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User Directed Translation Framework

Newly introduced technologies are often not appropriate for local social, economic and political contexts and can lead to unexpected and, too frequently, inequitable outcomes. Conventional technology development processes rarely consider these challenges, which may, and often does, result in technologies that are ill-suited to the diverse contexts of many potential users and create or reinforce unequal power relationships. While these challenges need to be addressed at all stages of the technology development process, the technology translation phase presents opportunities to refine technologies to fit diverse social, political and economic contexts and promote equitable access, use and benefits. We define *technology translation* as moving from prototypes to a technology that is ready to be widely distributed and used in practice. Here, the term *technology* refers to technical characteristics and the social aspects that determine technological outcomes in specific contexts. This paper proposes a framework for *user-directed translation* processes, the result of which is a socio-technical intervention that supports users to adapt technologies to their local contexts and promotes equitable access and outcomes. The framework aims to inform the translation stage of the integrated Participatory Technology Development (iPTD) program and to start a conversation with researchers and practitioners interested in developing equitable technologies.

In the first section of this paper, we review literature from different disciplines including science and technology studies, development studies and innovation studies that discuss technology translation processes, different forms of user involvement in technology innovation, and the socio-technical nature of technology. The second section draws on insights and concepts from this literature to propose a framework to guide user-directed translation processes aimed at developing socio-technical interventions to support users in making new technologies work equitably in their local contexts. The framework addresses the challenge of how prototypes that were (co)designed to equitably address the needs of specific groups of users in their contexts can be adapted to work for a wide range of potential users.

Literature

The role of users in technology development is extensively covered in the literature. However, the focus is largely on the early phases of technology (co)development rather than the technology translation phase (Bengtsson and Edquist, 2022; Ghasemzadeh, Bortoluzzi and Yordanova, 2022; Ensor et al., 2023). In addition, while much of the literature explores user engagement to increase the efficiency and effectiveness of commercial product development (Ghasemzadeh, Bortoluzzi and

Yordanova, 2022; von Hippel, 2007; Bogers, Afuah and Bastian, 2010), the relationship between technology development and users' social contexts, and the potential benefits of user engagement to promote equitable outcomes, remain relatively unexplored (Wailoo, Dzau and Yamamoto, 2023; Rodriguez et al., 2023). In contrast to conventional accounts of technology translation, we foreground the social aspects of technology and explore the potential of technology translation processes to bring about equitable technologies that work in diverse contexts.

Early innovation research inspired by Schumpeter (1934) depicts researchers and engineers as the producers of innovation and users as passive recipients with limited influence over innovation processes (Bengtsson and Edquist, 2022; Bogers, Afuah and Bastian, 2010; Williams, Stewart and Slack, 2005). These linear or pipeline models view goods and services as developed by formal innovators and sold to intermediate or consumer users (Bogers, Afuah and Bastian, 2010; Douthwaite, Keatinge and Park, 2000). Where users are consulted, they are primarily viewed as a source of information to inform technical specifications (Bogers, Afuah and Bastian, 2010). These traditional models focus on the material, technical features and embodied knowledge of technological artefacts with the assumption that these could be easily transferred between different contexts (Glover et al., 2019).

While the pipeline model continues to be influential, from the late 1970s, the view of technology innovation and diffusion which sees technology development as the exclusive domain of formal innovators and regards users as passive consumers is increasingly challenged (Oudshoorn and Pinch, 2005) and the benefits of user contribution to innovation are widely acknowledged (Chatterji et al., 2017). Authors note that linear views of innovation obscure the role of users in the innovation process (Bogers, Afuah and Bastian, 2010; Glover et al., 2019) and that the focus on technical specification is insufficient to inform economic and social goals (Rodriguez et al., 2023; Williams, Stewart and Slack, 2005; Malkin, 2007).

Mainstream technocratic accounts of technological change, which assume that technology can be rationally applied to meet the needs of users, are challenged by authors exploring how technology and society relate (Williams, Stewart and Slack, 2005). Rather than viewing technology as a fixed entity with embodied characteristics that determine outcomes, they see technology as composed of social and technical factors, which influence their design, use and social implications (Williams, Stewart and Slack, 2005; Glover et al., 2019). For example, Glover et al., (2019) argue that technology is best understood as a technical practice. This type of socio-technical lens lends itself to analysing the interplay between technology and society and how technologies are integrated into local technological and social systems and acquire meaning (Williams, Stewart and Slack, 2005).

Von Hippel's (1976) seminal work, which demonstrates that users can play an active role in shaping innovation, sparked interest in research on user innovation, the importance of users' knowledge and the benefits of user engagement (Ghasemzadeh, Bortoluzzi and Yordanova, 2022; Bogers, Afuah and Bastian, 2010), which has been shown to substantially benefit economic and social welfare outcomes (Bengtsson and Edquist, 2022). This body of literature on user innovation explores the role of users in informing and taking part in innovation processes (Bogers, Afuah and Bastian, 2010; Glover et al., 2019), the adoption and diffusion of new technologies and the unintended or undesired social outcomes it may cause (Williams, Stewart and Slack, 2005).

(Rogers, 1995) theory of technology adoption and diffusion, first published in 1962, inspired technological change literature exploring factors that enable or contain the adoption of technology to explain and address the low adoption rate of externally introduced technologies (Glover et al., 2019; Curry et al., 2021). For example, (Curry et al., 2021) attributed technology adoption inertia to the perceived risk of sociocultural change, information gaps and requirements to amend values, practices and behaviours. They note that technologies that are seen as a means of strengthening elements of established cultural and social order are more likely to be adopted than those that potentially disrupt it (Curry et al., 2021). The authors argue that disruptive technological change is most likely to be successful 'when tensions and conflicts, including gender and generational conflicts, require changes in socio-cultural practices and values' (Curry et al., 2021). Whether to adopt new technologies is not necessarily decided by factors such as potential economic or productivity gains but may be determined by users' perceptions of how the technologies align with local or indigenous socio-cultural values and institutions (Glover et al., 2019; Curry et al., 2021). Here, institutions are defined as the socio-cultural "rules of the game" (North, 1990, p. 3) that shape incentives, behaviour and choice (Ensor, 2023; Curry et al., 2021).

While models of technology adoption provide useful insights into technological change processes, they have been critiqued for not sufficiently capturing 'the complex reconfiguration of social and technical components of a technological practice or system' (Glover et al., 2019) and for directing the focus on the role of formal innovators as the source of innovation while presenting users' agency as limited to a reactive decision about whether or not to adopt a technology (Douthwaite, Keatinge and Park, 2000; Glover et al., 2019).

In contrast to technology adoption models, collaborative or participatory approaches to technological change focus on users' agency in designing, modifying and adapting technologies (Glover et al., 2019; Oudshoorn and Pinch, 2005, Ghasemzadeh, Bortoluzzi and Yordanova, 2022; Williams, Stewart and Slack, 2005;

Hurmelinna-Laukkanen, Nätti and Pikkarainen, 2021), and the importance of local contexts (Curry et al., 2021, Rodriguez et al., 2023, Glover et al., 2019).

Participatory approaches to technology development recognise the importance of users' particular forms of expertise, local knowledge and insights in aligning socio-technical innovations with local contexts (Rodriguez et al., 2023; Curry et al., 2021). Designing or refining prototypes directly with users in their environment reduces the need for iterative problem-solving between formal innovators and users and related communication challenges (von Hippel, 2021). This was found to enhance the effectiveness of adapting technologies to fit the local context (Ghasemzadeh, Bortoluzzi and Yordanova, 2022; Williams, Stewart and Slack, 2005; Douthwaite, Keatinge and Park, 2000). Participatory approaches combine the knowledge of technology users, researchers and other key stakeholders (Williams, Stewart and Slack, 2005; Douthwaite, Keatinge and Park, 2000). They draw on social science theory and international development practice and are commonly used in technology development projects in developing country contexts with greater cultural differences between formal innovators and communities (Rodriguez et al., 2023). These approaches lend themselves to exploring both technical and social aspects of technology and considering user preferences and contexts (Rodriguez et al., 2023). The term *community-based* participatory design is sometimes used to describe participatory approaches that are co-led by users and engage communities in all aspects of technology design (Rodriguez et al., 2023). Community-based participatory design processes may provide benefits to participants that go beyond the technology development intervention, for example as a result of their engagement in co-learning, community organising and policy advocacy activities (Rodriguez et al., 2023). However, since these approaches are very time and resource-intensive, they are not always feasible to implement at scale and the use of genuinely participatory approaches is still rare in technology design (Rodriguez et al., 2023).

Douthwaite, Keatinge and Park (2000) note that not all technology development processes require participatory methods. They argue that different technologies require different amounts of user interaction which increases with the complexity of the technology and the context in which they are introduced (Douthwaite, Keatinge and Park, 2000). The authors distinguish between knowledge embodied in hardware and disembodied knowledge that is socially constructed. According to the authors, technologies that are easy to use and do not require users to change their practices can be successfully introduced through more linear approaches (Douthwaite, Keatinge and Park, 2000). For example, seed-based technologies may have embodied knowledge that will lead to higher yields than other varieties when planted in the same way (Douthwaite, Keatinge and Park, 2000). Conversely, technologies with high technical and social system complexity and scope for modification benefit from participatory approaches to be adapted to local contexts (Douthwaite, Keatinge and Park, 2000). Williams, Stewart and Slack (2005) view this distinction as less clear-cut. They argue that while a technological device can embody the values or objectives instilled by designers, its implementation and use remain flexible and determined by direct and intermediate users (Williams, Stewart and Slack, 2005). Using a *social shaping of technology* (SST) lens (MacKenzie and Wajcman, 1999), the authors argue that while technical devices can impose particular uses and outcomes, their social outcomes are contingent on how they are governed and used in different contexts. They regard technological change as a result of complex negotiations between a range of actors with different knowledge and understanding of the context-specific utility of a technology, which challenges the view that knowledge or meaning can be built into a device and distributed to passive consumers. The authors note that “a variety of technical options are available at every stage in both generation and implementation of new technologies, which of these is selected cannot be reduced to simple 'technical considerations, but is patterned by a range of broader 'social' factors" (Williams, Stewart and Slack, 2005, page 10). Accordingly, a single device can have a range of outcomes and impacts, which makes the outcomes of introducing a technology uncertain and difficult to predict and limits the ability of formal innovators to anticipate impacts, applications and uses of technologies (Williams, Stewart and Slack, 2005; Oudshoorn and Pinch, 2005).

The introduction of new technologies can cause considerable disruption to existing social relations and practices which can impact equity and social justice (Glover et al., 2019). Critical theories highlight how power imbalances can be created or reproduced by technologies (Glover et al., 2019), which led some authors to argue for making equity the guiding principle for technology development (Wailoo, Dzau and Yamamoto, 2023; Rodriguez et al., 2023). Since the 1980s, feminist theory has been influential in highlighting the diversity of users and the exclusion of marginalised groups including women from technology decision-making and benefits (Hackett *et al.* (Eds), 2008). This focus on the perceptions, needs and barriers of groups who are routinely marginalised from technology development and use is crucial for policy and methods aimed at achieving equitable outcomes (Wailoo, Dzau and Yamamoto, 2023).

Feminist authors argue that a lack of diversity can limit the range of perspectives that inform the technology development cycle (Wailoo, Dzau and Yamamoto, 2023). They call for methodologies that pay attention to the diversity of users and locations (Hackett *et al.* (Eds), 2008) as well as intermediaries and non-users (Williams, Stewart and Slack, 2005; Oudshoorn and Pinch, 2005; Wyatt, 2005). Intermediaries, such as groups who represent users (user advocacy groups or consumer organisations), policymakers, experts or salespeople, influence and are influenced by technology development processes and new technologies in different ways (Oudshoorn and Pinch, 2005; Hackett *et al.* (Eds), 2008; Wyatt, 2005; Oudshoorn and Pinch, 2003). For example, intermediate users can act as spokespeople of users (Oudshoorn and Pinch, 2005) or employ the goods designed and manufactured by others to produce their goods or services and can be sources of innovation in their sectors (Bogers, Afuah and Bastian, 2010). Non-users also shape and are shaped by technical and societal outcomes and should therefore be considered in technology development processes (Williams, Stewart and Slack, 2005; Oudshoorn and Pinch, 2005; Wyatt, 2005). Wyatt (2005) gives the example of cars impacting their users by increasing mobility while representing a potential threat to non-users' safety. Significantly, feminist scholars highlight the role of power dynamics and conflict in technological change (Oudshoorn and Pinch, 2005). Oudshoorn and Pinch (2005) caution that "a neglect of differences among and between producers and users may result in a romantic voluntarism that celebrates the creative agency of users, leaving no room for any form of critical understanding of the social and cultural constraints on user-technology relations" (p. 16). Rodriguez et al. (2023) argue that neither traditional technocentric, nor user-centred approaches are sufficient to promote equitable outcomes and stress the need for human and equity-focused technology development approaches to improve the design and adoption of new technologies. These focus on the impact of technologies in and on the social context of users, including how new technologies can lead to unexpected inequalities (Rodriguez et al., 2023). Writing in the context of healthcare technologies, the authors argue that technical specifications are rarely sufficient for technologies to succeed. They critique the lack of exploring the role of contextual factors, power dynamics and researchers' positionality in engineering courses and argue that engineers must recognise the importance of contextual and socio-technical considerations to improve equitable outcomes (Wailoo, Dzau and Yamamoto, 2023).

Complex innovation systems connect different bodies of knowledge and practice including formal informal, local, traditional, or experiential knowledge usually held by users (Glover et al., 2019). Accordingly, Glover et al. (2019) argue that complex socio-technical design needs to either target specific populations of users or have wide-ranging affordances, which allow users to adapt it to their circumstances. According to the authors, 'an affordance is an opportunity, perceived by an agent, to put an object or material to some use', which 'arise from the material properties of an object or environment and the characteristics of the people interacting with it' (Glover et al., 2019, page 173 -174). Others have argued for the integration of technology into wider human systems by extending the focus of technology design processes beyond users to those that impact or are impacted by the socio-technical problem or the proposed technologies to address it (Rodriguez et al., 2023). Holistic systems analyses can help strengthen user innovation systems by identifying ways to go beyond traditional technology development methods, for example by relaxing or removing barriers towards modifications, open licensing, promoting a maker culture and open R&D, offering toolkits and modularity and supporting user communities, forums and user entrepreneurship (Bengtsson and Edquist, 2022).

Consumers are increasingly able to customise expensive technologies, from cars to computers and software, to meet their different use cases (von Hippel, 2021). These modular products start with a standard version and let customers add or subtract features as desired (von Hippel, 2021). The iPad is frequently used as an example of a product that has built-in flexibility that can be adapted (through software apps) to perform very different tasks that it was not originally designed for (Benade et al., 2016). Modular approaches to technology development do not rely on companies knowing specific use cases, but rather a solution space that informs the development of different modules (von Hippel, 2021). Toolkits, based on sets of standard modules, can help to present user innovators with a range of options to trial and customise products in their context, thereby shifting specific need-related aspects of the innovation process to users (von Hippel, 2021). Where users' needs exceed the limits of the solution space, they can indicate how the toolkit can be improved to expand the solution space (von Hippel, 2021). Toolkits may contain modular technical components, printed materials or, increasingly, computer interfaces that provide information where it is relevant (von Hippel, 2021). Von Hippel (2021) argues that the use of toolkits generally results in technology that is better adapted to user needs and that the use of toolkits will become very common with companies that offer customised products.

Since the user contexts and needs change over time (von Hippel, 2021), ongoing engagement between formal innovators and users may be necessary to enable iterative adaptation of technologies in the longer term. This can be achieved by setting up mechanisms for continuous collaboration. These can work through intermediaries, as in the case of agricultural extension workers creating a link between formal innovators and farmers (Douthwaite, Keatinge and Park, 2000) or directly, for example through online platforms. The Internet has made it cheaper and easier for technology users to collaborate with other users and formal innovators (Ghasemzadeh, Bortoluzzi and Yordanova, 2022) and collect public inputs through online platforms (Mahyar, 2020). However, online platforms may fail to reach marginalised groups (Mahyar, 2020). Mahyar (2020) argue that data collection needs to be inclusive and representative to reflect the values, priorities and needs of diverse groups of people but that this is rarely the case.

A framework for user-directed translation

The benefits of technology are often unevenly shared as conventional approaches to technology development routinely and often inadvertently disadvantage some groups of users. To address this challenge, we consider how technical and social aspects of technology design and use can be shaped to produce equitable access to and benefits from the technology for all potential users. In the following, insights from the literature reviewed above are combined into a framework to guide user-directed translation of technologies.

The literature reviewed above highlights several considerations for developing a framework for UDT:

- Technologies are composed of social and technical factors that determine their adoption, use and outcomes (Williams, Stewart and Slack, 2005; Glover et al., 2019)
- The adoption of new technologies is frequently linked to the alignment of their social and technical aspects with existing local institutions or a widespread desire for socio-cultural change (Curry et al.,2019; Glover et al., 2021)
- Intermediaries and non-users impact and are impacted by technologies and are key stakeholders in adapting technologies (Williams, Stewart and Slack, 2005; Oudshoorn and Pinch, 2005; Wyatt, 2005)
- The knowledge, expertise and insights of potential users (and non-users that may be impacted by the technology) are essential to designing or adapting technologies to fit their specific contexts (Williams, Stewart and Slack, 2005; Oudshoorn and Pinch, 2005; Wyatt, 2005)
- Participatory approaches can promote users' agency to align technologies and local contexts (Ghasemzadeh, Bortoluzzi and Yordanova, 2022; Williams, Stewart and Slack, 2005; Douthwaite, Keatinge and Park, 2000)
- Technology design (including institutional arrangements governing deployment of technical components) impact on equitable use and outcomes of technologies (Ensor, 2023; Wailoo, Dzau and Yamamoto, 2023; Wailoo, Dzau and Yamamoto, 2023)
- Methodologies aimed at promoting equitable outcomes need to pay attention to power dynamics and the diversity of users (Ensor, 2023; Oudshoorn and Pinch, 2005; Glover et al., 2019)
- Systematic barriers to adapting and using technologies need to be identified and addressed (Wailoo, Dzau and Yamamoto, 2023).
- Modular approaches to technology development can enable users to adapt technologies to their local context (Bengtsson and Edquist, 2022; von Hippel, 2021)

In the following, we draw on these findings, to construct a framework for user-directed translation that considers social and technical aspects of technology as well as the diverse and changing needs of potential users and promotes equitable benefits. The framework is intended to guide the design of user-directed translation processes to develop and pilot interventions that support users to consider social and technical aspects of technology, direct how technologies are adapted to their context and deliberately consider how benefits can be shared equitably. We outline methods that support users to refine specifications for technical hardware, integrate this hardware in different social, political and environmental contexts and to consider potential social impacts. The framework informs the user-directed translation (UTD) stage of the integrated Participatory Technology Development Project (iPTD) in Vanuatu and aims to initiate a discussion on methods for user-directed approaches to develop equitable technologies.

The iPTD project addresses the problem that community-managed drinking water sources in remote communities in Vanuatu are at a high risk of contamination, particularly following disasters. In the first project phase, the authors co-developed a new technology to detect drinking water safety with four remote, rural communities and other stakeholders in the Pacific Island country Vanuatu. This technology enables communities to identify which of their water sources are safe to drink at any one time. The technology consists of a prototype water-testing device with modular elements that can be adapted to suit the needs of each community as well as context-specific institutional arrangements to govern the device. These arrangements include rules on who uses and maintains the device, how information about water quality is shared between community members, and how funds are raised for maintaining the device and purchasing consumables. The process of developing these context-specific socio-technical packages involved a range of creative, participatory and user-driven methods as outlined in Ensor et al. (2023).

The UDT phase aims to translate these context-specific prototypes into viable socio-technical interventions that can be implemented in diverse social, economic and political contexts to support communities to adapt the technology. Many of these contexts will differ from those in the communities in which the prototypes were developed. The goal of UDT is to create equitable technologies: technologies that allow equitable access and provide equitable benefits to all users.

A practical approach to achieving equitable socio-technical outcomes in a range of contexts calls for methods that allow technical specifications and social governance arrangements to be adapted to fit diverse local needs. The aim of UDT is therefore not to produce a single technology but rather a flexible socio-technical intervention that can be implemented by outside stakeholders to introduce and adapt the water safety testing technology to new communities. This package will include guidelines for facilitators to support community members in adapting the modular technical

features of the water safety testing device and to agree on governance arrangements that fit the local context and promote equitable outcomes.
The user-directed translation phase therefore consists of several interlinked components:

1. Refining the technical specification for the device and identifying if additional modules are necessary to suit a wide range of contexts
2. Developing, piloting and consolidating institutional models to govern the device in different contexts
3. Piloting methods to support communities in combining technical modules and equitable institutional arrangements to govern the device

The user-directed translation phase is preceded by the co-development of the prototype with four communities (Ensor et al., 2023) and followed by an implementation phase in which the resulting socio-technical package will be rolled out to over 2000 communities in Vanuatu, which will provide over 300,000 people with ongoing access to information about the safety of their water sources. This is likely to lead to a significant reduction in waterborne diseases and child mortality across the country.

Recognising the diversity of contexts and the socio-technical nature of technology, communities need to be able to adapt technical and institutional aspects of the technology to suit their local contexts. In addition, technical and institutional features may promote equitable benefits in one context but not another. Accordingly, many technologies need to be adapted to be used in different contexts to ensure equitable access and produce equitable benefits. UDT methods therefore need to consider how communities can be supported to adapt the technical and institutional aspects of the prototype to fit their needs. This may take the form of a facilitated, participatory process that guides users in adapting the device and developing related institutions with the aim that the device will work equitably in their local context. We use the term user-directed to describe this process to highlight the leading decision-making role of community members who will use the technology in actively choosing and adapting technical and institutional characteristics.

Since technical and institutional requirements differ between contexts, it is unlikely that one technology will be universally appropriate. Modular approaches are well-suited to customise socio-technical products to different requirements and contexts. However, infinite modularity, particularly in technical aspects of the technology, is rarely feasible at scale. The UDT process, therefore, needs to determine a level of irreducible technical and institutional modularity that is likely to allow all potential users to find a modular option that works in their contexts.

In the following, we discuss how the interlinked components that make up the UDT intervention will be piloted in practice as part of the iPTD project:

1. Refining the technical specification for the device and identifying modules necessary to suit a wide range of contexts

In the iPTD project, the co-development process included the design of a base model device and a limited number of modules that can be interchanged to meet the specifications requested by the different participating communities. For example, one community wanted the device to display detailed information about the quality of their water sources while another preferred a simple safe/not safe/inconclusive traffic light display.

In the technology translation phase, prototypes are piloted and refined in successively larger groups to gather feedback on the suitability of the device in different contexts. Since these initial prototypes have been co-developed with a small number of communities in their specific contexts they may require additional modular adaptation options to meet the technical specification requirements of communities in different contexts. The UDT phase will aim to identify the crossover in technical requirements between communities and the minimum number of modular options necessary to address them across communities. The pilot project will explore whether it is possible to narrow down modular options to a point where the technology can be adapted to fit every context likely to be encountered in the implementation phase.

This process of refining the technical specification of the base model prototype and its modular options will be less time-intensive for participants and researchers than the initial technology co-development phase (Ensor et al., 2023), which makes it possible to engage a much larger number of communities in the UDT phase. As the prototypes are refined the focus shifts from further refining technical specifications to choosing which existing specification would produce the desired outcome in the local context. While formal innovators may still provide technical inputs in the early stages of UDT, their input is no longer required in the implementation phase.

2. Develop and pilot methods to support communities in adapting the device to work in their local context

A modular approach can also be used to support communities in choosing and adapting technology governance institutions that fit their local context. In the first phase of the iPTD project, community members participated in a facilitated process to develop mechanisms to govern the water safety testing device (Ensor et al., 2023). This included rules, roles and responsibilities that govern, for example, how the device is used and maintained, and how results are shared and acted upon. In the early stages of the UDT phase, this exercise will be conducted with additional communities and diverse contexts to identify common governance mechanisms to promote equitable technology access and benefits. These are analysed and synthesised and will be combined in a toolkit of institutional modules to serve as inspiration for communities to identify or develop governance arrangements that would deliver equitable outcomes in their local context. In the implementation phase, facilitators support communities in combining governance arrangements to fit their context, which may lead to the creation of new institutional arrangements or expand the role of existing local ones. As discussed above in the context of technical specifications, the development and piloting of a toolkit with institutional options as part of the translation process will progressively reduce time requirements on community members and researchers.

3. Develop and pilot methods to support communities in developing equitable socio-technical institutional arrangements

Due to the diversity and complexity of social and political contexts, additional methods may be required to support communities in achieving context-specific, sustainable and equitable outcomes. The UDT phase provides a platform to pilot and refine the methods outlined above and identify how to best support communities in adapting technical and social features of the technology to produce equitable outcomes in their contexts. This may, for example, include facilitated discussions in disaggregated groups that can support participants to consider how social and technical components interact to explore different combinations of technical and institutional modules. For the technology to generate equitable outcomes in a range of contexts, technical and social aspects need to be deliberately considered with a view to anticipate and avoid unintended outcomes such as creating or reinforcing inequitable power relations. Facilitated processes can support community members to jointly explore fundamental questions including why equitable outcomes are desirable in their context and how they can be achieved. Comprehensive training of facilitation teams including facilitation training and implementation practice in communities will be provided by the iPTD project team. The device is designed in a way that it could be manufactured and repaired in-country which creates opportunities for partnerships with local private sector actors.

The outcome of the UDT process is a socio-technical package that enables the distribution of the technology at scale and, at the same time, supports communities to adapt it to their local context. This includes the development of guidelines for facilitators to lead workshops that support communities in choosing, adapting and/or creating socio-technical characteristics that fit their context and produce equitable outcomes. A range of participatory and creative methods are piloted and chosen during the UDT process and detailed guidelines are provided in a facilitation guide. In addition to offering methods aimed at supporting participants in combining technical and social aspects of the technology, the guidelines include methods to choose representative groups of participants, develop a shared language, build relationships and trust, reduce power imbalances between participants, ensure participants with diverse experiences and knowledge are able to contribute to the discussions and identify problems, goals and possible solutions. A collection of practical example tools addressing these categories is available on the authors' website: www.york.ac.uk/sei/equitable-tech/methodsandtools/). A participant handbook will provide information on technical modules and a range of case studies of institutional arrangements in different contexts, amalgamated from common institutional arrangements developed during the translation phase. Workshop participants will also map and discuss the role of other stakeholders within the community and at other levels who may be relevant to the successful implementation of the technology. This enables participants to identify enabling factors and barriers to successful, equitable technology use and devise strategies to address them.

Since contexts are subject to change over time, users need to be able to adapt and improve the technology beyond the initial intervention. UDT processes need to consider how the socio-technical package can create conditions for future adaptation processes after the technology has been introduced. This may take the form of technical designs that encourage further modification and a focus on enhancing community skills to develop and adapt social institutions. User forums (for example through online discussion forums or WhatsApp groups) can also provide ongoing opportunities for users, intermediaries including workshop facilitators and formal innovators to share and discuss technical and social aspects of the technology. Ongoing engagement may encourage users to innovate and alert the formal innovators to contexts in which further refinement of the socio-technical package is needed.

Many communities in Vanuatu have little engagement with the cash economy, which makes it unlikely that the device along with the workshop to customise its socio-technical features could be financed by communities. To ensure that the technology benefits a large number of communities in Vanuatu the business model for UDT and the resulting diffusion of the socio-technical package requires donor support to fund intervention and hardware. The implementation of the socio-technical package at scale could be part of existing community engagement initiatives by the Vanuatu government or NGOs or be carried out by local consultants as a standalone project. In addition to direct benefits to communities, the implementation phase provides opportunities to monitor and report water quality in all communities to inform DoWR decision-making and prioritisation of support. UDT interventions also need to identify broader stakeholders at different levels who may be relevant to the successful implementation of the technology such as intermediaries, government departments or private sector companies and explore if and how they can be engaged in collaboration processes.

The UDT framework outlined above aims to guide the development of a socio-technical package that can be implemented at scale. This package provides communities with tools to adapt the socio-technical characteristics of a drinking water safety testing technology to suit their local context and achieve equitable outcomes. Implementing user-directed translation in a wide range of circumstances makes it possible to narrow socio-technical options, which makes it feasible to support a large number of communities to adapt technologies and promote equitable outcomes.

Further research and development of methods is necessary to explore the practical implementation of user-directed translation and the impacts of the resulting socio-technical interventions in different contexts, including their impact on local power structures. Pilot projects are needed to determine whether it is possible to identify minimum numbers of technical and institutional modules to suit most or all contexts and whether it is possible to identify processes that drive equitable benefits. The development of toolkits and facilitation guides containing a range of methods may also serve as a starting point for other projects aimed at adapting technologies to diverse contexts.

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