particular focus on player experience, core actions and theme.

Figure 3. Participant sharing ideas in a social games codesign workshop.

Figure 4. Working with National Marine Aquarium "Blue Meadow team" we are focussing games development on seagrass and its growing process.

G. Voice AI (Phone-based Access to Internet Services)

Nearly 40% of those 75+ in the UK had never used the internet in 2020 [66]. Providing them with phone access to the Internet is one way to address such digital inequality. But even among those with internet access, previous research has shown that older people may abandon voice assistant services on smart speakers after unsuccessful attempts [67]. We are working with older and younger participants to discover how older people with no previous computer experience want to interact with various resources. The main objective is to create bidirectional voice communication with internet services through phone calls, which can be achieved through an IP phone (IP PBX) server that is called by the DEOPs so that it connects them to the application programming interfaces (APIs) of the cloud-based voice assistants (e.g., Amazon Alexa) and services (Caller Smart Speaker API). These intelligent assistants receive voice-based instructions or questions from DEOPs and reply to them through the phone using the available information online or through the other connected service APIs.

We have explored three contexts: (i) existing audio content from Cornwall Museums that had previously been

made available via smart speaker [68] (ii) and 'social prescribing' [69]. For the initial development stage, we focussed on the local events and services, exploring the social prescribing aspect of the technology, with the view of further including other sources of information. Social prescribing is an approach to connect people to community activities, groups, and services for their health and wellbeing in primary care. For this first stage we are supported by our content-provider partners: Patientcards Help@Hand mobile application for community group information, Cornwall Link [70], a web platform managed by Made Open for AgeUK Cornwall, and local Pendeen village newsletter Outreach. As our application is location dependent, our initial development has focused on (i) Help@Hand application, running codesign workshops in St Austell area, and (ii) working with Pendeen village and their community newsletter (Figure 5).

We have been conducting codesign workshops with two groups in Cornwall starting in January 2024. Our rural community group has taken part in three codesign workshops focusing on Voice AI technology, and another group based in St Austell is taking part in workshops focusing on access to social prescribing resources in the local area, using the Help@Hand database and has so far had one workshop making four in total (Table 2). These workshops will be employing common conversational interaction design tools like Wizard-Of-Oz (WoZ) for prototyping [71]. Our pilot workshop revealed a need to explore subtle voice interaction features like pauses and intonations for natural voice interaction. We have partnered with the University of Exeter's conversational analysis group to study these features to enhance user satisfaction and engagement in the provided service. Early codesign workshops with both groups have focused on the problem statement for this technology, highlighting difficulties in coastal and rural digital infrastructure. Additional activities have included demonstrations of related technologies (e.g. smart speakers, large language models) and early-stage evaluation of phone-based Voice AI prototypes. Later workshops included prototype testing based on Anthropic Claude-3 Haiku LLM model and supported by real-time speech recognition and text-to-speech engines.

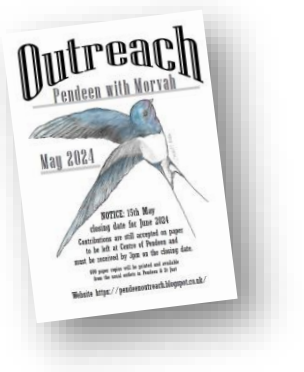

Figure 5. Voice AI workshops have been with two communities. One of these is via a community newsletter "Outreach" for Pendeen village.

H. Exit Interview, Evaluation and Analysis

Participants will be interviewed on leaving the study to gauge their assessment of the intergenerational interactions within the workshops. We will also use workshop recordings to identify patterns in how the generations work together or if there are specific technical preferences associated with either age group. Some preliminary observations from workshops for the first two technologies suggest that DEOP tend to take the role of 'directors' and let the YP do the hands-on design activities/idea presentation. We will adapt and adjust our methods to try to get the best from this aspect of the study design. The participant 'exit interview' will be used to assess whether using the four co-created technologies improved their digital access, wellbeing and sense of community and environmental connection (for DEOP), or digital involvement and digital employability (for YP) (Objective (v)). Finally, we will be discussing with the further and higher education providers among our partners how to sustain opportunities and embed these processes into curricula for their students (Objective (vi)).

V. PRELIMINARY RESULTS AND DISCUSSION

We are making progress in our aim to develop four novel technologies codesigned by intergenerational groups of people who are in some way digitally excluded living in coastal communities.

A. Recruitment and intergenerational interaction

We managed to engage 36 partner organizations and by June 2024 had recruited 95 of our target 120 participants for workshops. Our approach in offering participants direct reimbursement appears to be more successful than methods used in GOALD [12][13]. However, recruitment has been difficult due to the requirement of older participants to be digitally excluded, and the availability of YP, means that we have not yet reached the same direct intergenerational participant balance within workshop groups as other projects [72]. Attracting DEOP has required a focused effort to work with the project's partners to share ICONIC's messaging. This has proven a successful approach, as it has allowed us to set up workshops in digitally marginalized areas. In these workshops participants have articulated clear issues with the local digital infrastructure. A further barrier has been a lack of interest in the project from some groups due to the desire for more foundational access to technology, that can offer practical support for using digital technologies. This has been particularly evident with some village partners supporting our recruitment efforts but being unable to successfully recruit participants in their local communities to the project. It is difficult to recruit YP for synchronous events as they may be working or studying during daytime when DEOP want to meet, but our work to date has shown the importance of intergenerational collaboration [73]. Asynchronous codesign workshops have allowed us to expand our reach for younger participants, supported by our external partners, following techniques employed in response to the COVID-19 pandemic

[74]. Whilst this does not provide direct intergenerational interaction, we have been able to introduce the different generational groups to the other generation's respective priorities for the XR, Underwater Telepresence, and Social Games technologies. This has revealed some similarities and differences in perspectives and outlook on problem statements, ideation, and interactive components of these technologies, driving the codesign process forward.

TABLE 2. SUMMARY OF CODESIGN WORKSHOPS

Technology	**Workshops**
Extended Reality	10
Underwater telepresence	9
Social Games	7
Voice AI	4
Total	30

A further lesson from the codesign sessions is the importance, when working with digitally excluded older adults, to articulate the researchers' impartiality, and emphasize the need to learn about the difficulties. Part of this messaging involves clearly explaining that the project is not designed to promote technology, but to identify how technology can support societal inclusion and support vulnerable populations, and also identify current barriers that prevent access to digital resources for vulnerable populations.

B. Technology developments

Our XR workshops have resulted in the development of bespoke controlling and handling functionalities for the Quest 2 headset. We 3D scanned and documented artefacts for the Cotehele team as part of our partnership working. As part of the workshop held at the FE college, students were introduced to photogrammetry as a methodology for capturing 3D objects digitally. Ongoing XR workshop activities focus on addressing the integration of locomotion and interaction design elements, and to incorporate narrative and storytelling strategies on the final codesign of XR experiences.

Underwater telepresence workshops have shown a preference for an immersive, real-time experience of a local underwater environment with on-demand access to information about the surroundings. These preferences have been distilled into a prototype of a live video streaming from a static 360 camera with a backend marine life classification engine and a simple user interface (UI) delivered over the head-mounted display with interactive controllers.

For digital social games we created 6 design values, that enabled the codesign team to focus on one aspect of game design in each workshop with the last workshop being reserved for testing and evaluation. The six design values (i)Theme, (ii) Player Experience, (iii) Challenges, (iv) Decision making, (v) Skills and strategy, and (vi) Look and Feel. Our overall aim, to be pursued in subsequent workshops, is to use the approach, lessons and tools developed during the codesign process as the foundation of an open-source framework that will enable the development of similar games through a social enterprise.

In the voice AI workshops participants expressed diverse attitudes towards the application with feedback surrounding the quality of the information provided and clarity of the voice. Some concerns regarding privacy and absence of emotion awareness of the system were also expressed. As the application is still being developed, we will iterate the prototype based on participants' feedback.

C. Limitations

Finding a niche for new technology development is difficult given the rapidity of background technology developments. This is an unusual project in that we work hard to engage the digitally excluded and with them to identify novel technologies while novel technologies are most frequently designed by those deeply embedded in and at the cutting edge of technology development. We are trying to be in 'two places at once' – looking at the digital accessibility needs of those who are infrequent users of technology, trying to make sure their voice is heard by technology developers.

Our project's impact may be limited by the short timescale of digital developments. We may also be limited by the findings from this one geographical locality. It may therefore be difficult to find generalizable design recommendations, but we hope that at least the observations on our methods will be generalizable to other locations.

VI. CONCLUSIONS

Recruiting older and younger people who are digitally disadvantaged to participate in the codesign of four novel technologies that make use of regional cultural and environmental resources is a difficult 'space' to occupy. However, we are making good progress in doing that and are producing novel technologies in extended reality, underwater telepresence, digital social games and AI voice interfaces. We think it is worth the effort and through design will help to address digital exclusion. Further work is needed to explore methods such as our asynchronous approaches to intergenerational codesign in other settings. Further work is also needed to assess the impact on digital inclusion of new technologies, for example, the use of voice interfaces in social prescribing, if embedded in routine services.

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