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Challenges of Interdisciplinary Research: Reconciling Qualitative and Quantitative Methods for Understanding Human-Landscape Systems

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Interdisciplinary research has been proposed and increasingly practiced as a way to transcend the limitations of our individual disciplines, which compartmentalize and limit the production of knowledge in multiple ways. While the compartmentalized knowledge that we know as modern science has provided many breakthroughs in understanding the world, it does not seem to be a match for the many complex and wicked problems facing us in the 21st century. As many have pointed out, there is increasing recognition that most environmental issues are interdependent with social issues, which has led to increasing calls for and funding that brings together different disciplines in multi-, inter-, and/or trans-disciplinary research. Yet, the concepts and methods we bring to these efforts are primarily rooted in the disciplines that shape the way we think about the world and how we conduct research, making these interdisciplinary enterprises challenging and often frustrating.

The good news is that natural and social scientists tend to share an understanding and acceptance of a scientific approach. This approach to science can be the basis of collaborative conversations even though very few scientists of any discipline continue to believe in the kind of positivism espoused by the simplest explanations of the scientific process (e.g., Bauer 1992) or even agree on what we mean when we say science (e.g., Chalmers 1982). We can mostly agree that research carried out in a scientific way is empirically based, systematic, skeptical, and ethical (e.g., Merton 1942). Obvious disciplinary differences, however, quickly emerge when it comes time to determine a methodological approach: questions to ask; appropriate methods for collecting data; what actually constitutes data; applicable analytic tools; what evidence looks like. One of the most observable epistemological boundaries is between those natural and social scientists who use quantitative data and those – primarily a subset of social scientists – who rely on qualitative data.

Qualitative data, usually in the form of words from observations, interviews, or documents, has been the primary data source for some social science disciplines throughout their history (e.g., anthropology, political science) and most social science disciplines regard qualitative data methods as critical tools in understanding the social world (e.g., Miles and Huberman 1994). Observing and documenting people at their work or play; talking with them about what they know, believe, or feel; and examining the artifacts they leave behind are all sources of data that are difficult for those not trained in their use to understand or value. Quantitatively inclined scientists are disposed to see these types of data as more suspect than data in the form of numbers. The skepticism comes in multiple forms including concerns regarding subjectivity of both the researcher and the informant, lack of generalizability to other contexts due to absence of random samples, difficulty in replicating the research, and the possibility for multiple interpretations of data.

Concerns raised by social scientists about traditional expectations for science, on the other hand, are related to the subject of their study – people who are conscious agents with ideas about their world and what it means. In addition, these subjects are constantly learning and changing, even from research questions that may be asked. In a national survey of ecological scientists, my co-authors and I were interested in how these scientists perceived and acted on their role in natural resource policy (e.g., Steel et al. 2001). As this is a very small world, one of my colleagues at another university received the random sample survey; after answering the questions and returning it he gave me a call. As he considered the questions and his answers over time, he realized he had changed his mind on the role of scientists in policy making. As a survey researcher, I recognize that any data collected is a snapshot of what was happening at the moment respondents fill in a survey and that many factors affect any subsequent meaning they place on the role of scientists (or whatever social phenomenon I am studying). This quick learning and consequent change in perception common to humans was starkly revealed in this particular instance although all social scientists realize this is happening with their subjects. This is one of the factors that make it difficult to talk about stable findings in the social world and difficult for those not trained in the social sciences to accept the methods used to study social phenomena as scientific in the same way that they accept the limitations of their own disciplinary methods.

The open nature of social systems makes it nigh on impossible to create controlled environments where we can manipulate single variables to study impacts on individuals, groups, or other social phenomenon. Instead, we have to accept that we are dealing with probabilities and potentialities, with maybe some observable co-relation(s) of impact. Something that looks like a causal process may lead to specific predicted outcomes, but in other circumstances or situations it may not due to uncontrollable or even unknowable factors. Natural science faces many of the same challenges when working at the landscape level – an open system that cannot be hermetically sealed off from any outside impact or event. Open systems - social and natural - are "generated not by one, but by a multiplicity of causal structures, mechanisms, processes and fields" (Bhasker 2010: 4). Even as we study an open system it is likely to be affected in ways that are not the focus of the research (e.g., a scientist learning from the questions I ask). We may not capture the mechanisms, processes, or inputs that are actually contributing to any specific impact because we aren't looking for or at them.

These and other issues discussed below make it difficult to use what Kuhn (1996) calls "normal" science when studying open systems and when we try to integrate knowledge about natural and social systems. After taking a quick look at different ways of thinking about science that affect how we collect and analyze data, I propose an alternative approach that may hold the best options for interdisciplinary work that tries to integrate both natural and social science disciplines and traditions. Finally, a set of skills for interdisciplinary research are proposed and discussed.

Philosophical Roots of Research Methods

While we can talk about a general scientific attitude or approach, it is not obvious what we mean when we say science or scientific method. Years of philosophizing and studying science reveal that these terms cover a broad array of practices and procedures (e.g., Blaikie 1993; Chalmers 1982; Hacking 1999; Latour and Woolgar 1985). The standard view of science – science as facts, developing causal laws, and separate from values – is based in the philosophical approach called positivism, which has been defined in multiple ways by several generations of philosophers and scientists (see Box 1 for a summary). The post-WWII definition of positivism emphasizes value-free evidence, hard facts, and predictions (e.g., Hempel 1965). Positivists look for constant relationships between events or variables, searching for a theory of causation that can be generalized to all instances of the examined phenomena. This can most easily be done when the variable(s) of interest can be isolated and manipulated in a controlled environment.

Box 1: Characteristics of Positivistic Approaches

- The logic of inquiry is the same across all sciences.
- The goal of science is to explain and predict; the ultimate goal is to develop universal laws of cause and effect.
- Scientific knowledge is testable and can only be proved through empirical means and deductive reasoning.
- Science is based on data derived through strict procedures and is fundamentally different from common sense.
- Science is value free.
- Phenomena are operationalized in a way that can be measured quantitatively.
- Controlled experiments are the gold standard in data collection although other data collection methods are used.

While this approach can be relatively straightforward when studying many aspects of the material world, once scientists begin working outside a laboratory setting where inputs cannot completely be measured or controlled, it requires incredible resourcefulness and even some assumption-breaking to maintain the premises of positivistic science. For example, social studies of science have demonstrated that contrary to the positivistic assumption that scientific facts are possible because everyone sees reality the same way, what observers "see is not determined simply by the characteristics of the thing observed; the characteristics and the perspective of the observer also have an effect" (Robson 2002: 21). While this author is primarily concerned about how the preconceived (i.e., disciplinary) notions of scientists affect what questions they ask and how they see their results, particle physicists have also demonstrated famously, if mind-bendingly, that our observation alone can affect the presentation of particles as either particle or wave (Greiner 2001).

In reaction to criticisms of positivism as practiced by both natural and social scientists (e.g., Klee 1997) a post-positivistic approach has emerged. Post-positivists, for example, believe that while reality exists, we can only know that reality imperfectly due to our limitations, including the limitations of our scientific methods and approaches. There is also an acceptance that the perceptions, values, and knowledge of a researcher affect what is studied (e.g., Reichardt and Rallis 1994) although there remains a commitment to objectivity, which is managed through explicit recognition of possible biases by the researcher and/or methods.

Box 2: Characteristics of Relativistic Approaches

- Phenomena don't exist "out there," but in the minds of people and their interpretations of experience; there is no objective reality.
- Different ways of looking at the world, including but not limited to science, should be described rather than used to determine predictions or facts.
- Reality is represented through the eyes and words of participants; language is paramount as it is considered both data and the primary instrument through which participants construct reality.
- The meaning of behavior in all of its complexity can only be understood in context.
- Research is used to explore hypotheses rather than uncover empirical facts that can be transformed into universal laws.
- Qualitative methods are used to gather data that can be converted into text for analysis.

Some philosophers and social scientists see these tenets of positivism and post-positivism as restricting and even nonsensical when applied to the social world (e.g., Feyerabend 1978). For years, a battle raged between those social scientists who saw quantitative methods grounded in some version of positivism as a method for understanding the social world and those who took a more relativist approach, with a core assumption that what we perceive as reality can only be built through conceptual systems (see Box 2). Because different societies in different times and places have different conceptual systems, these scholars asked, how can there be anything we call an objective reality?

Relativists have been quite influential in the social sciences with their arguments that phenomena aren't "out there," but rather exist through interpretations in our minds, that we create reality through shared and ongoing social construction. This is a hard concept for many scientists – both natural and social - to take seriously and is often a barrier in interdisciplinary work. After all, we look out at the world and see something real – a tree, cars, other people. Relativists argue that we "construct" this realness by giving things we see names, relationships, histories, explanations and then characterize the outcome of that construction process as reality. This epistemological approach, so critical of positivism, goes by multiple names including interpretive, constructionist, and naturalistic. What the approaches share is an assumption that any study of humans has to take into account the meanings that people give to their world, actions, and their motivations. Reliance on qualitative data is another hallmark, with a rejection of quantitative methods that objectify humans and ignore the meanings that subjects give to their actions.

As an example of this philosophical approach, Keller (2000) traced the history of genomics beginning with emergence of the terms 'genetics' in 1906 and 'genes' in 1909. She described how scientists developed a concept of a physical phenomenon without any basis in the material world yet able to go on to develop amazing insights into how evolutionary processes work. Early in the 20th century, a scientist claimed, "The 'gene' is nothing but a very applicable little word, that can be combined with others…" (Johannsen 1911 as quoted in Keller 2000: 2). As late as 1933, there was still no consensus on genes, "whether they are real or purely fictitious" (Morgan 1933 as quoted in Keller 2000:2) although biologists were treating them as real with the capacity to "explain by their combinations the phenomena of the living world" (deVries 1889 as report in Keller 2000:3). Genes became real in the sense that scientists began to agree on what functions this concept commonly known as "genes" might serve and methods for studying those processes and phenomena, definitely a social process as much as an uncovering of some reality out there waiting to be discovered. Keller describes how the social arrangements of science – research following the general dictates of positivism – resulted in a reality that we now know as genomics. And, that reality continues to amaze us in ways as scientists continue to advance our knowledge of how living organisms function through metabolic networks, enzymes, and epigenetics.

Many social scientists working from an interpretive or constructivist perspective do not deny the possibility of an underlying reality although they have grave reservations about an objective reality that can be known through general laws and principles. Instead, the role of the researcher is to understand the multiple layers of meaning and knowledge created through social processes, including science, around the phenomena of interest. The goal is to get multiple perspectives through multiple methods, thereby revealing the "reality" of the world as known by the participants. As described in Keller's example above, science is the creation of a social consensus that is reified into "facts" that we come to accept as real, objective – at least until a new consensus challenges the world we perceive as real. Methods used by qualitative scientists include interviews, observations, and close reading of texts as language is viewed as the primary instrument through which we construct the world.

So, how might scientists studying dynamic social phenomena engage with natural scientists on issues as large and complex as landscape conservation, climate change, or even natural resource management? Realism is a philosophical approach that has long been used in both social and natural science for scientific explanation while avoiding the limitations of positivism and relativism, and may actually be a better description of what we're doing when we practice science (hence the label) (Blaikie 1993). Realism views the task of science as inventing theories to explain the world and then testing the theories through rigorous and replicable methods (see Box 3).

Box 3: Characteristics of Realistic Approaches

- Knowledge is a product of social and historical processes. All scientific findings can and will be challenged.
- The role of science is to formulate theories that explain the world and then to test the theories through rigorous and systematic analyses.
- The explanations focus on how mechanisms produce events in specific conditions. Events are to be explained even when they can't be predicted.
- A scientific law describes patterns or tendencies of a mechanism.

Realism suggests that there are no "facts" that are beyond dispute – new theories can replace old ones as credible explanations for how things work. Knowledge is a social and historical product with "facts" that are theory-laden (i.e., they reflect and are embedded in a specific theoretical perspective). Observations are always subject to reinterpretation as new theories emerge to explain the world.

A classic (and in this telling, simplistic) example is in the geosciences where scientists as early as the 16th century observed that most of the continents seem to fit together like a puzzle (e.g., Kious and Tilling 2001).   It wasn't until the middle of the 20th century that a theory – not an observation – of plate tectonics became accepted as a consensus explanation of the large scale motions of the earth's lithosphere. As that theory became a working explanation, scientists began to use it to explain paleontological observations of similar plant and animal fossils on different continents, the formation of mountains during different geological time periods, and geomagnetic anomalies in mid-oceanic ridges. All these phenomena had been "explained" through earlier theories that were displaced by the ideas first of continental drift and then plate tectonics.

Realism assumes that there is a reality that exists independently of our perceptions. Scientists explore the mechanisms by which actions cause an outcome, as well as the context which provides the conditions under which mechanisms can act (Robson 2002). In a simple illustration, gunpowder obviously blows up when exposed to a flame. Except when it doesn't. There are circumstances when gunpowder doesn't blow up – it's damp, no oxygen is available, heat isn't available for a long enough time. Realist approaches recognize that there are unlikely to be universal laws that work in every instance in the natural and social world and the role of the scientist is to understand not just the mechanisms (i.e., flame and gunpowder) but also the impacts of the specific situations in which the mechanisms do and don't work.   Realism also acknowledges that our scientific theories may be incomplete and even wrong yet appear to explain what we observe; they may even be a close enough explanation that we can continue to fruitfully study the phenomenon of interest for long periods of time.

The realism approach may be a bridge between social and natural sciences in interdisciplinary projects, especially when we're working on complex and open systems. While causal processes may lead to predicted outcomes in some situations, it is equally likely that other outcomes may occur because there are multiple mechanisms at play in any given situation. Our task becomes one of hypothesizing what those mechanisms might be and then looking for evidence about the actual existence as well as the functioning of those mechanisms. Realism provides a philosophical approach that values "what works" – it points us toward a method for studying systems where mechanisms are operating on multiple levels on numerous and interdependent phenomena. Our task as interdisciplinary researchers is to use the insights of our disciplines in the context of the problem to co-produce a theory that explains the variables of interest. Of course, this is much easier said than done as evidenced by the difficulty of interdisciplinary research.

A real challenge has been integrating social science results, especially those drawn from the relativistic traditions, into models dominated by quantitative input. Some interdisciplinary integration has occurred through GIS (or other databases) linking different kinds of data without trying to standardize them (Strang 2009). Another emerging technique for studying the human and natural dynamics in large complex systems is agent based modeling, which may offer an opportunity to integrate the rich detail of meaning that is uncovered through qualitative research. The models simulate the concurrent actions and interactions of multiple agents using simple behavioral rules to generate complex behavior. However, developing simple behavioral rules that integrate credible and sophisticated individual and group behavior has been difficult. In an earlier study regarding the use of probabilistic climate forecasts by water managers, my co-authors and I conducted more than 100 interviews with managers in three different water basins around the country (Lach, Rayner, and Ingram 2005). Through the analysis of the interviews we came to see a set of norms operating consistently across organizations at multiple scales. Those who manage water in this country value reliability of the system (water comes out when you turn on the faucet), safety and quality (the water is potable), and cost – in that order. These norms were not necessarily things that water managers could talk about about directly when we asked – most of us are not able to characterize the institutionalized norms we live by. But after the analysis was completed and we went back to talk with them we heard even more examples of how these norms were entrenched in their day-to-day operations. Studies that use qualitative research methods to uncover the meaning that people have about their day to day practices may provide an empirical basis for simple behavioral rules that drive agents in an agent-based model exploring water resources.

Results from previous social science research, as well as research from integrated studies, can provide not just valuable insights into the social world, but act as input for models that traditionally depend on quantitative data from the natural sciences. However, one thing we have learned from years of trying interdisciplinary research, to get to the point where scientists can see their research as compatible, complementary, and integratable, a certain set of traits and skills is required for success.

Traits and Skills of Successful Interdisciplinary Scholars

Interdisciplinary research challenges our disciplinary training and ways of thinking. "The effect, if not the purpose, of interdisciplinarity is often nothing less than to alter the way we think about thinking" (Geertz 1980: 165-166). An extensive study of interdisciplinarity has emerged over the past

Box 4: Competencies for Interdisciplinary Researchers (Repko 2008)

Traits
- Entrepreneurial spiral
- Love of learning
- Ability to reflect
- Tolerance
- Receptivity and respect for other disciplines
- Ability to understand other disciplines
- Respect for other points of view
- Willing to work with others
- Humility

Skills
- Communication competence
- Abstract thinking
- Ability to assess multiple arguments
- Nonlinear thinking
- Creative thinking
- Holistic thinking

decade or so and a set of traits (distinguishing qualities) and skills (cognitive abilities) have emerged as fundamental to functioning effectively in interdisciplinary settings (see Box 4).

Critical for those who engage in interdisciplinary research are a tolerance for ambiguity and paradox in the midst of complexity, willingness to work with others, openness to the perspectives of other disciplines, and humility. Unlike research based in our disciplinary training and experience, interdisciplinary projects have been described as "moving into foreign territory" (Bromme 2000: 116) with all the concomitant dislocations, confusion, and frustrations when we don't understand the language, the practices, or even the way people see the world. This unsettledness can be upsetting to those who expect a clear path to understanding. It is understandable why disciplinary science is so appealing with its rules, focus, and especially its boundaries that legitimately draw borders on what we should be studying and what we should be ignoring. Interdisciplinary science requires us to set our own boundaries without any real fundamental basis for doing so. Theory-generating approaches like realism may be the one of the strongest methods for taming some of this angst-generating ambiguity if we can learn to think and talk together creatively about how we think the systems we're studying work.

Another paradox of interdisciplinarity is the requirement that practitioners bring strong disciplinary knowledge and practice into a setting to inform but probably not direct the research, which is likely to look like nothing going on in any single discipline. We have to be ready to integrate our knowledge and practice into conversations with people who not only don't share our perspective but bring equally robust but different knowledge and practice to the discussion. After months working with an interdisciplinary team on urban wetlands, for example, we came to a common understanding that while wetlands provide certain critical ecological functions, they also provide valued social services although not in the form that ecologists view as optimal (Santelmann and Larson 2005). Community members perceived natural wetlands as swamps, vermin and mosquito breeding grounds, and dangerous places where undesirables hang out. Our interdisciplinary team of landscape architects, ecologists, geographers, economists, and sociologists, excited about our progress, attended the annual Ecological Society of American (ESA) meetings to talk about our approach and findings. To say this was underwhelming to the gathered ecologists is an overstatement – most people in the audience had no idea what we were going on about. They asked disciplinary-focused questions that even our ecologists had difficulty answering because the team had moved into a new way of thinking about urban wetlands and the services they provide (this was before the concept of ecosystem services was widespread). Unfortunately, we did not have the communication skills so others from outside the project could relate to what we were doing. While we were getting better at letting our disciplinary practices be transformed through interdisciplinary research, we hadn't yet gained the skills to re-translate what we were learning into language, concepts, and methods that our disciplinary peers can understand or learn from.

The Future of Interdisciplinary Research on Human-Landscape Systems

In a report that is now more than seven years old, the National Academies of Science (2004) reviewed interdisciplinary research in academic and non-academic settings. The NAS identified ways that funding agencies can provide incentives for interdisciplinary research (e.g., funding problems rather than disciplines), professional societies can provide professional development and incentives for those involved in interdisciplinary work, and academic institutions can provide interdisciplinary training (e.g., funding graduate students across departments). In many ways, this report is a call to action that is now reflected in multiple agency efforts.

In a recent report, *Rebuilding the Mosaic* (NSF 2011), the NAS recommendations are echoed by social scientists who report that the future of research in their fields will be interdisciplinary as well as data driven and collaborative in nature. It will be problem-focused and concentrated on developing new ways to solve problems and do research. Those scholars and NSF all realize that this vision stands in direct contradiction to current academic and research organizations structured along disciplinary lines, so funding needs to include capacity building opportunities to help us become collaborative and interdisciplinary researchers.

The National Institutes of Health (NIH) are also challenging the academic research culture to facilitate interdisciplinary research. They are funding initiatives to "dissolve academic departments within academic institutions…, train scientists to cultivate interdisciplinary efforts, and build bridges between the biological sciences and the behavioral and social sciences" (NIH 2012). Like NSF, NIH is aware that building capacity of scientists at all career levels is critical so is supporting programs that allow researchers to learn new disciplines that complement their original training.

There are two general approaches to interdisciplinary research: one is to bring together disciplinary scientists on a common problem and the other is to train scientists to think interdisciplinarily. Many new graduate degree programs are emerging (with support from funding agencies and academia) to begin training interdisciplinary scientists. And, many disciplinarily-trained scientists are creating collaborative teams to respond to interdisciplinary calls for proposals. We need both approaches – scientists who can think deeply on a focused area and others who can think broadly across multiple areas – to face the large questions posed by the interactions of humans and landscapes. And, when we come together on a research project we need access to the fullest range of methods for understanding the world. This requires not just a tolerance for the unfamiliar but a welcoming of different traditions, different perspectives, and ultimately different solutions.

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