# What does interdisciplinarity look like in practice: Mapping interdisciplinarity and its limits in the environmental sciences

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## ABSTRACT

In this paper we take a close look at current interdisciplinary modeling practices in the environmental sciences, and suggest that closer attention needs to be paid to the nature of scientific practices when investigating and planning interdisciplinarity. While interdisciplinarity is often portrayed as a medium of novel and transformative methodological work, current modeling strategies in the environmental sciences are conservative, avoiding methodological conflict, while confining interdisciplinary interactions to a relatively small set of pre-existing modeling frameworks and strategies (a process we call *crystallization*). We argue that such practices can be rationalized as responses in part to *cognitive constraints* which restrict interdisciplinary work. We identify four salient integrative modeling strategies in environmental sciences, and argue that this crystallization, while contradicting somewhat the novel goals many have for interdisciplinarity, makes sense when considered in the light of common disciplinary practices and cognitive constraints. These results provide cause to rethink in more concrete methodological terms what interdisciplinarity amounts to, and what kinds of interdisciplinarity are obtainable in the environmental sciences and elsewhere.

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## 1. Introduction

Interdisciplinarity (ID)[1] has been called upon to address a wide range of pressing environmental problems on the grounds that social, economic, ecological and climate systems are causally entwined. Solving these problems, it is thought, requires conceptually or methodologically integrated approaches from multiple social and natural sciences, and may also require the participation of extra-academic stakeholders (see Klein et al., 2012). There is thus a strong policy interest in promoting and funding collaboration among ecologists, economists, sociologists, civil engineers, atmospheric scientists and many others working on environmental problems. However, despite a large and still growing literature on the subject of interdisciplinarity, it remains uncertain how interdisciplinary work between fields like these can be cognitively structured in order to achieve gainful interdisciplinary responses to resource management and other environmental problems.

Much current literature characterizes (and often defines) "interdisciplinary" (ID) interactions as localized problem-driven interactions which result in novel and transformative methodological and conceptual developments (see Huutoniemi, Klein, Bruun, & Hukkinen, 2010 for an overview of how "interdisciplinarity" is understood in the literature). However, we will show here that in the case of environmental sciences much cross-border modeling is conservative, making use of pre-existing methodological frameworks. Rather than exhibiting substantial methodological innovation and diversification, interdisciplinary practices are *crystallizing* around four principal integrative methodological platforms - each of which we describe here. Each has various *interdisciplinary affordances*. These affordances help explain the effectiveness of these frameworks in bridging the institutional and cognitive constraints which generally inhibit interdisciplinarity in the environmental sciences. We will argue that crystallization of this kind is not a counter-intuitive phenomenon, however much it might run counter to the normative methodological assumptions or expectations of interdisciplinarity scholars. It can be understood as a rather natural attempt to build well-structured interdisciplinary interactions around a limited set of manageable modeling frameworks and strategies in a similar way to which participating fields

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[1] Throughout the paper, we will abbreviate both the noun "interdisciplinarity" and adjective "interdisciplinary" as "ID".

themselves internally structure their own practices around such frameworks and strategies (see Humphreys, 2004).

These lessons from scientific practice suggest that there is cause to be more cautious or more strategic about how interdisciplinarity is managed and implemented, and what we can reasonably expect from it.[2] The current presumption that interdisciplinarity needs highly problem-driven contexts requiring fundamentally novel conceptual solutions and methodological approaches should be weighed against our findings that the crystallizing strategies of interdisciplinary practice are more consistent with traditional models of scientific discovery. Such models favor incremental development by building from well-established mathematical frameworks, and adjusting concepts and methods at the outer edges of fields. Such techniques avoid disruption to fields but put them in a good position to develop solid cross-border collaboration or integration now and in the future.

The paper proceeds as follows: the following section provides a general background concerning increasing expectations of interdisciplinary research. Section 3 discusses a more specific context in which interdisciplinary research is demanded in the environmental sciences as a result of increasing interactions between natural and social systems, which have traditionally been studied separately. Section 4 offers our typology of emerging ID modeling strategies, namely, data-driven modeling, modular model-coupling, integral modeling, and substitutive model-coupling, drawing on our ongoing case study. Section 5 draws several methodological lessons for interdisciplinarity based on our findings, and more generally argues for the importance of understanding scientific practice in order to prescribe how to conduct interdisciplinary research. Section 6 concludes by summarizing our argument.

## 2. Expectations of interdisciplinarity (ID)

Over the last 20 years or so interdisciplinarity (ID) has been widely discussed in science policy, science studies and education science. Much of this discussion is strongly favorable towards ID, seeing it as essential to resolving 21st century environmental, social and health problems, while perceiving the institutional and cognitive rigidity of established disciplines as obstacles to effectively resolving such problems. New approaches are required, and ID interactions (whether collaborative or otherwise) are seen as the medium through which such approaches can be developed. As a result, an important imperative has been placed on identifying "genuine" ID interactions which achieve these goals, from those that do not, particularly for research funding purposes (see Huutoniemi et al., 2010).

However, agreeing on a definition of ID which can distinguish genuine ID interactions from other kinds of cross border interactions or exchanges, such as multidisciplinary or even imperialistic (Mäki, 2013) ones, has proved difficult. Indeed a major focus of ID studies has been on taxonomizing different ways interdisciplinarity and multidisciplinarity can be conceptualized or occur in practice (Klein, 2010). Scientists are by no means united themselves on what they might mean by it (see Aboelela et al., 2006). The broadest encompassing definitions do not take a stance on what kinds of activities or interactions ID consists of. Klein (1990, p. 196), for instance, gives the following general definition: "Interdisciplinarity is a means of solving problems and

answering questions that cannot be satisfactorily addressed using single methods or approaches."

Within this many activities could be considered interdisciplinary. However, in recent years a predominant view has formed around the expectation that genuine ID requires *integration* (see Lattuca, 2003). That is, interdisciplinarity is,

> a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession … [by] draw[ing] upon disciplinary perspectives and integrat[ing] their insights through construction of a more comprehensive perspective. (Klein & Newell, 1997, pp. 393-394)

The National Academy of Sciences (2006) gives a similar definition, according to which interdisciplinarity is:

> "a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or field of research practice."

ID interactions are integrative to the extent that methodological and conceptual frameworks or other disciplinary resources from separate disciplines and fields are integrated in order to solve a problem. In theory, integration serves to distinguish ID from multidisciplinarity. In multidisciplinary contexts researchers simply break up a problem into parts recognizable as disciplinary problems, and go away and solve those parts separately without forging any real connections between their approaches. Integration and similar concepts are, however, often cashed out in the relevant literature in term of metaphors rather than harder methodological or conceptual criteria. Klein (2010) cites a range of "key descriptors" applied to describe ID; "integrating", "interacting", "linking", "focusing" and "blending".[3] Other popular metaphors include "boundary crossing" or "bridge building" or "bilingualism" (Repko, Szostak, & Buchberger, 2016). Multidisciplinarity in contrast is associated with phrases such as "juxtaposing", "sequencing" or "coordinating". "Integration" itself however remains arguably vague (although see O'Rourke, Crowley, and Gonnerman (2016) for some philosophical attempt to clarify the concept using cases from biology).

While many notions of ID treat integration as the crux of ID, some concepts require more, often motivated by the strong normative stances authors take towards ID, and what they expect from it. Two additional requirements, or at least expectations, stand out in this regard. The first is that proper ID requires earnest attempts to address real-world problems. The motivation for this relates to the objectives many have for ID in the first place, and/or the conditions required for prompting integration. ID research or problem-solving should be applied to outward-looking research and problem-solving work, rather than being inwardly directed at questions or problems framed within disciplinary contexts. Further, real-world problem-solving contexts create the pressure for ID interaction insofar as real-world problems cannot be reduced to one discipline's methods, concepts, etc. Such problems are complex and cross disciplinary boundaries (Repko et al., 2016). Hence there is an expectation that real-world problem-solving prompts or

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