

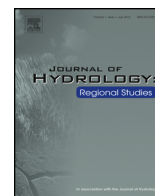


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## Supporting collaboration in interdisciplinary research of water–energy–food nexus by means of ontology engineering

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### ABSTRACT

*Study region:* We do not target particular region, but we implement the workshop experiments towards the researcher groups in the laboratories.

*Study focus:* When we discuss hydrology in the context of water–energy–food nexus, the discussion will inevitably include interdisciplinary contents. For example, in the impact assessment of groundwater use we need understanding whole mechanisms composed of all kinds of causal linkages from the groundwater concept or the groundwater issues. In this article we focus on ontology engineering, which is one of the base technologies in Semantic Web technology, as a method providing common terms, concepts, and semantics.

*New hydrological insights:* We discuss the effectiveness of ontology engineering approach in the process of collaborative research, and propose the way of ontology use contributing to interdisciplinary research through the experimental workshops of research development.

The introduction of ontology engineering approach will enable us to share a common language and a common theoretical basis. But the development of the new method based on ontology engineering is necessary. For example, knowledge structuring according to each perspective of researchers and simple figure accompanied with a reasoned argument in the background are the directions of tool development.

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## 1. Introduction

When we discuss hydrology in the context of water–energy–food nexus, the discussion inevitably includes interdisciplinary content. For example, in the impact assessment of groundwater use, we need to understand all of the mechanisms comprising all causal linkages. Considering the case of groundwater pumping for geothermal power generation, the volume of groundwater used will change if the pumped groundwater is discharged into a surface water stream, such as a river. In this case it is necessary to understand the impacts of such a volume change on the ecosystem and fisheries. This assessment process includes a discussion of solving the problems that involve multiple fields, as well as discussions from various perspectives and temporal–spatial scales. The [Committee on Facilitating Interdisciplinary Research \(2004\)](#) states that interdisciplinary research is typically collaborative and involves people from disparate backgrounds because such research is pluralistic in both method and focus.

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In the field of the science of team science (SOTS), is various methods and frameworks to support interdisciplinarity and transdisciplinarity have been proposed. However, as the SOTS fields matures, there is a need to develop more sophisticated methods and research designs, such as prospective quasi-experimental research designs (Stokols et al., 2010), to assess processes and outcomes of team science. In particular, as a new perspective, process-oriented approaches have been discussed in the field of sustainability science (Miller, 2013). But how do we facilitate the collaboration process in interdisciplinary and transdisciplinary approaches? Defila and Di Giulio (2010) reported that the existence of many different frames, or definitions of the problem, suggests a need to develop common goals and a common language. In particular, in the interdisciplinary field, Defilia et al. (2006) demonstrated that researchers having achieved a synthesis were also successful in the development of a common language and a common theoretical basis.

In this article we focus on ontology engineering, which is a base technology in Semantic Web technology, as a method providing common terms, concepts, and semantics. This article discusses the effectiveness of ontology engineering approach in the process of collaborative research. For this purpose, we first describe how to identify/design the research question in an interdisciplinary activity. Second, we describe the ontology as a domain-neutral metamodel and represent (illustrate) its construction process in a domain-neutral manner. Third, we attempt to apply the ontological approach to the experimental environment of the interdisciplinary research process. Finally, we discuss the future direction of collaboration support by means of ontology based on the problems of ontological approach which were revealed through a series of experiments.

## 2. How do we identify/design research question in interdisciplinary activity?

### 2.1. Related research

The approach discussed in this article introduces the collaborative design approach (Holsapple and Joshi, 2002) in the context of the transition management approach in sustainability science approach (Loorbach, 2007; Grin and Rotmans, 2010). As Miller (2013) reported, it is crucial to create a space for a more democratic and reflexive research agenda in process-oriented sustainability science. In other words, SS must deal with dynamics in the sense that SS can adaptively react according to the goals/requirements of the users.

In particular, since new developments will bring unexpected risks and sustainable development is a long term, open-ended goal, it is necessary to construct a base of knowledge that can flexibly correspond to the current situation (Kemp and Martens, 2007; Kajikawa, 2008). For this reason, a conceptual framework that facilitates collaboration and communication between researchers from different academic fields plays a crucial role in the knowledge structuring process. Kumazawa et al. (2009) proposed a framework of knowledge structuring in the sustainability science that includes a dynamic process of knowledge production, usage, and updating, based on ontology engineering. In response, Mizoguchi et al. (2011) discussed more concrete and technological aspects of knowledge structuring with the goal of implementation on a computer. Based on the framework proposed in Kumazawa et al. (2009) and Kumazawa et al. (2014a) we designed the initial design process for constructing an ontology for SS from the aspect of a knowledge-sharing tool to support co-deliberation.

### 2.2. Method for understanding the production process from initial interest to the development of a research question

Difficulty in interdisciplinary research involved in developing a research question can be identified through understanding the individual research interests of researchers and their areas of expertise. Documents used in meetings for research development, individual interviews with researchers, discussions and meetings during research and development, and structural drawings written on whiteboards and papers are materials that make up the texts used to clarify the contexts of a proposed research question and the interests of individual researchers.

However, the question arises as to how individual events, processes, reasons, questions, emerging problems and impacts, and goals are interconnected and are considered in developing the research question. As Fig. 1 shows, we can find the research questions from the context underlying discussions. We then must consider what connects the texts and contexts. The authors recognize that the layer of concepts and semantic relationships are positioned between the layer of text as an individual instance and the layer of a general context. Then, we must consider the relationship between researchers and the research domains of these concepts, as well as semantic relationships. This hypothetical framework, in Section 2.3, we discuss the framework upon which to understand this relationship.

### 2.3. Metamodel framework to share the knowledge structures of researchers and general models

Consider the following question: How does honeybee's world exist? Uexküll and Kriszat (1934) proposed the concept of the "unwelt" to explain the state of their existence. The "unwelt" is different from the environment, in that each actor constructs the unwelt by giving meanings to objects and events experienced in the environment. Uexküll reported that what really exists for each actor is not objective environment but rather a subjectively constructed world. From the same perspective, we attempt to grasp the knowledge structure of each researcher.

On the other hand, Giqch (1991) defines a model as an output obtained from the process of modelling, and defines modeling as one component of system design by which real-world problems are given a representation to facilitate decision making and problem solving. Furthermore, the epistemology of modeling originates in metamodeling.

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