24. Transdisciplinarity at the Research Institute for Humanity and Nature, Kyoto, Japan

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INTRODUCTION

The Research Institute for Humanity and Nature (RIHN)[1] is an inter-university research institute established by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of the Japanese government after the signing of the Kyoto Protocol at Conferece of the Parties 3 of the United Nations Framework Convention on Climate Change in 1997. RIHN has a mandate to serve the Japanese university community and to advance the development of comprehensive approaches to the study of global environmental problems. In this, the application and development of transdisciplinary (TD) approaches, as well as interdisciplinary studies, are mandatory to pursue RIHN's mission of achieving harmonious relationships with the environment of the Earth. The mandate to work with the university community led RIHN to set up a unique project-development mechanism described in this chapter. The emphasis on comprehensive understanding of environmental issues put RIHN on an interdisciplinary trajectory right from its establishment. This was followed by efforts to make RIHN research TD too.

The interdisciplinary orientation of RIHN research is referred to in the English name of the Institute and is often expressed in the Japanese phrase *bunriyūgō* 文理融合, literally "fusion of humanities, social sciences, and natural sciences." This term has become commonly used in Japanese discussions of interdisciplinarity where multiple disciplines work together in an integrated manner. While *bunriyūgō* is widely used in an aspirational sense, RIHN is still a relatively rare example where systematic efforts are made to incorporate humanities and social science scholars and approaches into investigations of global environmental change. This is founded, first, on the realization that environmental issues cannot be understood solely from the perspective of the conventional natural-science-oriented environmental science that was mainstream at the beginning of this century when RIHN was established. This broad orientation is reflected in the inclusion of the word *sōgō* (総合, "comprehensive") in the Japanese name of the Institute. More concretely, the approach is based on the insight actively promoted by the founding director of RIHN, that "Environmental problems are problems of human culture in the widest sense of the word" (Hidaka, 2003). This understanding has been instrumental in anchoring the positioning of the Institute's research in the field of environmental studies. Overall, in recent years, the composition of collaborating project researchers has been slightly skewed toward the natural sciences. For example, in 2021, out of 553 collaborating researchers, 10 percent had a humanities background, 28 percent were from the social sciences, and 62 percent were natural scientists. Such interdisciplinary collaboration is one key element of TD research that contributes to solving societal problems together with stakeholders, and at the same time generates new scientific knowledge.

This chapter first provides a brief overview of the history and development of interdisciplinary and TD research at RIHN. Then it introduces the recent methodological development of TD research by explaining the outcomes of the two projects. Finally, it presents the TERRA School as a capacity-building platform for young researchers from Asian countries to learn and develop TD research.

OVERVIEW OF INTER- AND TRANSDISCIPLINARY RESEARCH

A Short History of TD Research at RIHN

While initially RIHN research stayed within the academic realm, increasingly the need was felt to address and contribute to solving real-world environmental problems. At first, this was labeled "design science," in the sense of researchers designing solutions—in other words "science *for* society." Over the past ten years, this has given way to engagement with problems together with stakeholders, or "science *with* society." RIHN researchers began to frame their solution-oriented research in terms of the international (especially Swiss-German) discourses on TD research. In 2013, when Future Earth was launched internationally as a platform for TD research on global environmental problems and to promote sustainability sciences (see Chapter 29), RIHN decided to join this international program and started to coordinate Asian countries by hosting the Future Earth Asian Regional Center. This center aims to involve the overall RIHN research projects more efficiently and effectively with Asian research communities. In practice, most RIHN research projects include community and local government engagement in rural and sometimes urban settings in Japan, Asia, and sometimes Africa. As part of the capacity building for this international collaboration, TERRA School was launched.

Procedure of Interdisciplinary and TD Research at RIHN

In the Japanese research system, the core function of inter-university research institutes, such as RIHN, is to serve the wider research community. Typically, this is done by providing access to very large research installations (e.g., an advanced telescope for astronomy, or a huge particle accelerator for physics) or special collections (e.g., of historical documents) for humanities.

In the case of RIHN, the joint-use function is embodied in collaborative research projects.[2] These are relatively large projects with, in the early years, an annual budget of around $1 million, but recently only about half of that amount. They have a lifecycle of seven years, which starts with a researcher from the community outside RIHN proposing a project idea. Once or twice each year, project proposals are publicly solicited and screened by an internal evaluation committee. The successful proposals enter a one-year Incubation Study (IS) period, with a small budget to further develop the project approach, methodology, network, and so on. This is followed by another screening and, for successful proposals, an additional Feasibility Study year, during which the concrete, operational aspects of the project are prepared and elaborated. The preparatory phase ends with an evaluation by the external research evaluation committee, including 15 senior and distinguished experts in various fields from Japan and overseas, as well as some representatives from stakeholders outside research. Once this final hurdle is cleared, the project starts its Full Research phase of five years. The original project proponent then moves to RIHN where they are employed as faculty for the duration of the

project. A research budget is made available from RIHN core funding from the MEXT. Part of this budget is used to hire a small team of researchers, also based at RIHN during project implementation. After the project is completed, both leader and team leave RIHN and pursue a career in the academic community.

This continuous staff circulation poses challenges in terms of institutional continuity, but the "cultivation" of researchers with extensive experience in interdisciplinary and TD research is regarded as one important manifestation of RIHN's contribution to the research community. Another aspect of this role of supporting the community is that the project is not simply carried out by the RIHN-based team because it involves networks of collaborative researchers in Japan and (usually) abroad. Most projects engage about 50 to 100 such collaborative researchers. Thus, the projects are proposed, developed, and implemented by the research community, with RIHN playing the role of enabler and facilitator.

RIHN Projects as a Platform for TD Experimentation

The project selection and development process is the main way that RIHN can guide the direction and approach of projects. This includes ensuring that the research is both interdisciplinary and TD. During the IS phase, proponents are invited to intensive workshops where RIHN researchers share their experiences and discuss project plans with the proponents. Specific senior researchers at RIHN are tasked with guiding the project-development process, and most projects organize seminars in the preparation period where they interact with RIHN staff. Only about one in ten IS proposals makes it all the way to adoption as a Full Research project. The successive screenings of the proposals as they move through the development process employ evaluation criteria that embody RIHN-specific requirements, in addition to some that are likely to be used in most research proposal evaluations elsewhere to ensure originality, relevance, and quality.

This selection procedure includes expectations that the research is internationally oriented, integrates different disciplines, and works with societal stakeholders in a TD fashion. In this way, guided by the evaluation criteria and comments of the evaluators, proponents have two years to develop their projects. The preparation phase provides time and modest resources to reach out to researchers from other fields, build an interdisciplinary team, and explore broader integrative frameworks for the research. Further, the long lead time allows projects to develop relationships with fieldwork localities, build trust with stakeholders, and undertake preliminary inquiries. Thus, the two-plus-five-year project timeframe is intended to facilitate the co-design of the research by providing opportunities and resources to discuss with researchers from a range of disciplines, as well as with local governments, nongovernmental organizations, social entrepreneurs, and community organizations. The basic logistic and technical supports and the archives of meta-data and scientific outcomes from all the projects are routinely made by the RIHN Center (for research infrastructure, communication, domestic, and international collaborations).

METHODOLOGICAL DEVELOPMENT OF TRANSDISCIPLINARY RESEARCH

This section presents two completed and ongoing relatively small projects focusing on some new methodologies for TD research, which are expected to apply to the overall RIHN research projects described in the previous section.

Open Team Science: A Methodology for Inclusive Community-Based Research for Socio-Environmental Cases

Reduction of socio-psychological asymmetries

Environmental deterioration is often perceived as a wicked problem that has no obvious solution (DeFries & Nagendra, 2017). Such a problem cannot simply be solved by research experts of one or more academic fields. Collaborations and community building with diverse actors are essential to "resolve" the target problem. The actors may include experts from different academic fields (interdisciplinary research; Repko & Szostak, 2020), and practitioners from governments, funding bodies, industry, nonprofit organizations, and members of civil society, and so on, as TD research. Nonetheless, community-based research projects are often disrupted by asymmetric information (initially defined in Akerlof, 1970), knowledge, wisdom (Bellinger et al., 2004), values, socioeconomic status (Kraus et al., 2010), and power among the actors mentioned above, as well as by different historical and geopolitical contexts. To reduce these asymmetries and enable more effective community-based research for socio-environmental cases, we developed the Open Team Science Method (hereafter OpenTS Method).

Self-Checklist for Community-Based Projects

We disseminated the OpenTS Method as a form of self-checklist (Figure 24.1) for community-based projects (e.g., Kondo et al., 2019). Conceptually, we interlinked open science and TD research (Kondo et al., 2019). The Organisation for Economic Co-operation and Development (OECD, 2015) 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" (p. 7), while we broadened this definition to an open scientific knowledge production system. We also identified boundary spanning (Fleming & Waguespack, 2007; Wang et al., 2018) as a fundamental concept of transdisciplinary research to transform in-between spaces into shared epistemic living spaces (Vilsmaier et al., 2017).

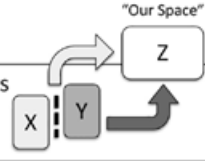
From psychological and behavioral viewpoints, boundary spanning can be achieved through an optimal combination of (1) ethical equity, (2) visualization and transparency, (3) dialogue and synlogue, and (4) transcend, as follows (Figure 24.1).

First, it is necessary to ensure ethical equity (Medvecky, 2017) between project leaders and other members. The membership must always be inclusive and dynamic. It is necessary to pay attention to empowering marginalized actors who have relatively small voices. If included, marginalized actors should be encouraged to participate and draw out their potential. If asymmetries in socioeconomic status or power exist (e.g., exploitation), they should be neutralized as much as possible.

Ethical Equity	• Is our project **inclusive** (anyone can join & leave at any time)? • Do we empower and encourage marginalized (or "small voice") actors to participate? • Do we eliminate socio-economic inequities?

Visualization & Transparency	Do we ensure transparency of research process through visualizing and sharing them widely?
	• **Traceability** and **synchronousness** may build and warrant **trust**.
	  • Do we obtain informed consent of actors?
	  • Do we disclose the research process with considering actors' right and interest?

Dialogue & Synlogue	Do we facilitate mutual conversation to understand other views and conditions? → **Trust** • Synlogue in Japanese contexts (Chen 2020)
Transcend	Do we build a platform to perceive and share problems from multiple viewpoints? • Multipaths are allowed.



Source: After Kondo (2021).

Figure 24.1 Self-checklist of the Open Team Science Method

Second, it is vital to ensure transparency by making the research process visible and sharing it widely to track and verify it. Since solving social problems is a one-time social experiment, it is impossible to reproduce the process as in scientific experiments. However, it is possible to track back the cause and effect to correct the project's trajectory when it does not evolve as expected.

It is also necessary for all concerned to synchronize the ever-changing status of the project without severe delay. Online communication tools such as Slack are helpful to synchronize information. Moreover, it is important to inform the involved people of project goals, interests, and plans, and obtain their consent. When disclosing the process to the public, the situation of the involved people should be considered. Informed consent and disclosure are essential for building and maintaining trust.

Third, to foster mutual understanding and trust, it is necessary to engage in dialogue to understand differences by listening to others on an equal footing. However, in the Western style of dialogue, the two sides do not interchange their points of view, as one keeps silent and listens until the other finishes speaking. In Japanese contexts, synlogue, or a conversation in which another speaker seamlessly succeeds on the first speaker's speech (Chen, 2020), is also observed.

Fourth, transcend (initially suggested by Galtung, 2004) can be applied when actors X and Y have conflicting interests or are on the verge of stopping thinking. They can shift their perspectives and create a new platform (Z) to recognize and share the goals they can tackle together. Multipath is allowed to approach platform Z.

This self-checklist aims to reflect on activities when collaborative research is not progressing well. The method is no more than a working hypothesis. We aim to further improve and disseminate the OpenTS Method to community-based projects on broader research topics,

such as living heritage management, public health education, and biocultural diversity conservation (e.g., Kondo et al., 2019). This enterprise explores a new dimension of open science for and with society.

Co-Creation Methods in Practice: Introduction and Early Findings

Gaps between ideal and real TD processes

Global environmental problems are often referred to as wicked problems (Rittel & Webber, 1973) because they are highly complex, the stakes are high, and science alone cannot provide a definite solution. For this reason, it is increasingly recognized that TD approaches are useful in creating new knowledge and solutions through collaboration between scientists and stakeholders concerned by the problem (Pohl, 2008; Wiek, 2007). The TD method has been developed mainly by European researchers since the 1970s; but it has recently been applied in many countries (e.g., Fazey et al., 2018; Pereira et al., 2019). While the number of studies increases, TD research still seems to face many challenges, notably large gaps between the ideal and real TD processes (i.e., theory and practice), a lack of a universally accepted definition, and a lack of practical frameworks (e.g., Zscheischler et al. 2017; Thompson et al., 2017).

Co-creation: A new approach

RIHN is one of the few research institutes in Japan that has implemented several projects focusing on community engagement in environmental studies. As the Institute operates on a project-based system, where every project finishes in 3 or 5 years, knowledge and experience gained by project members are often lost, along with the members, when the teams are dissolved at the end of the project cycle. Moreover, while collaborations between RIHN researchers and the relevant stakeholders (including local residents) are encouraged, as in most research institutes, the projects are evaluated mainly by the academic achievements of the project members. There has been little interest in evaluating the changes in the communities or the stakeholders.

Against this background of institutional capacity building, the Co-Creation Project (n.d.) has been proposed and accepted as a research project for the three years of 2020–22. These collaborative projects focus on accumulating and systematizing the experiences and lessons learned by researchers and stakeholders who have participated in RIHN projects. Also, developing a practical methodology that can easily be applied in TD research to foster knowledge co-creation and societal outcomes is a priority. To that end, the project has established three core themes: (1) TD landscape, (2) lessons learned, and (3) capacity building. The descriptions and some of the early findings from each theme are presented below.

TD Landscape

First, the project aims at clarifying what is termed as TD in practice and provides a comprehensive overview of co-creation research. In particular, the project looks at the differences between different schools of thought in TD, interdisciplinarity, participatory approaches, and action research. The project considers that these approaches are part of co-creation, or 共創 (*Kyoso*) in Japanese, which has become popular in Japan in recent years. For example, the Japanese government emphasizes in the 6th Science, Technology, and Innovation Basic Plan

(2021–25) that science and society should interact by doing "Kyoso" to access innovative solutions to societal problems.

TD is generally said to have two main schools, notably, the German (or Zurich) and French (or Nicolescu) schools. In 2013, an international research program for global sustainability, Future Earth, adopted the definition used by the German school to refer to the engagement of the societal stakeholders in the research process and started facilitating this type of TD in environmental research (Future Earth, 2013). The Co-Creation Project investigated academic papers in Web of Science and Scopus, (including the terms transdiciplinary and transdisciplinarity) and found that many of the papers did not follow the definitions or the research process suggested by either of the two European TD schools. It appears that researchers in environmental studies are increasingly using the term TD to refer to the methods that include some kind of engagement with extra-scientists in the research process. This contrasts with the French TD school where integration of science is a central premise, and also with the German TD school where integration of knowledge from relevant disciplines and expertise is one of the core elements. When TD is used without interdisciplinarity, it can be considered synonymous to other approaches, including engagement of societal actors, participatory approaches, action research, and integration of science, among others.

Lessons Learned

The objective of the lessons learned component is to elucidate the knowledge and experience that researchers and stakeholders have gained from participating in TD research, then to organize and present it in a way that it can be easily adopted in future activities. To this end, the research focused on two perspectives. First, the project created a pattern language for co-creation (TD pattern language) for TD researchers by applying the "pattern language" method (Alexander, 1977) to explore and systematize the knowledge and experiences accumulated by individuals. The project carried out interviews and workshops with researchers who had experience with co-creation projects to identify tips, knowledge, and methods for coping with complex problems and promoting collaboration with stakeholders.

Secondly, the project aimed at developing a framework for elucidating the societal outcomes of the TD projects. The researchers conducted interviews and workshops with the societal actors involved in the completed TD projects at RIHN to explore effective methods for reflecting the project outcomes with the residents in a community where a TD project took place.

For example, one research project at RIHN investigated ways to link the watershed scale conservation with local environmental actions. One of their field sites was a rice farming region called Kosaji at Shiga Prefecture in Japan, where the project proposed a model for facilitating the practices of environmentally friendly agriculture with the local initiative.

After the project ended, the Co-Creation Project visited the region and carried out a series of workshops with the local farmers. During the first workshop, it became apparent that the local farmers had difficulties recalling the activities that happened nearly five years ago. Thus, after discussions with the farmers, the Co-Creation Project organized a workshop to present the main findings from the project and to reflect upon the activities that led to the scientific findings. Based on this reflection, the interview questions were formulated to ask the farmers about the societal changes during and after the project. It was found that the local farmers became

more aware and had more positive feelings toward the environmentally friendly agricultural practices, and their interest in the living organisms grew over the time.

Capacity and Network Building

The Co-Creation Project uses the findings from the research under the above themes to build the capacity of researchers wishing to undertake TD research. The project disseminates information related to TD and co-creation through a website (https://cocreationproject.jp) and social media accounts. In addition, the project aims to expand our outreach and research activities by expanding our collaboration with domestic and overseas TD researchers and networks. The feedback from the students, readers, and researchers is passed on to the research team to improve the outcomes in the above two themes.

The Co-Creation Project is still underway, and some of the components may be modified through the course of the remaining project period. Hopefully, the findings from this project will provide new insights for the international TD debates and some practical guidance to the researchers who are starting TD research.

RECENT PROGRESS OF TD RESEARCH

In this section, we outline two ongoing TD research projects that apply a unique methodology and a concept developed at RIHN.

Environmental Traceability: A New Approach for TD research

The RIHN considers that global environmental issues find their roots in human culture. Environmental degradation can be understood as an imbalance in the interaction between human beings and natural systems. From a historical point of view, regulations have been issued to protect society from environmental pollution. Environmental monitoring of chemical or biological substances has been undertaken for this kind of problem. On the other hand, knowledge and evidence about the physical, ecological, and social mechanisms that underpin global and regional environmental changes need to be combined under the dynamic planet.

Use of Multiple Elements and Multiple Isotope Measurements

The concept of traceability, whereby we can trace the path of agricultural products and foods in the global economy, is useful for ensuring the safety and quality of such products. We can also use traceability information to identify the source and origin of environmental materials. This utility is invaluable for elucidating the interactive links between human activities and natural environments, such as the atmosphere, hydrosphere, biosphere, and pedosphere (Nakano, 2017). Thus, we consider environmental traceability a key concept in solving environmental issues.

The RIHN has laboratories dedicated to stable isotope analysis of multiple elements. Stable isotope ratios of elements, together with the concentrations of elements, can trace a matter flow, the environmental condition of sites, ecosystem structure, and food products (Ohkouchi et al., 2010). Spatio-temporal variation of multiple isotope ratios can be used for studying the

Earth systems from a local to global point of view. Stable isotope ratios of light elements such as hydrogen (H), carbon (C), nitrogen (N), oxygen (O), and sulfur (S) can trace hydrological movement of water, photosynthetic pathways in plants, and food web structures in ecosystems, whereby they indicate information about natural resources for humans. The method is sometimes called a "stable isotope fingerprint," in which the stable isotope ratio of each element contains its information of origin and pathways of reactions (Wada, 2009). The information can be obtained from any natural substances; therefore, it is indicative of material cycling. In contrast, stable isotope ratios of heavy elements such as strontium (Sr), neodymium (Nd), and lead (Pb) in rocks and ore show significant geographical variations reflecting geological processes during the evolution of the Earth and small isotopic effects during the movement of the heavy elements through the various spheres on Earth. Nakano (2016) demonstrated the unique nature of heavy stable isotopes that originate from geological materials in the lithosphere and their potential use as a tracer of their interaction and transportation among the spheres of the Earth's surface environment.

Since 2012, RIHN has been organizing the cooperative research program, the "Environmental Isotope Study", to provide academic researchers with the isotope method. The method has been used in a variety of specialized fields, such as geochemistry, hydrology, ecology, geology, mineralogy, anthropology, food provenance, and forensic science, and in a wide variety of environmental studies. In particular, spatial variation of elemental compositions and isotopic compositions of multiple elements is useful information to distinguish matter flow in ecosystems. Therefore, we consider Multi-ISOSCAPES (derived from the term "isotope landscape"; use of multiple elements and multiple isotope ratios), and the GIS-based mapping technique (Bowen, 2010; West et al., 2010) to provide the essential information for realizing environmental traceability.

TD Studies on Water Management with Local Governments and Residents

We have been providing various researchers with this technique to help them cope with global to local environmental issues concerning multiple stakeholders. The information may serve as a key for local people to consider water security, food security, and environmental security, which are fundamental for the sustainability of human society.

RIHN members studied at multiple local sites together with local government officials and residents. Saijo City in Ehime prefecture has been utilizing plenty of groundwater resources, and more than 3000 artesian wells are used for various purposes. However, some wells have suffered from saltwater intrusion in some circumstances, and the movement of groundwater needs to be studied (Tokumasu et al., 2019). Saijo City proposed that the public collect simultaneous samples, and 1032 groundwater samples were recovered by residents. The RIHN researchers visualized groundwater movement using multiple maps (Nakano et al., 2015). The research results contributed to developing the "Management Plan for the Conservation of Saijo City Groundwater" in 2017 (Saijo City, 2017).

Ono City in Fukui has been using groundwater, but the water tables decreased in the 1970s to 1980s due to the excess use. As a result, the residents are watching the groundwater level of some wells every day to monitor the water resources of the city. However, there still is a potential water shortage and water quality problems within the city. After discussing the issue with city officials and residents, RIHN researchers analyzed the water characteristics and showed the results on a map (Nakano & Kaeriyama, 2018). The data showed clear groundwa-

ter flow under the city, and the research results were included in the "Basic Plan for Watershed Management" in February 2021 (Ono City, 2021). Based on this collaboration, Ono City opened the educational and research facility Mizu-no-Gakko (Water School) in March 2020 to share scientific knowledge with society. The research facility can connect with city officials, residents, and researchers.

Oshino Village in Yamanashi Prefecture needs to keep houses from flooding and to conserve the Oshino-Hakkai springs, one component of the World Cultural Heritage of Mt. Fuji. The village needs to solve two contradictory problems: enhancing drainage and maintaining the water level. The RIHN researchers and the village office worked together, and we identified the water flow and its sources in the village. Then, we presented the results at a symposium held by the village in January 2018. At that symposium, we investigated the effectiveness of cooperative transdisciplinary research in the village using a survey. The results showed that the residents have higher degrees of interest in the information obtained using isotope techniques (origin, flow, age of groundwater) compared with the information obtained by the other techniques (quality, volume, temperature of groundwater). As a result, groundwater flow was identified as an important focus of future studies for groundwater conservation. While increasing knowledge about isotope analysis and interest in groundwater remains an issue, this study suggests that isotope analysis can facilitate obtaining a consensus of various stakeholders as one structural factor in groundwater management, even if management is initiated by the local government (Fujiyoshi et al., 2019).

Internet Website as a Platform for the Environmental Traceability Methodology

As a result of multiple symposia with residents and workshops with city officials, we developed a website as an Open Access platform (The World as Illustrated by Environmental Isotope Studies). The website invites decision-makers, citizens (including nonprofit organizations), and researchers (not only those specialized in isotope science) to participate in collaborative research based on the environmental traceability methodology. All the findings obtained from the cooperative research program on the Environmental Isotope Study are included in this website (https://www.environmentalisotope.jp) and in an online publication within the site (Tayasu et al., 2022).

TD Research on the Water–Energy–Food Nexus in Japan

The METABOLIC project

The water–energy–food (WEF) nexus is a focus of the Knowledge Action Network of Future Earth, and several studies have been conducted to explore the WEF nexus in the Asia-Pacific region (Taniguchi et al., 2018), as well as the agricultural relationship between the WEF nexus and climate change in Asia (Lee et al., 2020). One example of transdisciplinary studies in Asia related to the WEF nexus is the Japanese team working on the project "METABOLIC: Intelligent Urban Metabolic Systems for Green Cities of Tomorrow: A WEF Nexus-Based Approach," funded by the Belmont Forum from 2018 to 2021. The Belmont Forum is an international partnership that mobilizes funding of environmental change research and accelerates its delivery to remove critical barriers to sustainability (see Chapter 29).

There are four research teams working on METABOLIC, including Japan (Co-Principal Investigator [PI]: Makoto Taniguchi, RIHN); Taiwan (PI: Fi-John Chang, National Taiwan

University, Partner: Kuei-Kuang Chen, Sunny Rich Power Co., Ltd., Taipei); the United States (Co-PI: Luis Rodríguez, University of Illinois at Urbana-Champaign); and Brazil (Co-PI: José Vicente Caixeta-Filho, University of São Paulo). The objectives of the METABOLIC project are: (1) incorporate advanced tools/models into a scientific collaboration framework; (2) propose governance strategies to decision-makers and stakeholders; (3) develop an international WEF nexus capacity-building system; and (4) validate the models developed via data collected and/or simulated. This project also contributes to integrate many of the United Nations Sustainable Development Goals (SDGs).

The most important contributions the METABOLIC project can provide include: (1) improve management for WEF delivery to urban centers under the premise of inevitably increasing urbanization around the world; (2) understand the relationships between the delivery of WEF resources to urban centers, the associated variations in demographics, economy, and land utilization, and the impacts on the peri-urban regions where resources are produced; (3) address emerging risks and tradeoffs at the intersection of sustainable urbanization and the WEF nexus; (4) minimize potential degradation of environmental quality as well as socioeconomic impacts in urban and peri-urban regions; and (5) explore the potential of renewable energy.

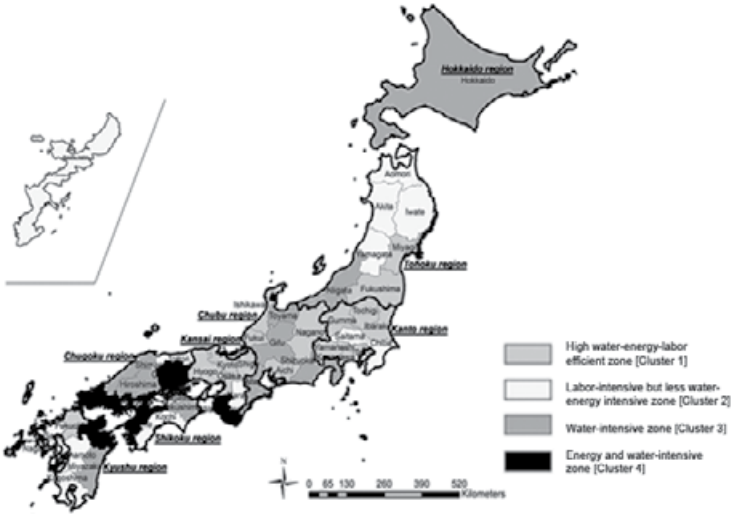
TD study on the WEF nexus in Kyoto

The Japan team on the METABOLIC project tackled the WEF nexus as a form of multi-sector resources management in the historical city of Kyoto, Japan. The purpose of the TD study in Kyoto is to identify the synergy among WEF resources, to understand nexus efficiency, and to determine how to best mix policies involving different sectors, such as WEF, through multiple processes, production, transportation, distribution, consumption, and disposal, as well as addressing other factors, such as climate change, land use, and labor.

We analyzed the efficiency of integrated water–energy management in Kyoto City and found water–energy synergy, which means reduced energy consumption through a reduction of the amount of water allocated (water transport and pumping). Another analysis of the WEF nexus studied local food consumption and production policies. Cases with more local food production and consumption in the Kansai region, including Kyoto, yielded lower energy consumption and carbon emissions because less food was being transported. However, there is a larger water footprint because of the higher water consumption used in food production in the Tohoku region, from where many foods are transported to Kansai (Figure 24.2).

In this project, researchers will benefit from the following results of interdisciplinary studies: (1) the development of a database on the WEF nexus for understanding the linkage between resources in the nexus in Kyoto; (2) the development of a nexus model in Kyoto which identifies the synergy and tradeoff among resources; and (3) recommendations of the best mixed policy on WEF. In addition, local governments, farmers, industrial sectors, and citizens will also benefit from the results of this project, including: (1) working with stakeholders to develop a future plan in Kyoto; (2) structuring local society with social, economic, and environmental factors using a nexus model for the sustainable management of the resources in other areas; and (3) the integration of the WEF nexus and SDGs, which can be used by more people, such as practitioners and decision-makers.

Given the complexity of nexus themes, TD studies of the WEF nexus can help to identify joint issues between researchers and stakeholders. Researchers benefit from listening to the



Source: Lee et al. (2021).

Figure 24.2 Four clusters based on water–energy–labor intensities in the industrial sector in prefectures in Japan

various thoughts of actors in different sectors, such as WEF, which are usually separated and rarely discussed together.

Notably, city officers in Kyoto gave researchers many ideas and information from local knowledge about how human behavior and policies are related to local culture, and why general policy did not work in the traditional and historical city. For instance, there was a tradeoff between increasing the renewable energy produced by mounting solar panels on roof tops, and tourism regulations governing the landscape in the historic city. This kind of information is useful for developing future scenarios and analyzing the tradeoffs and synergy in the TD study.

As a TD study in Asia, the Japan team's results from the METABOLIC project suggest the following two issues. First, because nexus connections are very complex (e.g., WEF, SDGs, society–economy–environment), conventional visualization does not work for stakeholders. We need to develop new simulation tools for mutual learning between scientists and stakeholders. The second issue involves what we learned from our collaboration with other partners, such as city managers/officers and other stakeholders.

"TERRA SCHOOL" FOR EARLY-CAREER TD RESEARCHERS IN ASIA

Rationale for RIHN

There has long been a desire within RIHN for an outreach activity such as a summer school. RIHN members had the initial idea to organize a summer school where young researchers

from Asia can visit the Institute and be informed about its various projects. Given that RIHN has acknowledged the importance of TD approaches, and that it has strong affiliations with large international networks that have embraced transdisciplinarity, such as Future Earth and the International Science Council, it made sense for the course to focus on TD approaches (see Chapter 16). Furthermore, the "RIHN School" was conceptualized under the auspices of the Future Earth Regional Center for Asia. During the development of the program, the title "*T*ransdisciplinarity for *E*arly-caree*R* *R*esearchers in *A*sia" (TERRA) was coined, and the acronym was based on the word *terra*, the Latin term for "earth" (*chikyu* in Japanese).

Theory and Practice of Transdisciplinarity

The TERRA School is designed as a short course spanning several days (one week for the in-person course, or 2–3 weeks for an online format) and includes lectures, workshops, and interactive sessions on theories and practices of TD research.

The course covers the theoretical foundations of transdisciplinarity with some ideal TD processes discussed in the context of describing the various ways that TD is understood. However, the real-world experiences of conducting TD by many RIHN research projects indicate that this process is nonlinear and often not followed. Therefore, numerous entry points for engagement between researchers and non-academic participants within the lifetime of any one project are emphasized.

Another important feature of the TERRA School is direct interaction with local stakeholders of a TD project. During the first year of the course, this occurred in the form of a field visit to Kameoka City; it provided participants with on-the-ground exposure and face-to-face interaction with stakeholders of the FEAST (Sustainable Food Consumption and Production) project, who worked to build civic food networks. It served as a cultivation encounter, allowing participants to freely engage in conversations with the local government officers, community innovators, organic farmers, and other project partners. Through direct and rich interaction, the participants of the TERRA School had a deeper understanding of the diversity of stakeholders' values and reflected on researchers' roles for engagement and collaboration.

Finally, the TERRA School includes structured learning about some tools and methodologies useful for TD research, specifically on clarifying and diagnosing the problem(s); identifying strategic stakeholders to engage with; looking at shared objects of interest; and developing a theory of change for the TD research. Participants learn how to work collaboratively in small teams on various hands-on exercises to apply the tools that have been introduced. Essential for conceptualizing TD research is reflecting on the interactions among outcomes, research questions, and the project's theory of change. The course culminates in plenary presentations of the teams' respective TD project ideas.

From Physical to Distance e-Learning

The first course was held in the winter month of December 2019 and brought 16 participants from ten countries to RIHN for one week to be immersed in transdisciplinarity. Succeeding iterations were affected by the COVID-19 pandemic and had to be converted into a virtual course, spanning 2–3 weeks. The added challenge of an online format was initially daunting, but the use of innovative online platforms and some program tweaking enabled a collaborative and interactive learning environment. Although an actual field visit was not possible, an online

interaction space was created by inviting local stakeholders for an open discussion with participants. Local partners of the FEAST project from Kyoto City, Nagano City, and Kameoka City provided an opportunity to interact directly with stakeholders. Simultaneous interpretation allowed the FEAST project partners to share freely in Japanese, their native language.

Showcasing RIHN TD Contributions

The TERRA School serves as a platform to showcase the rich variety of case studies and TD research projects conducted at RIHN. The projects featured a range of themes, including water resource management, tropical peatland issues, sanitation value chains, and food systems. The course also spotlighted the localized, place-based approach that characterizes many of RIHN's projects. The participants were able to learn in detail how the TD approach was practiced in actual research projects, what difficulties were encountered, how they were dealt with, and the expected outcomes of the TD research projects, using the RIHN projects as examples.

Participants also came to understand various institutional obstacles to the implementation of TD research that are rooted in the way universities and research institutions have been organized around scientific disciplines with little to no incentives for engaging across disciplines. However, the unique research scheme and funding structure at RIHN exposes them to an alternative space where researchers are not only allowed to explore but are encouraged to engage in TD approaches. This is particularly useful for a number of participants who were being tasked to set up new units within their respective institutions that embrace disciplinary boundary-crossing.

Building Capacity for TD

While only a handful of the participants had experience with TD research, the course provided them with a strong grounding in the theory and practical applications of this approach. A large number have indicated that it was insightful and inspiring to go beyond their disciplinary fields. Some appreciated the rich case studies and on-the-ground exposure, and others felt better equipped to engage TD research and apply the tools learned.

One encouraging outcome of the course came in the form of an alumnus who shared his experience of being accepted as a research fellow for a TD project of a major global challenge research funding program:

> Exposure to TD research in TERRA School at RIHN really helped me to respond to the interviewers' questions at the recruitment stage. It also helped me to plan the activities of our work package for this transdisciplinary project. It included presentations, brainstorming sessions, and also getting inputs from the participants on my proposed research through (I proposed and implemented [a] 45-min group exercise as we did in TERRA School – it was planned on a one-day notice, and it worked – Thanks to TERRA School).

Many universities and academic institutions are slowly acknowledging the importance of addressing societal issues, and an increasing number are reorganizing their structures and creating new units and platforms to accommodate TD research. Some funding institutions, especially in the sustainability field, are focused on societal challenges and are mandating TD approaches. It is thus important to prepare and equip early-career researchers who are eager to take on these new roles.

Building a Network of Early-Career Researchers in Asia

The TERRA School is still in its infancy, but it has brought together 50 early-career researchers with diverse backgrounds in the natural and social sciences from 13 countries in Asia (Malaysia, Taiwan, Philippines, Korea, Cambodia, Indonesia, Bhutan, China, Thailand, Mongolia, India, Japan, and Australia). The alumni currently comprise a loose network of early-career scholars in Asia and are included in the various outreach activities of Future Earth. Several have joined Future Earth National Committees and are active in their respective networks. One was selected as an Early-Career Champion of the Sustainability Research Innovation Congress 2021. They have participated as speakers in various international symposia and conferences. Some are pursuing TD research; one alumna was accepted as a Visiting Fellow at RIHN, and others are developing their own TD proposals for funding. There are plans of formalizing an early-career network of researchers in Asia within Future Earth, and it is expected that alumni from the TERRA School can provide leadership within the network.

CONCLUSION

This chapter summarizes some recent trends of the recent TD research at RIHN. These trends are based on the experience and accumulated knowledge of interdisciplinary research about various environmental issues for 20 years since the establishment of the Institute.

First, we introduced the application, acceptance, and implementation of interdisciplinary and TD research projects that have been conducted at RIHN for the past 20 years. As part of TD methodological research, we proposed a checklist for promoting Open Team Science. The importance of follow-up after the completion of the TD research has also been confirmed, especially for the full involvement and understanding of stakeholders. As part of new TD research at RIHN, we have proposed environmental isotopes or isotope analysis, which facilitate collaboration between researchers, public authorities, and citizens, as a so-called "boundary object" or a platform. The "Water School" established by one local city is an example of such a platform. Another important example of TD research on the WEF nexus has confirmed another boundary object for both researchers and stakeholders, including local governments, and why they should be aware of each other. The activity of the TERRA School as a capacity-building platform about TD research for young researchers from Asian countries was also introduced; the school is hosted by the Future Earth Asian Regional Center.

One of the remaining major issues in TD research is how to evaluate the results of the TD outcomes from the viewpoints of both science and practice in society. Whether it is pure discipline-oriented science or interdisciplinary research in a broader sense, as long as it is scientific research within the academy, the ordinary or conventional evaluation system (e.g., number and quality of papers, citations, etc.) will work. However, in the case of TD research, another perspective (e.g., how the project contributed to solving the problem in society) is required. This latter evaluation method has not yet been established in the academic community or in society. The MEXT, the central government ministry for RIHN, is encouraging the Institute to lead the development of such an evaluation method for TD research. The RIHN has been working with the international program and platform Future Earth for global to regional sustainability. We will continue to promote these initiatives, including the evaluation issue, by

taking advantage of opportunities, such as international commitments to Future Earth and the United Nations SDGs.

NOTES

1. In Japanese: 総合地球環境学研究所, or "Research Institute for Comprehensive Environmental Studies" as a direct translation to English.
2. See https://www.chikyu.ac.jp/rihn_e/projects.html for an overview of these projects.

REFERENCES

Akerlof, G. (1970). The market for lemons: Quality uncertainty and the market mechanism. *Quarterly Journal of Economics*, *84*(3), 488–500. https://doi.org/10.2307/1879431

Alexander, C. (1977). *A pattern language: Towns, buildings, construction*. Oxford University Press.

Bellinger, G., Castro, D., & Mills, A. (2004). *Data, information, knowledge, and wisdom*. http://www.systems-thinking.org/dikw/dikw.htm

Bowen, G. J. (2010). Isoscapes: Spatial pattern in isotopic biogeochemistry. *Annual Review of Earth and Planetary Sciences*, *38*, 161–187.

Chen, D. (2020). *Languages to make the future: To bridge non-understandings* (未来をつくる言葉：わかりあえなさをつなぐために). Shinchōsha.

Co-Creation Project. (n.d.). https://cocreationproject.jp/en/

DeFries, R., & Nagendra, H. (2017). Ecosystem management as a wicked problem. *Science*, *356*, 265–270. https://doi.org/10.1126/science.aal1950

Environmental Isotope. (n.d.). *The world as illustrated by Environmental Isotope Studies*. https://www.environmentalisotope.jp

Fazey, I., Schäpke, N., Caniglia, G., Patterson, J., Hultman, J., van Mierlo, B. … Wyborn, C. (2018). Ten essentials for action-oriented and second order energy transitions, transformations and climate change research. *Energy Research & Social Science*, *40*, 54–70.

Fleming, L., & Waguespack, D. M. (2007). Brokerage, boundary spanning, and leadership in open innovation communities. *Organization Science*, *18*(2), 165–180. https://doi.org/10.1287/orsc.1060.0242

Fujiyoshi, L., Nishimura, T., Kato, T., & Tayasu, I. (2019). Residents' understanding of and interest in isotope techniques for groundwater conservation: A study of symposium participants in Oshino Village, Yamanashi Prefecture. *Papers on Environmental Information Science*, *33*, 133–138.

Future Earth. (2013). *Future Earth initial design: Report of the transition team*. International Council of Science.

Galtung, J. (2004). *Transcend and transform: An introduction to conflict work*. Routledge.

Hidaka, T. (2003). Preface. In *RIHN prospectus 2003–2004*. RIHN.

Kondo, Y. (2021). Open Team Science as a methodology of transparent collaborative research. *Trends in the Sciences*, *26*(2), 102–107. https://doi.org/10.5363/tits.26.2_102

Kondo, Y., Miyata, A., Ikeuchi, U., Nakahara, S., Nakashima, K., Ōnishi, H., Osawa, T., Ota, K., Sato, K., Ushijima, K., Vienni Baptista, B., Kumazawa, T., Hayashi, K., Murayama, Y., Okuda, N., & Nakanishi, H. (2019). Interlinking open science and community-based participatory research for socio-environmental issues. *Current Opinion in Environmental Sustainability*, *39*, 54–61. https://doi.org/10.1016/j.cosust.2019.07.001

Kraus, M. W., Côté, S., & Keltner, D. (2010). Social class, contextualism, and empathic accuracy. *Psychological Science*, *21*(11), 1716–1723. https://doi.org/10.1177/0956797610387613

Lee, S. H., Choi, J.-Y., Hur, S.-O., Taniguchi, M., Masuhara, N., Kim, K. S., Hyun, S., Choi, F., Sung, J.-h., & Yoo, S.-H. (2020). Food-centric interlinkages in agricultural food-energy-water nexus under climate change and irrigation management. *Resources, Conservation and Recycling*, *163*, 105099.

Lee, S. H., Taniguchi, M., Masuhara, N., Mohtar, R. H., Yoo, S. H., & Haraguchi H. (2021). Analysis of industrial water–energy–labor nexus zones for economic and resource-based impact assessment. *Resources, Conservation and Recycling*, *169*, 105483.

Medvecky, F. (2017). Fairness in knowing: Science communication and epistemic justice. *Science and Engineering Ethics*, *24*, 1393–1408. https://doi.org/10.1007/s11948-017-9977-0

Nakano, T. (2016). Potential uses of stable isotope ratios of Sr, Nd, and Pb in geological materials for environmental studies. *Proceedings of the Japan Academy*, *Ser. B*, *92*, 167–184.

Nakano, T. (2017). Attempt to utilize and nurture the traceability function of water quality. *Journal of Japan Society of Hydrology and Water Resources*, *30*, 147–148.

Nakano, T., & Kaeriyama, T. (2018). A trial for nourishing a healthy water environment by its visualization: An example of Ono City, Fukui Prefecture. *River Front*, *87*, 2–5.

Nakano, T., Saito, Y., Shin, K-C., Sasaki, K., & Tokumasu, M. (2015). Cooperative research of water quality between Saijo City and RIHN in order to prepare an act for conserving water cycle and nourishing water. *River Front*, *81*, 26–29.

Ohkouchi, N., Tayasu, I., & Koba, K. (Eds.). (2010). *Earth, life, and isotopes*. Kyoto University Press.

Ono City. (2021). *Basic plan for watershed management*. http://www.city.ono.fukui.jp/kurashi/kankyosumai/mizujunkan/mizujunkan/mizujyunkankeikaku.files/keikaku.pdf

OECD. (2015). Making open science a reality. *OECD Science, Technology and Industry Policy Papers*, *25*. https://doi.org/10.1787/5jrs2f963zs1-en

Pereira, L., Frantzeskaki, N., Hebinck, A., Charli-Joseph, L., Drimie, S., Dyer, M., Eakin, H., Galafassi, D., Karpouzoglou, T., Marshall, F., Moore, M.-L., Olsson, P., Siqueiros-García, J. M., van Zwanenberg, P., & Vervoort, J. M. (2019). Transformative spaces in the making: Key lessons from nine cases in the Global South. *Sustainability Science*, *15*, 161–178. https://doi.org/10.1007/s11625-019-00749-x

Pohl, C. (2008). From science to policy through transdisciplinary research. *Environmental Science & Policy*, *11*(1), 46–53.

Repko, A. F., & Szostak, R. (2020). *Interdisciplinary research: Process and theory* (4th ed.). SAGE.

Rittel, H. W. J., & Webber, M. M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, *4*(2), 155–169.

Saijo City. (2017). *Management plan for the conservation of Saijo City groundwater.* https://www.city.saijo.ehime.jp/uploaded/attachment/25984.pdf

Taniguchi, M., Masuhara, N., Teramoto, S. (2018). Tradeoffs in the water–energy–food nexus in the urbanizing Asia-Pacific Region. *Water International*, *43*(6), 892–903.

Tayasu, I., Shin, K.-C. & Takano, S. (2022). *The world as illustrated by Environmental Isotope Studies: 2022 edition*. https://www.environmentalisotope.jp/assets/pdf/isotope-book2022.pdf

Thompson, M. A., Owen, S., Lindsay, J. M., Leonard, G. S., & Cronin, S. J. (2017) Scientist and stakeholder perspectives of transdisciplinary research: Early attitudes, expectations, and tensions. *Environmental Science & Policy*, *74*, 30–39.

Tokumasu, M., Yamada, Y., Takase, K., & Nakano, T. (2019). The influence of the fault on Saijo Plain, Ehime Prefecture on groundwater level in the plain based on long-term observation data. *Journal of Groundwater Hydrology*, *61*, 183–196.

Vilsmaier, U., Brandner, V., Engbers, M. (2017). Research in-between: The constitutive role of cultural differences in transdisciplinarity. *Transdisciplinary Journal of Engineering & Science*, *8*, 169–179. https://doi.org/10.22545/2017/00093

Wada, E. (2009). Stable $\delta^{15}N$ and $\delta^{13}C$ isotope ratios in aquatic ecosystems. *Proceeding of the Japanese Academy Series B*, *85*, 98–107.

Wang, D., Piazza, A., & Soule, S. A. (2018). Boundary-spanning in social movements: Antecedents and outcomes. *Annual Review of Sociology*, *44*, 167–187. https://doi.org/10.1146/annurev-soc-073117-041258

West, J. B., Bowen, G. J., Dawson, T. E., & Tu, K. P. (Eds.). (2010). *Isoscapes: Understanding movement, pattern, and process on Earth through isotope mapping*. Springer.

Wiek, A. (2007). Challenges of transdisciplinary research as interactive knowledge generation: Experiences from transdisciplinary case study research. *GAIA*, *16*(1), 52–57.

Zscheischler, J., Rogga, S., & Busse, M. (2017). The adoption and implementation of transdisciplinary research in the field of land-use science: A comparative case study. *Sustainability*, *9*(11), 1926.