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From the Sustainable Perspective:Participatory Design in Developing Countries

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Abstract. This paper evaluates a typical participatory design project for water management in Africa from the sustainability science perspective through an object-process-subject based analytical model. The conclusions show that the project exemplifies the object hierarchy, process iterations, and complex interactions among subjects of sustainable development. Object hierarchy implies the principle of intra-generational equity in a global context and reconciling sustainable development's environmental, economic, and social dimensions. Process iteration comes from the six iterative cycles of the participatory design process, stimulating real needs and broad participation. The total consideration of the local nature and complexity of the subject is conducive to the coordination of different stakeholders. The model's analytical results and shortcomings provide effective lessons for sustainable participatory design in developing countries.

Keywords: sustainability science; participatory design; technology and humanity.

1. Introduction

Safe drinking water and sanitation are critical to poverty reduction, sustainable development, and even the achievement of any of the Millennium Development Goals. However, access to safe drinking water is difficult in many rural areas of Africa due to the lack of effectiveness and enforcement of governance mechanisms in practice and the fragmentation of authority at lower levels of the operational process [1]. This has placed demands on water resources management, requiring further improvement of legal provisions, enhancement of state cooperation, resolution of water resources ownership disputes, and reduction of public water diversion [2].

The key challenge for water management in developing countries is obtaining reliable, real-time information and using how to obtain reliable, real-time information and use it to guide policy development [2]. Lack of timely data updates and fragmentation are important challenges for water resources management [3]. Uganda has undertaken several Information and Communication Technology (ICT) projects, which are technology interventions aimed at improving public governance and information transparency and are often facilitated and financially supported by international organizations. However, due to the lack of long-term financial, personnel, and technical support, as well as the difficulty of fitting external assistance into the local social structure, most of these projects ceased to function after some time.

The PM4W (pay me for water) project inspires to break Uganda's water management dilemma. The project aims to manage public water resources in rural communities through ICT and uses a participatory design approach to facilitate the continued operation of the technology. This paper assesses the project's sustainability from the perspective of sustainability science using an object-process-subject based analytical model. The conclusions show that the case demonstrates object hierarchy, process iterations, and complex interactions among subjects of sustainable development. However, the project still has some problems. Due to the involvement of multiple ICT assistance projects, the water management model, which uses various standards and multiple technical tools, is too fragmented to integrate information at a national level. Researchers' departure has also created difficulties in equipment updating and project tracking.

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2. Method

2.1 Sustainability Science: An Analytical Model Based on Object-Process-Subject

In order to better integrate the economic, social, and environmental dimensions of sustainable development and to strengthen the link between sustainable development research and governance, Zhu [4] proposed a conceptual model of sustainability science based on object-process-subject as an analytical framework for sustainable development theory and practice. The model considers sustainability science as an integrated theoretical model and analytical approach to sustainable development, focusing on the integration of three aspects: objects (economy, society, environment), subjects (government, enterprises, social organizations), and processes (state, pressure, response).

Based on the object perspective, the model breaks the weak sustainability view of the neoclassical scripture continuation and emphasizes the balanced development of the three dimensions of sustainability (economic, social, and environmental), i.e., when dealing with sustainability issues, it first determines the ecological scale of resources and environment that can be consumed, secondly determines the per capita possession of resources and environment, and finally increases efficiency through the price mechanism. This requires attention to ecological equity issues in both developed and developing countries and the long-neglected issue of social benefits. Based on the process perspective, the model uses the PSR (Pressure, State, Response) approach to diagnose and analyze sustainability problems, thereby discovering the complex cause-and-effect relationships among the economic, social, and environmental aspects of sustainable development and deriving real and effective solutions. Based on the subject perspective, the model emphasizes the role of hybrid organizations in sustainable governance. Integrating stakeholders based on shared awareness and common actions leads to collaborative governance. The model integrates the object, process, and subject of sustainable development and provides an effective analytical tool for sustainable development governance issues “Fig. 1”.

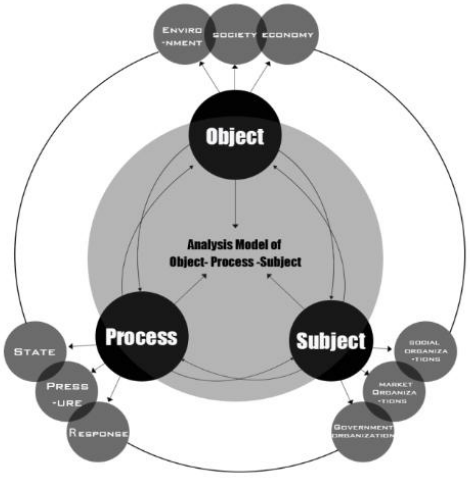

Fig. 1 The analytical model based on Object-Process-Subject

2.2 Case Study: PM4W (pay me for water) Project

The failure of many ICT projects illustrates Uganda's challenging nature of technology interventions. PM4W (pay me for water) was created as a response to the dilemma of unsustainable results, technical rejection by residents, and confusion in community water management systems and is a typical example of participatory technology intervention in developing countries. The project, which took place between June 2014 and May 2015, was a collaboration between the University of Cape Town and the Water Authority of Kabarole District, Uganda, to develop a water

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management application, PM4W, for local rural communities to improve water management efficiency [5]. This paper uses an object-process-subject based analytical model to assess the sustainability of this classic project. The integrated analysis provides experiences and inspiration for water resources management in developing countries.

3. Results

3.1 Object Perspective: Strong Sustainability Linkages between Environment, Society, and Economy

What the PM4W project changed was the paradigm of water management without generating new productive energy consumption. The data-based water use information creates an efficient link between the water supply side and the water use side, significantly improving the efficiency and accuracy of local pipeline maintenance, construction of new water points, and financial division of water use in administrative districts [6], increasing the utilization of water resources and government financial expenditures, and increasing people's well-being.

It is essential to note that the political institutions and civic education in developing countries are not well developed compared to developed countries. Uganda's attitude toward technology is not optimistic due to the lack of awareness of sustainable development and related technologies and the lack of professionals to manipulate technology [7]. Therefore, for researchers with PM4W, it is crucial to fully understand the context in which technology is used and the people who use it, but more importantly, how to help local people in Uganda overcome their fear of technology and realize the benefits it can bring to them. This process can be called technology empowerment and falls under social sustainability.

Over time, participants became increasingly proactive in sharing their knowledge, making suggestions, expressing their opinions, and coming to realize that they could benefit, that they were capable of contributing, and that their contributions were valuable [8]. In addition to increased self-efficacy, after the program, some participants expressed a strong interest in science and technology, facilitating subsequent technical support projects and the local application of technology for emerging development. At the same time, this interaction of technology learning reveals implicit human-technical relationships and social networks that contribute to broader technology development [9].

3.2 Process Perspective: Whole Process Thinking of State, Pressure, and Response

Uganda faces a complex dilemma in water resources management. The external difficulty is because technical assistance in Uganda comes mainly from NGOs, and the results of external aid are often unsustainable due to frequent funding shortages and staff turnover. At the same time, initiatives by external agencies are hardly ever genuinely involved with regions and governments and often serve only as a short-term corrective measure. The internal dilemma is that the local context and cultural environment must be fully considered when implementing ICT in developing countries due to lower literacy and technology levels[10]. Lack of data updating mechanisms or lack of interaction between researchers and practitioners during the design phase can also exacerbate the rejection of technology by local villagers [11]. Therefore, the essence of technical intervention is the coordination of different stakeholders and dealing with this relationship not only helps to solve the organizational and cultural problems of ICT projects but also influences the project progress and the subsequent usability of the system [12] [13] [14].

Based on the above status and pressures, the researchers and participants developed a water management app through participatory design and conducted six iterations of action research “Fig. 2” through semi-structured interviews, workshops, and focus group discussions “Tab. I”.

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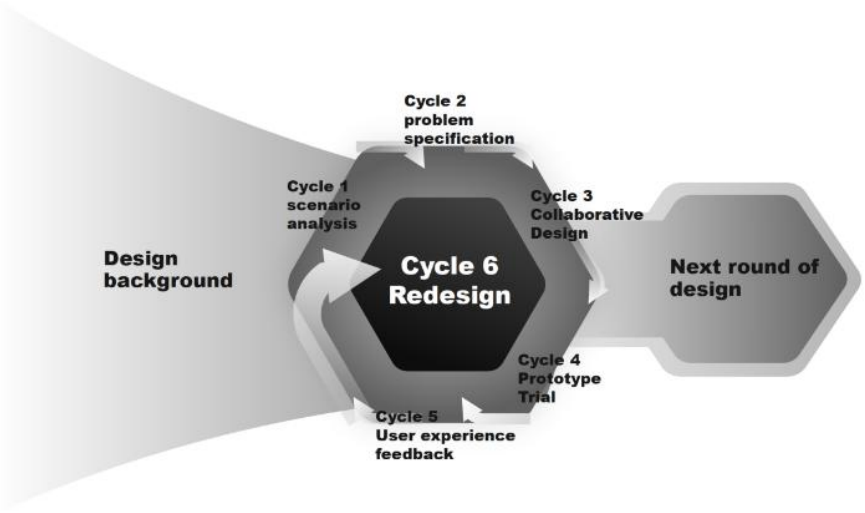

Fig. 2 Flow chart of 6 design iterations

Table 1. Design Process

Cycle	Title	Content
1	Scenario Analysis	Using stakeholder analysis, the researcher found that the project's core mission was to build a sustainable financial management system for water use that would provide efficient, convenient, open, and transparent technical support for water users and managers.
2	Problem Specification	The groups with different identities analyzed their own structures and roles in community water use and worked together to define the design requirements after defining the community's water management system. The requirements include user records, payment of fees, reminders for payment, and billing disclosure.
3	Collaborative Design	Participatory design provides a space for joint co-creation, coordinating input from all parties through improved high-fidelity models and testing whether the process can meet community requirements.
4	Prototype Trial	Ten participants, including six water watchers and four accountants, participated in the prototype test and skills training.
5	User Experience Feedback	Six months after the program was put into use, the research team analyzed the experience of ten participants through semi-structured interviews. It concluded that the program had language barriers and low usage problems in some areas.
6	Redesign	Through the co-design workshop, participants identified the new need for the program to focus on localization. The latest version of PM4W supports a local offline database to accommodate poor local communication networks and provides English and a local language, Rutooro, to ensure majority access. At the same time, 20 water managers were trained to use the program and will continue to serve as local technical advisors.

3.3 Subject Perspective: Shared Consciousness and Pluralistic Action in Hybrid Organizations

In Uganda, Africa, rural water facilities are managed through a community-based management model [15]. Water source caretakers (people who live near the water source and are jointly elected by community members) are responsible for community water records and collection of water fees, which are turned over to the community water council and become a community savings fund. With

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the need to manage records manually, an arrangement prone to data loss, and a lack of clear accountability and transparency, communities are becoming increasingly apathetic about public water management.

The research team and forty participants worked together on the design. Twenty-two are water source caretakers, eight are also responsible for the maintenance of water supply equipment, and six are water board treasurers who supervise the caretakers. Eight representatives of community residents are elected by the caretakers of each community. Two district water officers manage water in the district. One community development specialist, who is the community-level representative of the Ministry of Water and Environment in Uganda. One representative of Non-Governmental Organization. The participants ranged from 25 to 65 years old, with an average age of 43. Thirty-five percent of them were women [16]. Participants in the first cycle represent national stakeholders. Participants in cycles 2 - 6 represent community stakeholders.

In the complex context of people, the research team decided to adopt the Community-Based Co-creation approach. This participatory design approach applies to designs involving multiple subjects. It brings together different groups in the community, allowing them to reach an understanding as they learn from each other and participate together [17]. It provides a voice for marginalized populations [18]. At the same time, it constructs a common norm between external researchers and internal community members that evolves and develops through communication and understanding, implicitly embodying the principles of reciprocity and respect [19].

4. Discussion

4.1 Hierarchy of Sustainable Development

4.1.1 Regional Hierarchy - An Intra-Generational Equity Perspective

If viewed according to the standards of developed countries, the project does not meet environmental sustainability requirements. Still, considering the actual situation in Uganda, this type of development that does not add additional energy consumption and improves the utilization of existing resources meets the requirements of local, sustainable development. In the face of a severe existential crisis, safeguarding the local right to safe water without causing environmental damage is a reasonable choice under the principle of the regional hierarchy of sustainable development. Principle VI of the Rio Declaration on Environment and Development emphasizes the regional hierarchy of environmental sustainability in the global context, whereby developed and developing countries have common but differentiated responsibilities concerning environmental sustainability. For the poorest countries or regions of the world, their basic needs for survival and development should be respected and supported as the basis for intra-generational equity. According to the levels of developed, middle, and developing countries, environmentally sustainable development criteria can be expanded into scalable, sustainable, and deterioration-mitigating development. This reflects the value orientation of pluralistic and equitable sustainable development and contributes to achieving sustainable development in a global context at multiple levels [20].

4.1.2 Object Hierarchy - An Empowerment Perspective

For developing countries, "development" is the core of sustainable development, and eradicating social poverty and improving people's living, education, and health are the primary tasks facing developing countries. Safe water is a fundamental human right and central to sustainable development, essential to poverty eradication, and closely linked to health, agriculture, energy, and biodiversity. Despite the large amount of water infrastructure built by the international community in Africa, the status of safe water in rural areas remains a concern, as the problem of access to water in rural areas is apparently technical but is socially and politically motivated [21]. Social sustainability is, therefore, a central concern in addressing the issue of safe water in Uganda. The project is significant not only for its success in providing technical tools for local water

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management but also for raising the awareness of the local population to learn about technology and embrace it, contributing to future technological interventions, and potentially changing the local development paradigm.

4.2 Stakeholder locality

A new structural system can be unconventional when implemented in other regions [22]. Therefore, external technological interventions should be integrated into the policy system and the original organizational structure as a complement, not a substitute [23]. Researchers can use the cultural information collected as a starting point for research and use low technology exposure and a strong sense of community as principles for technological interventions in developing regions [9].PM4W did not disrupt the original local water management structure and was integrated into the existing government structure in a low-impact manner. And after the study team left, Conquest Point water officials were able to conduct regular meetings and training for local community members, maintain communication and contact with the community, provide them with service support, and help them use and adapt the system, which allowed the community's water management system to operate independently of the intermediaries [5].

4.3 Shortcomings

PM4W has inspired water management in developing countries, but some problems exist. Due to the lack of sufficient funding and workforce, PM4W does not cover the whole country and can only improve water resources management on a regional basis. There are many other similar projects within Uganda, and the lack of uniform standard technical tools and data types hinders uniform management at the national level. In addition, although the researchers trained some local people and stimulated their interest in learning and using the technology, the system has not been updated to date. Project tracking is difficult because they do not have access to the technology.

5. Conclusion

From the perspective of sustainability science, this paper assesses a typical case of participatory design in Africa through an object-process-subject-based analytical model. Based on the model's findings, the article focuses on the object hierarchy, process iteration, and complex interactions among subjects of sustainable development, providing lessons for optimizing resource management and providing technical interventions in developing countries. Object hierarchy means that the principle of intra-generational equity is followed globally. Countries with different levels of development have different development goals and judging criteria for environmental sustainability and bear common but differentiated responsibilities. At the same time, when addressing sustainability issues in developing countries, attention should be paid to social sustainability, which is conducive to fundamentally promoting a change in the development approach. Process iteration means that participatory design brings stakeholders into the core discussions of the design during the cycle of the iterative cycle, directly aligning with the needs and keeping participation open and free. The complex interaction between the subjects illustrates that when coordinating different stakeholders, the locality is an important condition for the project's success, and the intervention of methods and technologies needs to take into account the local cultural and social elements. The Community-Based Co-creation approach can effectively resolve conflicts when facing complex interest groups. The shortcomings of this case also provide us with a warning.

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