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Interlinking open science and community-based participatory research for socio-environmental issues

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This paper discusses how open science can be interlinked with community-based participatory research (CBPR) to address socio-environmental issues. By reviewing three case studies in Japan, the authors developed a theoretical framework to span these inter-actor boundaries by (1) discovering and sharing goals that actors with different interests could tackle together (the transcend method); (2) considering ethical equity with special attention to empowering marginalized (or 'small voice') actors; (3) developing fair data visualization based on the FAIR Data Principles and (4) facilitating dialogue. A civic tech approach, in which civic engineers develop a solution to local issues by using open governmental data and information and communication technologies, is applied. This framework will reflectively be tested using case studies.

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Introduction

Top-down and bottom-up actions of open science

Open science is a conceptual complex of top-down and bottom-up movements. The top-down approach stems from the G8 Science Ministers' Statement in 2013. In 2015, the OECD report [1] defined open science as "efforts to make the output of publicly funded research more widely accessible in digital format to the scientific community, the business sector, or society more generally." In this context, and as described in the Open Definition (URL: https://opendefinition.org), the word 'open' refers to "data and content that can be freely used, modified, and shared by anyone for any purpose". Bottom-up actions include citizen science, defined in the Oxford English Dictionary as "scientific work undertaken by members of the general public, often in collaboration with or under the direction of professional scientists and scientific institutions" [2••,3•], and crowdfunding science [4]. These top-down and bottom-up actions are oriented to trans-sectoral collaboration between academia and society [5]. In short, open science is a movement to bring more inclusivity to the scientific knowledge production system.

Community-based participatory research

The Sustainable Development Goals (SDGs) Target 17.16 aims to enhance the global partnerships for sustainable development, complemented by multi-stakeholder partnerships that mobilize and share knowledge, expertise, technology, and financial resources (URL: https://unstats.un.org/sdgs/metadata/?Target=17.16). Associated with the emphasis on partnership of the SDGs, 'science with society' is a conceptual foundation in issue-driven and solution-oriented research to address real world problems that cannot be managed with a scientific approach alone [6,7,8•]. To this end, a transdisciplinary (TD) approach [9,10] and translational/transformative community-based participatory research (CBPR) [11,12,13•] are applied. In these approaches, research experts and societal stakeholders such as governmental agencies, industries, non-profit organizations, and civil members adopt co-leadership roles to reach decisions and solve

issues by co-designing research agendas, co-producing knowledge, and co-disseminating the results [14]. During this process, joint learning and integration of knowledge through mutual understanding between different actors is of particular importance [15,16,17•].

Trends in civic tech and research questions

Recent trends in the concept of open government stem from the memorandom released by U.S. President Barack Obama in January 2009, which emphasized the importance of transparency, participation, and accessibility for governments (URL: http://opengovernmentinitiative.org) [18,19]. Open government is practically implemented using the civic tech approach, where voluntary civic engineers create solutions to social issues by using information and communication technologies (ICT) and open government data [20].

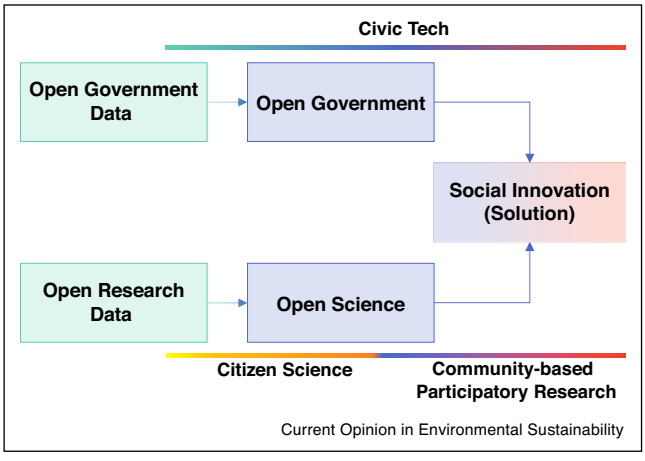
The civic tech approach can provide analogical evidence to joint citizen science and CBPR to enable actionable research for social innovation using open research data (Figure 1). Here, we aim to determine how this approach can be realized and what are the key points for implementation. To address these meta-research questions, we reviewed and compared three recent CBPR projects addressing local socio-environmental issues in Japan, paying special attention to (1) the background to the issue, (2) major stakeholders, (3) participants involved, (4) goal(s), and (5) openness of the project.

Recent socio-environmental CBPR cases in Japan

Participatory monitoring of alien plants in the Aso-Kuju National Park, Oita

In Kokonoe Town, part of the Aso-Kuju National Park, southwest Japan, an alien invasive plant (*Rudbeckia laciniata* L.) was recently introduced and quickly had a negative influence on local biodiversity. Local stakeholders, including governmental agencies, tourist associations, and naturalists, were fully aware of this problem. To address this ecological issue, one of the authors (Osawa) developed a data collection tool [21], and local civic participants used it to collect geospatial data for this species. These data were used to develop a management plan, which successfully reduced conflicts among stakeholders [22]. The data were disclosed as open data in a scholarly publication [23]. In this project, expert ecologists and non-experts contributed equally. In this collaboration, non-expert participants, as well as experts, were able to check and validate data, and even monitor the status of the plant.

Figure 1



Two pathways to connect open data to social innovation: open government and open science approaches.

Waterweed composting in the Lake Biwa catchment, Shiga

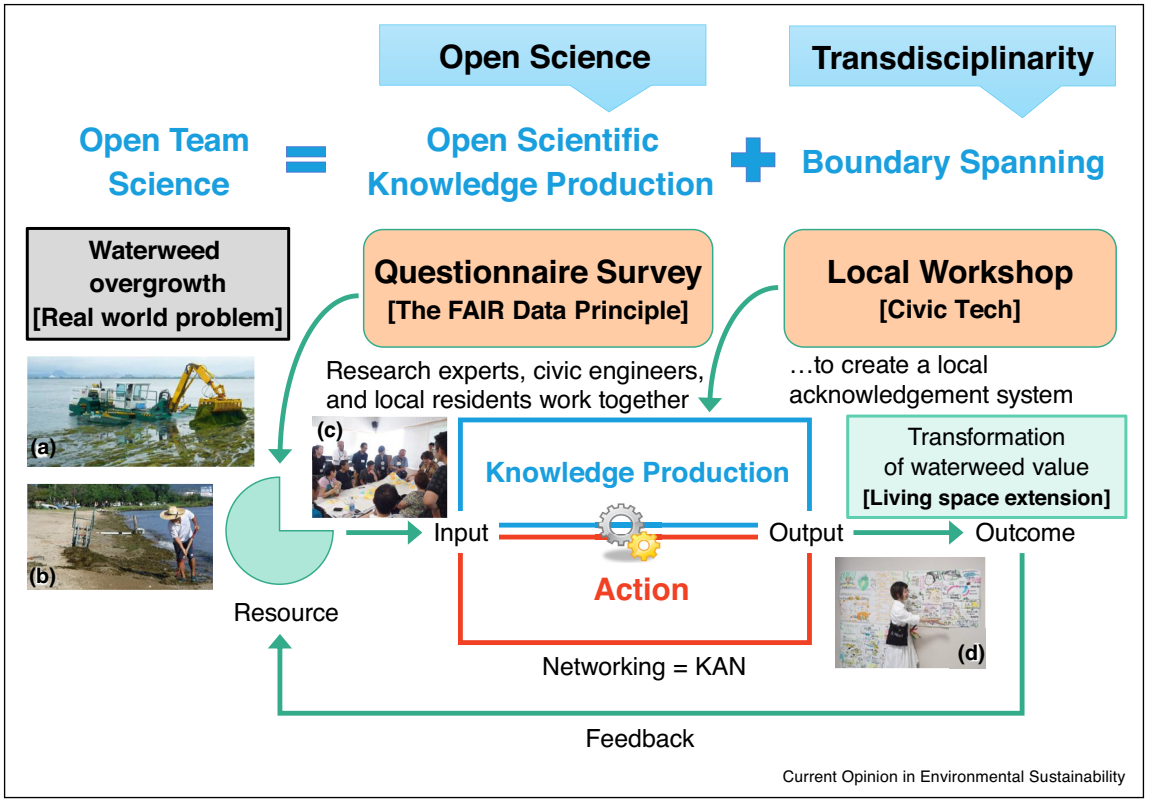
In Lake Biwa, located in Shiga Prefecture, mid-west Japan, waterweeds such as *Potamogeton maackianus* (endemic species) and *Egeria densa* (invasive species) have been proliferating year after year since a water drawdown in 1994 [24]. This issue was characterized by different values among stakeholders. The prefectural office, responsible for preserving the lake, removes overgrown waterweeds (Figure 2a) and composts them. However, once waterweed has drifted ashore, it becomes a social issue due to bad odors and waste, as claimed by coastal residents at the municipality offices in charge (Figure 2b). A postal questionnaire survey (URL: http://www.chikyu.ac.jp/e-rec/BiwakoSurvey2018Results.pdf) revealed that most of the unengaged public (including local taxpayers) seemed to be disinterested in this complex socio-environmental problem, although they expressed a high appreciation for the Lake Biwa environment.

To tackle this complex problem, we helped developing an actionable community and held four civic tech workshops with the participation of government employees, local residents, civic engineers, and graphic recorders (Figure 2c, d). The results of the above-mentioned survey results served as initial input. Through these workshops, some active participants decided to develop a fintech-based system to promote and acknowledge voluntary labor for cleaning beaches and making compost. Although the workshops were semi-closed, new connections expanded the community, and the process was made transparent through Facebook and blog posts.

Community-based managed water supply in Hokkaido

Sustainable management of the water supply system in areas with shrinking populations is a potentially serious social issue in rural areas of Japan, particularly in Hokkaido, a northern island. Local government functionalities are also being condensed and therefore it becomes more difficult for the public sector to provide sufficient water infrastructure management.

Figure 2



Concepts and workflow of a community-based approach for waterweed composting in the Lake Biwa catchment, Japan. Photograph **(a)**: a specially manufactured workboat removes overgrown waterweed in Lake Biwa (courtesy of the Lake Biwa Environmental Conservation Division of Shiga Prefectural Office); **(b)**: a local volunteer removes drifted waterweed from the shore in front of his guesthouse (courtesy of Eiji Yamada); **(c)**: a workshop held at the city on shore of Lake Biwa with participation of research experts, civic engineers, municipality officers, local business people, and residents. **(d)**: a graphic recording facilitates conversations during the workshop (graphic facilitator: Yuu Aruga).

To address the above-mentioned issues, the SIP water infrastructure project (see Acknowledgement for the full title), coordinated by one of the authors (Ushijima), pursued a best practice of community-based managed water supply (CBMW), focusing on local small-scale (i.e. 10–100 households) potable water supply systems [25]. The SIP project considered these to be a promising model for sustainable water infrastructure management in shrinking socio-economies. The project found that CBMW was possible in cases where agriculture-related skills, machines, and community and social networks were available. However, it also revealed their weakness, namely a high dependency on the quality of the water source and preventative barriers to reduce health risk, as well as a lack of sufficient asset information, such as a pipe network map.

In order to overcome these barriers, the project developed a support network for CBMW, including a local high school, municipality office, and experts from a variety of fields. In this support network, high school students used an easy GIS tool to draw digital maps of water pipe networks in combination with interviews with local water managers. The students also tested the water quality by using a scientific test kits to detect unusual water contamination. These data were shared with local water managers, local government, and associated specialists. The data collected by students were sufficient in both quality and reliability for multi-actor collaboration. More importantly, the educational benefits to the students, who will lead the local community in the future, were substantial.

In contrast to the previous cases, an open data principle was inapplicable in this case due to security concerns. Nonetheless, data sharing with a wide variety of actors at a limited scale worked effectively to bring about actionable research.

Discussion

The three cases presented in the previous section all deal with complex socio-environmental issues, while data sharing differed among the community-based projects

Table 1

Summary of three socio-environmental cases in Japan

Case Study	Participatory Monitoring of Alien Plants in Aso-Kuju National Park (Oita)	Waterweed composting in Lake Biwa (Shiga)	Community-based Managed Water Supply in Hokkaido
Backgrounds	Invasion of alien plant species	• Overgrowth of waterweed • Legal constraints	Shrinking population endangers sustainable small-scale potable water supply management
Major stakeholders	Municipality office and naturalists	Prefectural office, municipality offices, local residents, and fishermen	Local water supply managers and users
Participants involved	Research experts and civic volunteers	Research experts, governmental employees, local residents, civic engineers, and graphic facilitators	Research experts, local high school students, and local water supply managers
Approach	Mapping and planning	Developing a local acknowledge system	Mapping and water quality check
Project openness	Open	Semi-closed	Closed

and was open in the first case, semi-closed in second case, and closed in the third case (Table 1).

Despite these differences in the mode of data sharing, project coordinators commonly found that projects were disrupted by socio-psychological boundaries, particularly at the initial phase of team building. Such boundaries are often generated by asymmetric information, knowledge [26], wisdom (after the Bellinger's DIKW model; URL: http://www.systems-thinking.org/dikw/dikw.htm), values, socio-economic status [27,28], and power among actors. In the authors' opinion, it is possible to bridge these boundaries by sharing information, knowledge, and wisdom through appropriate visualizations and dialogue. The importance of inclusive and trans-sectoral knowledge-action networking [29•] was noted in all three cases.

Theoretical framework for open team science

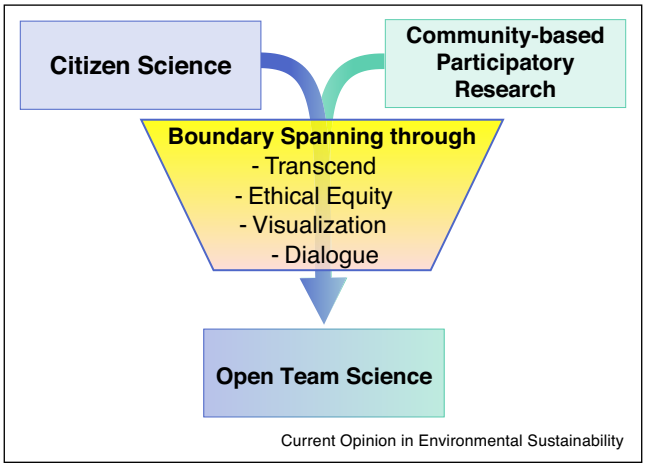
In accordance with the concepts described above, the authors are developing a theoretical framework to interlink citizen science and CBPR to address socio-environmental issues (Figure 3). This framework is tentatively called "open team science". In this framework, boundary spanning [30,31•] can be achieved by the transcend method (see below), or discovering and sharing the goals that actors with different interests can tackle together (Figure 4). It is important to carefully consider ethical equity, with special attention to empowering marginalized (or 'small voice') actors [32]. Ethical equity is associated with fair data visualization and dialogue. Civic tech can be applied as a holistic approach. The following three subsections discusses the concepts of transcend, ethical equity, and the FAIR Data Principles.

The concept of 'transcend' and the role of dialogue

To understand the significance of boundary spanning, it is useful to shed light on the concept of 'transcend', which was introduced by Johan Galtung [33]. The 'transcend' method is fundamentally based on the notion of conflict transformation which means to transform the characteristics of conflict by peaceful means, including dialogue, negotiation, and mediation. The transcend method is an attempt at constructing new realities among conflicting parties and provide space for contradictions within the conflict to be transformed.

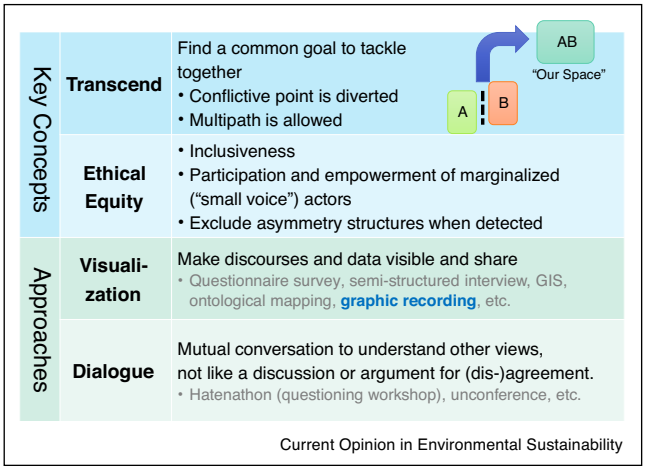
The presence of a mediator is a prerequisite. The role of the mediator is to assist the parties with ending a conflict situation and to facilitate dialogue among them. Once a dialogue emerges and develops, the parties in conflict can deepen their understanding of each other's perspectives and communicate in such a way that a divergence of perceptions about other parties can take place. This situation can, as Galtung maintains, pave a way for

Figure 3



Theoretical framework of open team science to interlink citizen science and community-based participatory research.

Figure 4



Key concepts and approaches for boundary spanning.

continued dialogue and negotiation by the parties in conflict.

A key question is how the transcend approach can be applied to open science. Open science is a framework, in which researchers, practitioners, policymakers, and civil members can share data, code, and protocols and collaborate with each other to produce scientific knowledge applicable to real world problems. In theory, open science frameworks and/or approaches are ideal, but in practice, different types of boundaries often exist among the stakeholders that participate in open science projects.

Boundary spanning is crucial for collaboration and knowledge production. Here, the transcend method is useful as it can provide openness and a virtuous cycle toward constructing a continuous dialogue among scientists, policymakers, and civil members, with the aim of sharing scientific products for the wellbeing of all participants of scientific knowledge and value production.

Ethical equity: empowerment of marginalized people

Ethical equity is often mentioned in the context of justice theory. Today, in processes for facilitating innovation or realizing a sustainable society, knowledge and information are regarded as resources that should be fairly evaluated and distributed [34•]. For example, in policy planning for sustainable development, governance paradigms that enable marginalized people to obtain autonomy and activity are required [35,36]. These paradigms must consider procedural or distributive justice for a variety of individuals with different goals and ideas, including marginalized people [37–39]. A recent report suggests that these types of justice play a key role in ensuring political agreement or building relationships among stakeholders in NIMBY-type public planning [40].

Another important point for successful agreement and relationships is that organizers or facilitators should spare no effort to understand marginalized people involved in their decision process. Organizers or facilitators should carefully consider the voices of marginalized actors as they tend to be masked during these processes [41]. These observations imply that attention must be paid to the process itself before directly aiming for agreement, in terms of ethical equity. The authors believe that these approaches could lead to increased contribution from marginalized people, resulting in better decisions for all stakeholders.

The FAIR Data Principles and fairness

Researchers' anxiety about the unintended use of data and exposure of 'inconvenient truths' is the most serious barrier to open research data, particularly for early career researchers who face tough employment competition [42•,43]; these researchers value data as a resource that is vital to their survival in academia. As a realistic solution to this dilemma of making research data available, the FAIR Data Principles (i.e. Findable, Accessible, Interoperable, and Reusable) was suggested [44••]. These principles place importance on the ability of data to be found and used automatically by machines, as well as reused by humans. It is not only academia that approves of these principles, but also many stakeholders, such as academic publishers and funding agencies also approve. FAIR has become a keyword in the open science movements [45,46•]. These principles are now gradually spreading throughout the scholarly community and changing researchers' mindset on data usage, and may eventually bring about fairness between data providers and users [47•].

Practical application of the open team science framework to the Lake Biwa case

To apply these concepts to technical operation of CBPR, open science is regarded as a movement within the open scientific knowledge production system, rather than open scientific knowledge only, while boundary spanning is regarded as a key concept of transdisciplinarity (Figure 2). Open research data are used in the process as an input resource. In the case of the Lake Biwa catchment (see Section 'Waterweed composting in the Lake Biwa catchment, Shiga'), the results of the questionnaire survey were disclosed as a FAIR data. As a method for boundary spanning and community-based co-creation, civic tech (Figure 2c, d) was applied to the team-based knowledge production [48••], action, and networking to co-create a solution as outcome. Civic tech workshops resulted in the development of a local acknowledgement system. Experience and lessons learned can inform the subsequent stages or new projects as input resources.

Conclusions and future tasks

This paper discussed how open science can be interlinked with CBPR for socio-environmental issues, exemplified by (1) the participatory monitoring of alien species using open data, (2) community development to address issues with waterweeds using FAIR data, and (3) small-scale water supply management improved by intra-team data sharing. On the basis of the lessons learned from these case studies, the authors are developing a theoretical framework to span inter-actor boundaries by (1) developing the goals that actors with different interests can tackle together (transcend method); (2) considering ethical equity with special attention paid to empowering marginalized actors; (3) developing data visualization based on the FAIR Data Principles; and (4) facilitating dialogue. Civic tech can be applied as a holistic approach. This working hypothesis is being tested through case studies (see the next subsection). Through this approach, theories of open science as an open scientific knowledge production system can be interlinked with transdisciplinarity as a driver of boundary spanning to develop a new research paradigm of open team science. The authors will continue developing this paradigm by extending a transsectoral knowledge-action network.

Evaluation of the effect of boundary spanning

The evaluation of the effect of boundary spanning is one of the important future tasks. The authors plan to apply the hypothesis-practice-assessment cycle [49] repeatedly within a short timeframe. The assessment methods comprise participatory observation, semi-structured interviews, and a periodic questionnaire. The outcomes and processed of the target projects, as well as the perceptual transformation of participants will be assessed. The case study in Lake Biwa is regularly improved using this method.

In order to clarify the effectiveness of these approaches, researchers or decision-makers must first measure the degree of difference in opinion between individuals involved in given socio-environmental issues, and determine whether these individuals display possessive senses of 'their' and 'our' living space [50••] when needed. Research on dual identity or common in-group identity is essential here. For example, in dual identity research, participants were asked how much they identified with groups A and B separately, using psychological scales. When participants showed high levels of identification with both groups, researchers concluded that they displayed a sense of dual identity. Those who have dual identity had better relationships with the out-group (for members of group A, group B) and a reduced prejudice to the out-group, as well as psychological adjustment in complex intergroup situations [51•,52•]. In this case, these individuals are capable of sharing living space with common in-groups, and working towards common goals such as resolving their socio-environmental issues.

Disclosure

The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.cosust.2019.07.001.

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