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COMMUNITY ESSAY

Tools for enhancing interdisciplinary communication

Leigh Winowiecki[1*], Sean Smukler[1], Kenneth Shirley[2], Roseline Remans[1], Gretchen Peltier[2], Erin Lothes[2], Elisabeth King[2], Liza Comita[2], Sandra Baptista[3], & Leontine Alkema[4]

[1] Tropical Agriculture and the Rural Environment Program, Earth Institute, Columbia University, 61 Route 9W, Palisades, NY 10964 USA (email: leigh.winowiecki@gmail.com)
[2] Earth Institute, Columbia University, Hogan Hall, Broadway, New York, NY 10025 USA
[3] Earth Institute, Center for International Earth Science Information Network (CIESIN), 61 Route 9W, Palisades, NY 10964 USA
[4] National University of Singapore, S16 Level 6, 6 Science Drive 2, 117546 Singapore

Authors' Personal Statement:

This is a collaborative community essay, written by ten postdoctoral research fellows who had the opportunity to come together at Columbia University's interdisciplinary Earth Institute. In many ways, we were different: our disciplinary backgrounds run the gamut in physical and social sciences; we study in different parts of the world, from sub-Saharan Africa to Latin America; we approach our work differently—some of us spend our days in the field collecting and analyzing soil samples, others conduct in-depth interviews in rural communities, while still others spend time in the lab elaborating formulas and crunching numbers. Yet, we found common ground: all of us are committed to addressing issues of sustainability in complex environments. As such, we wanted to harness our diversity and various strengths to bring together scientific, political, economic, demographic, geographic, ecological, and ethical perspectives on the challenges and opportunities of sustainable development. We remain ambitious in our aims. Nonetheless, we realized that our first task was figuring out how to communicate effectively across often disparate disciplines. This community essay chronicles that part of our journey. We hope it will be of use to others who endeavor to work across and beyond traditional academic disciplines.

Introduction

What do an ecologist, political scientist, and theologian have in common? In traditional universities, dominated by departmental silos, the answer may be, "not much." Yet, as the magnitude and complexity of problems such as climate change, globalization, and population growth increase, scholars and practitioners are developing creative ways to approach solutions. Enter interdisciplinary research.

Interdisciplinary research draws upon and combines knowledge, worldviews, and methods from several disciplines (Collins, 2002; Morse et al. 2007). Universities, granting agencies, and researchers are more and more recognizing the importance of interdisciplinary work, and a growing body of literature is discussing its necessity, as well as bridges and barriers for its implementation (Kinzig, 2001; Benda et al. 2002; Heemskerk et al. 2003; Eigenbrode et al. 2007; Morse et al. 2007; Longstaff, 2009; McArthur & Sachs, 2009). If, at one point, emerging techniques and standards were not yet widely known or implemented (Robertson et al. 2003), interdisciplinary practices have become much more accepted over the past few years (Buller, 2008; Bracken & Oughton, 2009). As disputes about the value of interdisciplinary research diminish (Redman et al. 2004), the debate is now framed around how interdisciplinary research is defined and practiced and how its outcomes differ from disciplinary projects (Heemskerk et al. 2003; Harris et al. 2008; White et al. 2008).

We broadly define interdisciplinary research as an integration of different discipline-based ontologies, epistemologies, and methodologies in order to develop emergent ideas (for other classifications, see Sillitoe, 2004; Morse et al. 2007; Harris et al. 2008). These integrated research ideas, we contend, are arguments for interdisciplinary research as they often acknowledge the research questions' true complexity. Eigenbrode et al. (2007) further suggest that understanding philosophical differences about the nature of knowledge deeply rooted in one's worldview, epistemology, and methodology can promote effective collaboration and communication among researchers with diverse disciplinary backgrounds. Others debate whether interdisciplinary research is most effectively carried out within the context of new fields of study defined by "problems"—say, a university Department of Water—or by specialists working together seeking common ground (Taylor, 2009). We recognize the current reality that most researchers attempting interdisciplinary work are firmly rooted in

their traditional academic disciplines.

Given disciplinary specialization, we argue that interdisciplinary projects can harness this specialized knowledge, using the rigorous depth and skills of core disciplines as an essential foundation for bridging them. As a diverse group of postdoctoral research fellows based at the Earth Institute at Columbia University, we had an opportunity to collaborate across an unusual range of disciplines. Although involved in our independent research projects within our various departments, we organized an informal seminar, meeting for 2-3 hours every Friday to discuss sustainability issues in complex environments. During these conversations, we quickly discovered communication barriers across disciplines that inhibited constructive discussion. We presumed these barriers would most certainly be common to any group of diverse researchers attempting to solve pressing issues facing society and naturally became interested in the process and concepts of interdisciplinary communication and research. To further structure the dialogue, we decided to focus on an urgent and relevant problem that best illustrated how different disciplines are entangled and embedded in these complex problems: *How can the world's population feed itself justly and sustainably by the year 2050?*

Upon initial discussions, we realized that before any substantive collaboration could occur, we needed to better understand our own ontologies, epistemologies, and methodologies and the way that they serve as the "building blocks" of research. In brief, ontology relates to our worldviews and assumptions about the nature of things; epistemology deals with our beliefs about knowledge: what we can know, how we can know it, as well as our values and aims; and methodology refers to the tools and techniques of research (Grix, 2002). While each of these three elements is highly personal, they also tend to be bound by disciplinary norms. We aimed for pluralism (Miller et. al. 2008) and had to acknowledge that some ontologies and/or epistemologies do not readily combine and that one frequently dominates (Hollis & Smith, 1990). Most of us had little, if any, prior formal training in communicating effectively with those outside of our respective fields, yet we felt leaving these issues unexamined was likely to stymie any attempt at interdisciplinary research.

In this essay we share highlights of our experiences using emerging communication tools, including a "philosophical toolbox" and scenario-building exercises, to enhance our collaborations as an interdisciplinary group of researchers. The activities we describe below may be useful for enhancing dialogue, defining research questions, and building collaboration within interdisciplinary research groups and institutes, both in undergraduate and graduate classrooms, and even, as we learned, among researchers in the same discipline.

Methods

Overview

At the time, we were a ten-person group of early career researchers trained in ecology, public health, geography, soil science, theology, agronomy, statistics, and political science. We were postdoctoral researchers within the Earth Institute at Columbia University, all enrolled in a unique Fellows Program that is "dedicated to a better understanding of critical scientific and social issues related to meeting global sustainable development goals."

Given the program's freedom and flexibility (and interdisciplinary nature), we self-organized a semester-long exercise to explore how a group of diverse researchers could begin to tackle a current environmental and social issue, focusing especially on interdisciplinary communication. We met as a group once a week to explore the processes of conducting interdisciplinary research. Because we are all firmly rooted in our respective disciplines, we decided to first spend time having each member expose and communicate her/his discipline to the rest of the group. This was done by circulating a key journal article within each discipline to discuss during a one-hour session. We next examined existing definitions of interdisciplinary research and invited guest speakers to further elaborate on the topic. After a seminar with guest speakers who specialized in developing scenarios surrounding the food crisis in East Africa, the group quickly became interested in scenario building. To follow up, we invited two facilitators to demonstrate specific scenario-building exercises (e.g., creating a timeline, mind mapping). Our efforts culminated in a weekend-long retreat employing exercises aimed to bolster interdisciplinary communication and research (Box 1).

Toolbox

Communicating and framing problems jointly is a defining mark of interdisciplinary research. However, our attempts to develop a common research question, let alone communicate our disciplines to one other, encountered unexpected barriers. We needed a tool that would expose these differences, locate at which level the barriers existed (e.g., epistemological, ontological, or methodological), and provide a platform for an open discussion. We decided to utilize a set of tools developed by Eigenbrode et al. (2007) and researchers at the University of Idaho to explore our philosophical differences.[1] The toolbox is essentially

[1] See http://www.cals.uidaho.edu/toolbox/index.asp.

Box 1 Communication tools employed.

- **Interdisciplinary Toolbox** – undertake structured dialogue about research assumptions.
- **Integrated Timeline** – brainstorm with all participants and disciplines about historic events that led to the current food-insecurity situation.
- **Mind Mapping** & **Mini-Mind Mapping** – brainstorm factors and drivers that influence food security.
- **Cross-Impact Analysis** – explore the relationships between each major theme identified in the mind-mapping exercises.
- **Imagining the Ideal** – create and share visions about the ideal outcome or solution to the research problem.
- **Backcasting** – undertake scenario-building exercise that works backward from imagining the problem is solved (the world is food secure) and explores the paths to get there.

a set of questions that ask the researcher to think about her/his scientific values, assumptions, and language. Questions ranged from how we viewed applied versus basic science to whether we thought the scientific process could be unbiased.

Exploring our views on these subjects revealed substantial differences, including epistemological disparities regarding whether there is a place for advocacy and if it is truly possible to conduct research without an inherent bias. While some colleagues felt complete lack of bias is impossible, others countered that, "an essential component of research is objectivity and advocacy would destroy that." Methodological differences were highlighted, especially in regard to prioritizing quantitative or qualitative methods. Some of these dissimilarities were rooted in our respective disciplinary training (e.g., social vs. natural science), but many were based on personal views and experiences, illustrating the value of this exercise even when collaborating with those in the same field. While we did not reach consensus on all issues, identifying and sharing our differences was insightful for individual researchers and was an essential first step for overcoming potential communication barriers or even future conflicts. For example, disciplines have different accepted validation methods: an ecologist may validate data using rigorous quantitative statistics while a theologian may do so using descriptive qualitative statistics. It is important for researchers from different disciplines to acknowledge and respect the different methodologies.

Scenario Building

Scenario building has been used in large scientific ventures to address problems such as climate change or global ecosystem health (MEA, 2005; IPCC, 2007; Hulme & Dessai, 2008; McLean & Egan, 2008; O'Neil et al. 2008; Parson, 2008; Wilkinson & Eidinow, 2008). We selected scenario building as a technique because it illustrates the interconnectedness among drivers, identifies a variety of perspectives surrounding a theme, and exposes challenges and consequences to a solution (or scenario). O'Neill & Nakicenovic (2008) highlight that scenario exercises can be either process- or product-oriented, and that the process-oriented perspective may have goals such as exposing challenges and perspectives of a given situation, finding consensus, or developing strategies. Our objective was to use scenario building as a tool to bridge disciplines, to explore interdisciplinary communication, and to develop joint research agendas. We were interested more in the process of communicating as an interdisciplinary team and used scenario building to explore complexity rather than as a quantitative predictive tool. While food security serves here as an illustration of how the activities played out, we clearly did not expect to answer the question itself through these preliminary exercises.

There are a variety of scenario-building techniques (see, e.g., Bishop et al. 2007). Collectively, we identified six techniques that we thought would be helpful in systematically collecting integrated information from all participants on the issue of food security. A professional facilitator generally leads scenario-building workshops, but we chose to rotate the role of facilitator among ourselves throughout the exercises.

Technique One—Integrated Timeline

In this exercise, we drew a timeline, pieced together from various disciplinary insights, of the major events that led up to the problem of global hunger. In preparation, each participant conducted a brief literature review of food security from the perspective of her/his specific discipline and then shared it with the group in an open forum. The timeline provided an opportunity for the group to collect complementary information about key historical events from our various disciplines. The exercise of highlighting issues and important events (from a disciplinary perspective) demonstrated important differences among disciplines, as well as the need for collaboration to fully address the issue's complexity. For example, the soil scientist discussed the use of synthetic fertilizers, the demographer emphasized population growth, and the political scientist reminded everyone of the role of political will. While it is common practice in any scientific project to review thoroughly the existing literature, the exercise of simultaneously examining literature from different disciplines and bringing together discipline-specific knowledge into a common format of discrete historical events allowed us to identify key linkages and gaps and to ask questions such as, "What has challenged us to work

to feed the world justly and sustainably in the past?" In terms of communication, the exercise also pushed us toward reorganizing and pooling our knowledge, identifying differences in our disciplinary language, and encouraging us to explicitly define key terms and concepts. Our choice of the term "researchers" to describe our group is one example. Including disciplines from the humanities means that not all of us, strictly speaking, identified ourselves as scientists!

Techniques Two and Three—Mind Mapping & Mini-Mind Mapping

Mind mapping is a brainstorming exercise about factors that influence a given subject. This includes identifying key historical events highlighted in the previously developed integrated timeline. In our case, the drivers spanned from the influence of the green revolution and political institutions to family planning and infrastructure (Figure 1). This exercise illustrated the issue's complexity and interdisciplinarity.

We identified three major themes that encompassed a majority of these factors: institutions, population dynamics, and land and water management. A subsequent mini-mind mapping exercise was performed under each theme (identifying and discussing specific factors influencing food security). These activities broadened our collective picture of the diverse issues that are generally targeted by different disciplines and often unseen by others. For example, social scientists might not think about the nitrogen cycle and ecologists might neglect democratic participation. Mind mapping also brought our respective priorities to the forefront and illustrated the different ways in which we each organize our thoughts (i.e., epistemological differences). Specific distinctions arose regarding prioritization of the three principal themes, including how abstract the themes should be. In addition, when we agreed on the major themes influencing food security, challenges arose in communicating ideas and providing a rationale to others outside of one's discipline. This activity also emphasized that tackling food security from one disciplinary perspective is not adequate, and that acknowledging and identifying the interactions among drivers are critical to addressing the problem from an interdisciplinary perspective. For a disciplinary scientist, this can be difficult to handle, as we generally like to believe that our discipline and specialty is the most important.

Technique Four—Cross-Impact Analysis

As its name implies, cross-impact analysis involves identifying and evaluating the impacts of factors, trends, or events upon one other. The cross-impact analysis we selected to employ was a brainstorm on how trends in each of the major themes identified in the mind-mapping exercise (i.e., institutions, population dynamics, and land and water management) influence the other themes in the framework of global food security (Figure 2). During this exercise, we explored the relationships, drivers, and interactions that link these different themes to better

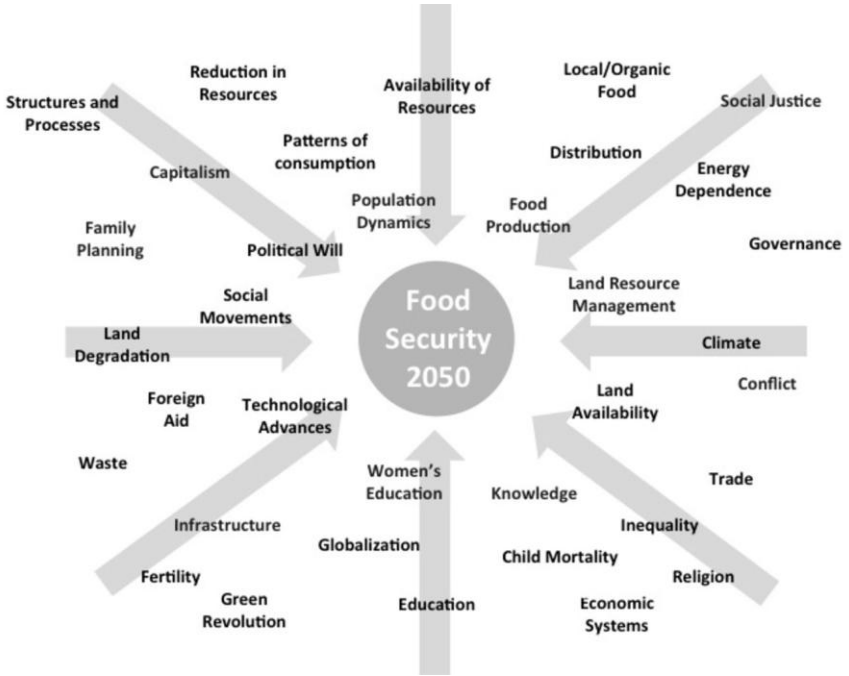

Figure 1 Example of mind-mapping brainstorm: drivers influencing food security.

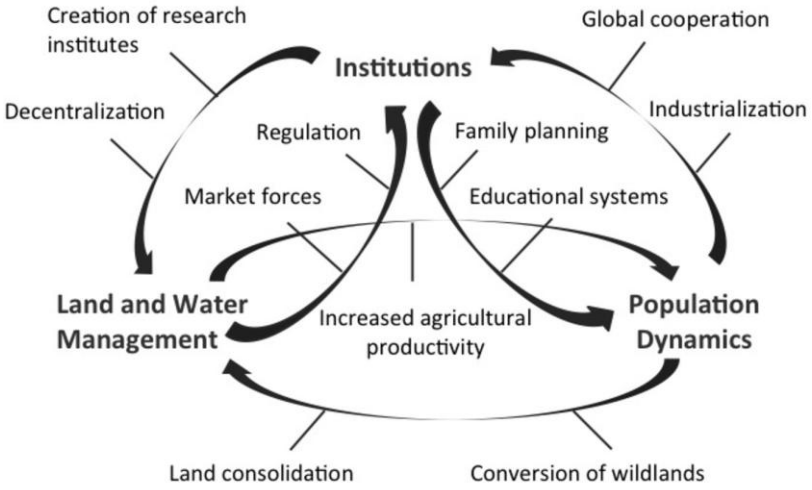

Figure 2 Example of a cross-impact analysis. Three principal themes from the mind-mapping exercise were selected. The relationship between these themes was explored as well as drivers, interactions, and cross-impacts influencing food security.

understand their interdependencies regarding food security. This activity illustrated the need to consider the complex interactions between and among drivers to develop a systems analysis of the problem.

Technique Five—Imagining the Ideal

Probably the most creative exercise we tested—and a group favorite—involved sharing our vision of the ideal outcome or solution to our research problem. Each participant developed her/his utopian vision of how the world might look in 2050 if food security were achieved. The guidelines for the exercise were deliberately loose to enable the greatest flexibility and creativity for sharing ideas.

Scenarios ranged from humans getting all of their required nutrients in a daily pill, to everyone living in cities with hydroponic roof gardens, to increased small-scale local organic farming. Even though many of us work on addressing sustainability issues, this was the first time we had envisioned what success might look like. It was in this exercise, rather than the philosophical survey described above, that ontological differences were most noticeably articulated. In fact, many of us initially thought that we all understood success in the same way, for example by promoting small-scale community development as a substitute for large-scale agriculture. Yet, other members of the group regarded the creation of bigger vertical cities surrounded by large-scale commercial farms as a viable way to increase food security and to promote economic prosperity. These diverse visions illustrated how our disciplinary and personal viewpoints influence how we see the world and define and approach problems. Once communicated, these differences explained some of the difficulties we were having as a group to come up with drivers affecting food security. Only when we were asked to stretch our imaginations to the extreme did many of these divergences surface. Without such an exercise, collaborations could be hung up by a number of seemingly subtle differences that are in fact related to much larger worldviews.

Technique Six—Backcasting

The final technique we deployed was "backcasting," a method for tracing a backwards pathway from a future state or goal to the present in order to identify key steps along the route (Carlsson-Kanyama et al. 2008). We imagined the central problem was already solved—there was sustainable food security for all—and then asked, "How did we get here?" Starting from the knowledge and thinking gained through the earlier exercises, the backcasting technique motivated the search for creative, holistic, and out-of-the-box solutions and, in our case, particularly led to defining interdisciplinary research questions. For example, "backcasting" requires that a previously identified outcome already exists (i.e., holistic research institutes whose agendas are implemented globally). The exercise required identifying all of the steps that made these institutes a reality. In the case of functioning institutes, the path included: government buy-in and support was achieved, creative and realistic research ideas were implemented, ongoing funding realized, and so forth. We also discussed backcasting scenarios for the establishment of strict family-planning protocols and the development of mechanisms for the distribution of nutritious food to ensure equal access (Box 2).

Since the backcasting exercise came sequentially last and built upon previous modes of engagement, it was the easiest activity in terms of communication.

Box 2 Examples of interdisciplinary research questions defined during the backcasting exercise.

- How do we measure resilience? What are the metrics needed? How do we measure if a system is prepared for change?
- Under what conditions are technological advances and inequality linked?
- Is it possible to have increased food production and equal access to food?
- How do we design agricultural systems with efficient nutrient cycles?
- How do we define and implement appropriate family planning?
- What is the role of education in food security?
- What is the role of the generation of knowledge in creating a food-secure world?

Backcasting combined the creativity of imagining the ideal with the logic of the timeline and mind mapping, showing how past exercises became a shared toolbox to move research forward. With this exercise, we began to develop creative ideas on how to improve food security from an interdisciplinary perspective—such as having agronomists, family planners, and engineers work together to develop practical strategies—suggesting the importance of long-term interdisciplinary collaboration. Participants also emerged with numerous ideas for future research projects and questions.

Writing of this Essay

In addition to the exercises described above, the process of writing this essay provided another opportunity to explore interdisciplinary interaction. Participating in interdisciplinary research requires patience, time, willingness to compromise, and preparedness to set aside commitments that one's discipline, ideas, or writing style is best. The writing process for us took the following form: 1) During a joint meeting, a rough outline was created and authors volunteered to write particular sections; 2) The outline was circulated again for further input from the team; 3) One person was identified to combine the sections and the integrated version was sent around to coauthors in a sequential order to edit. While exceptionally time consuming, we felt that this process most accurately captured our experiences and allowed for maximum collaboration. Beyond the already significant difficulties of discipline-oriented scientific articles, interdisciplinary papers often expose dramatically different writing styles, language, and formats, with much commitment to explain ideas and rationale. Even addressing the editors' comments was done by a group of the coauthors literally sitting together and jointly going through the paper with final edits circulated among the team.

Conclusion

Of course, we did not solve world hunger with these exercises, although we made steps in the right direction by improving our interdisciplinary communication and acknowledging that, to address complex problems, successful interdisciplinary collaboration is needed. For example, it may not be very often that a theologian and statistician sit together in the same room to discuss food security, nor are they commonly on the same research team to develop real-world solutions to such issues. Yet, despite our seemingly disparate disciplines, these exercises emphasized the necessity for the theologian to understand population-growth statistics and the statistician to understand the values and principles of the theologian to develop practical solutions to food security, including addressing population dynamics. Without an objective and open communication strategy, these interactions would certainly not occur. In addition, structuring these discussions on a focused topic/research question highlighted the functionality of the scenario-building techniques.

Our group concluded that these communication-enhancing techniques exposed critical differences in our epistemologies, ontologies, and methodologies, providing an important foundation for developing and conducting interdisciplinary work. We realized that much of our previous training had pushed us to focus on research products and outcomes, while paying inadequate attention to the process and potential barriers to successful interdisciplinary and collaborative research. These exercises, geared toward communication and group interaction, were new and quite often uncomfortable, forcing us to examine our disciplinary approaches and biases and to move forward despite them. In addition, while scenario-building exercises are commonly used in business situations, they can also bolster interdisciplinary communication and research.

As documented in the literature (Bracken & Oughton, 2006; Morse et al. 2007), we too acknowledge that differences in disciplinary language can be a significant barrier to conducting interdisciplinary research. We do not pretend that these exercises culminated in the development of a common language for our team. In fact, we suggest that formulating a "common" language may be too lofty a goal. We suggest aiming for open communication—the confidence to ask colleagues for clarification and to expose, to understand, and to accept differences among us. Quite often the vernacular of a disciplinary guild can limit full comprehension of those outside one's discipline, even when trying to address and frame the same questions. We expect that the effort invested in these exercises will have multifold payoffs in time

saved and problems avoided at later stages of interdisciplinary research.

While the tools that we explored here represent only a subset of the possible means of enhancing interdisciplinary learning and research collaborations, they clearly provided us with a solid foundation to embark on such work. Participation in these exercises was useful not only in our capacity as interdisciplinary researchers, experts in our respective disciplinary fields, and participants in a variety of social networks, but also in our role as educators who seek to encourage our students to think, to speak, to read, and to write analytically and critically about important global issues. In this essay, we have purposefully avoided the provision of a specific action agenda or rigid outline for successful interdisciplinary research. To do so would be to contradict one of our central points—that a reorganization of multiple, potentially equally valid ways of knowing requires a negotiation governed by the specifics of the question and the composition of the research team.

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References

Benda, L., Poff, N., Tague, C., Palmer, M., Pizzuto, H., Cooper, S., Stanley, E., & Modlen, G. 2002. How to avoid train wrecks when using science in environmental problem solving. *Bioscience* 52(12):1127–1136.

Bishop, P., Hines, A., & Collins, T. 2007. The current state of scenario development: an overview of techniques. *Foresight* 9(1):5–25.

Bracken, L. & Oughton, E. 2006. "What do you mean?" The importance of language in developing interdisciplinary research. *Transactions of the Institute of British Geographers* 31(3): 371–382.

Bracken, L. & Oughton, E. 2009. Interdisciplinarity within and beyond geography: introduction to special section. *Area* 41(4):371–373.

Buller, H. 2008. The lively process of interdisciplinarity. *Area* 41(4):395–403.

Carlsson-Kanyama, A., Dreborg, K., Moll, H., & Padovan, D. 2008. Participative backcasting: a tool for involving stakeholders in local sustainability planning. *Futures* 40(1):34–46.

Collins, J. 2002. May you live in interesting times: using multidisciplinary and interdisciplinary programs to cope with change in the life sciences. *Bioscience* 52(1):75–83.

Eigenbrode, S., O'Rourke M., Wulfhorst, J., Althoff, D., Goldberg, C., Merrill, K., Morse, W., Nielson-Pincus, M., Stephens, J., Winowiecki, L., & Bosque-Perez, N. 2007. Employing a philosophical dialogue in collaborative science. *Bioscience* 57(1):55–64.

Grix, J. 2002. Introducing students to the generic terminology of social research. *Politics* 22(3):175–186.

Harris, F., Lyon, F., & Clarke, S. 2008. Doing interdisciplinarity: motivation and collaboration in research for sustainable agriculture in the UK. *Area* 41(4):374–384.

Heemskerk, M., Wilson, K., & Parvao-Zuckerman, M. 2003. Conceptual models as tools for communication across disciplines. *Conservation Ecology* 7(3):1–8.

Hollis, M. & Smith, S. 1990. *Explaining and Understanding International Relations.* New York: Oxford University Press.

Hulme, H. & Dessai, S. 2008. Predicting, deciding, learning: can one evaluate the "success" of national climate scenarios? *Environmental Research Letters* 3(4):1–7.

Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: Synthesis Report*. Geneva, Switzerland: IPCC. http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm.

Kinzig, A. 2001. Bridging disciplinary divides to address environmental and intellectual challenges. *Ecosystems* 4(8):709–715.

Longstaff, P. 2009. Managing surprises in complex systems: multidisciplinary perspectives on resilience. *Ecology and Society* 14(1):49.

McArthur, J. & Sachs, J. 2009. Needed: a new generation of problem solvers. *The Chronicle of Higher Education* June 18. http://chronicle.com/article/Needed-Problem-Solvers/44512/.

McLean, G. & Egan, T. 2008. Applying organization development tools in scenario planning. *Advances in Developing Human Resources* 10(2):240–257.

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-being: Health Synthesis*. Washington, DC: Island Press.

Miller, T., Baird, T., Littlefield, C., Kofinas, G., Chapin III, F., & Redman, C. 2008. Epistemological pluralism: reorganizing interdisciplinary research. *Ecology and Society* 13(2):46.

Morse, W., Nielson-Pincus, M., Force, J., & Wulfhorst, J. 2007. Bridges and barriers to developing and conducting interdisciplinary graduate-student team research. *Ecology and Society* 12(2):8.

O'Neill, B. & Nakicenovic, N. 2008. Learning from global emissions scenarios. *Environmental Research Letters* 3(4):1–9.

O'Neill, B., Pulver, S., VanDeveer, S., & Garb, Y. 2008. Where next with global environmental scenarios? *Environmental Research Letters* 3(4):1–4.

Parson, E. 2008. Useful global-change scenarios: current issues and challenges. *Environmental Research Letters* 3(4):1–5.

Redman, C., Grove, J., & Kuby, L. 2004. Integrating social science into the Long-Term Ecological Research (LTER) Network: social dimensions of ecological change and ecological dimensions of social change. *Ecosystems* 7(2):161–171.

Robertson, D., Martin, D., & Singer, P. 2003. Interdisciplinary research: putting the methods under the microscope. *BMC Medical Research Methodology* 3(20):1–5.

Sillitoe, P. 2004. Interdisciplinary experiences: working with indigenous knowledge in development. *Interdisciplinary Science Reviews* 29(1):6–23.

Taylor, M. 2009. End the university as we know it. *New York Times* April 26:A23.

White, P., Cinderby, S., Raffaelli, D., de Bruin, A., Holt, A., & Huby, M. 2008. Enhancing the effectiveness of policy-relevant integrative research in rural areas. *Area* 41(4):414–424.

Wilkinson, A. & Eidinow, E. 2008. Evolving practices in environmental scenarios: a new scenario typology. *Environmental Research Letters* 3(4):1–11.