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Insight

A pedagogical model for integrative training in conservation and sustainability

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ABSTRACT. The benefits and challenges of interdisciplinary training are well documented, and several reviews have discussed the particular importance of interdisciplinary training for conservation scholars and practitioners. We discuss the progress within one university program to implement specific training models, elements, and tools designed to move beyond remaining barriers to graduate-level, interdisciplinary conservation education.

Key Words: *conservation; graduate education; integrative; interdisciplinary; sustainability*

INTRODUCTION

As scholars have recognized for decades, real-world environmental problems do not easily map onto the disciplines found in universities, and it is increasingly evident that no academic discipline or field of practice can address environmental challenges alone. As a result, arguments for interdisciplinary investigation of environmental issues have flourished (Noss 1997, Lubchenco 1998, Kinzig 2001). Likewise, attempts at interdisciplinary education and training are growing at a remarkable rate (for a review see Clark et al. 2011, Vincent and Focht 2011). However, interdisciplinary endeavors, both in research and training, often fail, or do not realize their maximum potential because of well-documented barriers, such as the persistence of disciplinary and epistemological silos and communication challenges (Noss 1997, CoFIR et al. 2005, Brosius 2006, Fox et al. 2006, Frodeman and Mitcham 2007). Furthermore, conservation, like many other fields, suffers from strained relations between academicians and practitioners (Welch-Devine and Campbell 2010). It is, therefore, critically important to confront these barriers directly as we train the next generation of environmental scholars and practitioners, equipping students not only with the knowledge and skills necessary to confront the challenges we face, but also with the tools and savvy to work effectively within institutions, to cross many types of barriers, and to make collaborations work.

In this article, we briefly review the literature on interdisciplinary training, both in the broad area of graduate education and in our area of particular focus, conservation and sustainability, to highlight the fundamental barriers to effective training identified by education scholars, conservation practitioners, and the broader scientific community. We then present a pedagogical model for conservation education to illustrate specific training elements that we have crafted to overcome particularly persistent challenges to interdisciplinary training. With this pedagogical model, called the triple helix, we expand on the concept of interdisciplinarity and focus instead on integrative training that we believe will produce "agile scientists" who have deep disciplinary knowledge and who are capable of moving easily between knowledge domains, brokering information across disciplinary and epistemological divides, and embracing and maximizing the potential of differing perspectives. Integrative training places depth and breadth in constant tension, and we discuss the challenges the concept presents and the calculated trade-offs it may require.

LITERATURE REVIEW

In both the literature review and the discussion, we focus on a select set of challenges and obstacles for interdisciplinary work that have been consistently difficult for PhD programs to address. What we present here is not meant to be an exhaustive catalogue of what makes interdisciplinary research and training particularly challenging, but rather, a highlighting of persistently problematic issues that have not yet been adequately addressed.

The first suite of challenges centers on the natures of disciplinary and interdisciplinary training, their relations to one another, and the silos that disciplinary training often creates. Every scientific discipline necessarily narrows its field of vision in particular ways in an effort to achieve precision, clarity, and rigor. Although this provides robust conceptual and methodological approaches for addressing compelling questions within the field, conventional disciplinary frames address only a narrow band of the spectrum of knowledge relevant to meeting contemporary conservation and sustainability challenges (Hirsch et al. 2011). Both in practice and education, scholars have proposed a spectrum of alternative approaches for expanding the narrow foci of disciplines (Max-Neef 2005, Reyers et al. 2010). Schneider et al. define multidisciplinary as a less integrated approach drawing on "knowledge from multiple disciplines derived from disciplinary methods, practices, and paradigms" (1995:7). Klein defines interdisciplinarity as "a means of solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches" (1990:196). Transdisciplinarity is an expansion of these concepts that both: (1) develops "novel conceptual and methodological frameworks with the potential to produce transcendent theoretical approaches," and (2) engages with a "wider range of stakeholders in society" (Klein 2008:S117). The traditional way of undertaking multidisciplinary-interdisciplinary-transdisciplinary work has been through collaborative projects that involve multiple individuals. However, there is growing interest in vesting individuals with expertise from multiple disciplines (Max-Neef 2005, Adams 2007) to prepare them for "problem-oriented research challenges" (NSF 2008:2).

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Some of the most difficult barriers to confront when undertaking multi-, inter-, or transdisciplinary work are related to disciplinary dogmatism. The power dynamics at play in disciplinarily diverse project teams often have an adverse impact on project planning and outcomes (MacMynowski 2007). When team members lack appreciation for other disciplinary perspectives, it can lead to defensiveness and dismissal of competing ideas (Lélé and Norgaard 2005). This is further compounded when perceptions concerning the relative value of different disciplines lead to unproductive conflicts within project-based teams and the minimization of the contributions of some team members (Campbell 2005, Miller et al. 2008). For example, social scientists in conservation teams often feel marginalized and complain of being brought in after questions or objectives are defined, of having their science placed in service to the ecological science, and of often having their roles misunderstood (Campbell 2005, Welch-Devine and Campbell 2010).

Though interdisciplinary projects, both in research and in practice, are often fraught with difficulty, academia faces many additional challenges in implementing effective interdisciplinary training programs. Faculty and students in interdisciplinary programs find themselves "work[ing] laterally across a typically hierarchical organization" (Boden et al. 2011:742). Despite paying lip service to the value of broad-based training, many educational institutions, particularly large research universities, tend toward institutional inertia, and it is precisely these unyielding structures that Boden et al. argue lie "at the heart of many of the challenges to interdisciplinary research and graduate training" (2011:744). Faculty members may find it difficult to participate in these training programs because of the demands of tenure and promotion (Campbell 2005, Boden and Borrego 2011), and as students proceed through their training programs, they are increasingly pulled back into disciplinary "silos" by departmental requirements such as qualifying exams and dissertations. "After a pleasant initial immersion in pools of interdisciplinarity, the advanced graduate student encounters the more treacherous waters and institutional realities of a nascent professional career" (Hackett and Rhoten 2009:424).

A second major challenge for conservation and sustainability education at the graduate level stems from divides and tensions between academic and practicing scientists. Fitzgerald and Stronza argue that "poor communication, coordination, and comprehension" prevent the translation of research advances into conservation applications (2009:564). Researchers have long called for closer collaboration between ecological and social scientists in conservation (Mascia et al. 2003, Brosius 2006), but a problem that is even less readily solved is the deep-seated distrust that can exist even between academics and practitioners from the same disciplinary backgrounds. Welch-Devine and Campbell (2010:344) highlight tensions between social scientists working in conservation organizations and those in academia, with those in practice referring to the work of their academic colleagues in the same disciplines as "counterproductive and a distraction."

A third suite of challenges relates to communication, both across disciplines and to nonspecialist audiences. Many conservation scientists have little exposure to the basic theories and methodologies of other relevant fields (Adams 2007), which leaves them not only less able to converse with their colleagues from other disciplines (Endter-Wada et al. 1998, Brewer 1999, Fox et al. 2006), but also less likely to value and appreciate the theoretical and methodological contributions that other disciplines can make (Lélé and Norgaard 2005). The field of conservation also suffers from "mixed taxonomies" (Lélé and Norgaard 2005), some of its disciplines use common terms, but with different or contested meanings, sometimes leading parties to believe they are discussing the same problem in the same terms, when in reality the meanings that they take from these terms may be quite different (Pickett et al. 1999, Haapala et al. 2007).

Given the complexity of today's conservation and sustainability challenges, Reyers et al. suggest that it is time for conservation planners to move beyond simply engaging with their counterparts in other academic disciplines and toward engaging in "the complex world of politics and decision making" (2010:963). This engagement would of course need to happen on many levels, and depending on the situation and context may require exchange with individual members of local communities, town or regional planning authorities, state and federal governments, or even international bodies. The ability to communicate clearly and effectively with people from nonscientific backgrounds is therefore becoming paramount.

Recognizing that there is much work yet to do to overcome these barriers to interdisciplinary training in conservation and sustainability, several researchers have examined existing training programs and made recommendations for improving their approaches. In a broad survey, Vincent and Focht found that consensus exists for, "an applied, interdisciplinary focus on the interface of coupled human-natural systems with a normative commitment to sustainability" (2011:14). They recommend a curriculum that emphasizes "three interdisciplinary knowledge areas (natural sciences, coupled human-nature systems, and economic development) and two integrated skill sets (problem analysis and problem solution and management)" (Vincent and Focht 2011:33). McBride et al. (2011) suggest the need to recreate the Renaissance scientist who is not an expert in each field but has an understanding of how other content areas could contribute to a problem. They recommend focusing on communication and teamwork and argue that combining these 21st century Renaissance scientists together as a team will lead to more effective problem solving. To avoid the common problems of goal ambiguity, disciplinary hodgepodge, and a curricular smorgasbord, Clark et al. (2011:724) recommend that a program "clarify its goals, teach and use an explicit interdisciplinary method, and improve educational quality and opportunity." The pedagogical model described below responds to many of the issues described in these reviews and recommendations and focuses specifically on addressing the three suites of issues elaborated above.

DISCUSSION

We present a pedagogical model for conservation and sustainability graduate education that we call the triple helix, showing how it was designed to address the specific and persistent barriers outlined above. The triple helix underpins the curriculum of a doctoral program in Integrative Conservation (ICON) at the University of Georgia (UGA). In designing this curriculum, the UGA faculty carefully reviewed the literature on interdisciplinary and conservation training, consulted conservation practitioners,

and drew on personal experiences. To address the most common and persistent concerns we identified, the triple helix is comprised of the intertwined elements of: (1) an integrative approach; (2) experiential learning; and (3) strategic communication.

The first strand of the triple helix is an integrative approach (Park 1996, Sill 2001, Newell et al. 2005, Tress et al. 2005), which addresses obstacles associated with disciplinary and epistemological silos, as well as institutional barriers to regular exchange across those silos. Conceptually, the ICON program is informed by the outcomes of the Advancing Conservation in a Social Context (ACSC) initiative, a four-year research initiative created by the MacArthur Foundation. ACSC participants developed an integrative framework for identifying, analyzing, and negotiating the trade-offs that inevitably occur because conservation and development decisions and activities generally advance some values, perceptions, or interests at the expense of others (McShane et al. 2011). The strength of the integrative framework is that it brings together different threads that are conceptualized as lenses as opposed to disciplines. Within any discipline there are subspecialties, theoretical perspectives, and methodologies that are both more alike and more dissimilar than we will find looking across disciplines. Both an anthropologist and an ecologist may fundamentally believe that the world can be described through models, or they may not. Because our epistemologies and methodologies may make us more comfortable with someone in a vastly different field than with someone in our own field, we believe that requiring interdisciplinary collaboration is too simplistic. The integrative framework, rather than simply pulling in people from multiple disciplines that may have similar worldviews, forces us to work across serious epistemological differences, to recognize that some ways of understanding the world simply may not be commensurable, and to recognize and value the richness that such pluralism can bring to the understanding of a problem (Miller et al. 2008).

The three "lenses" of the integrative framework were designed to help researchers and students explore complex social-ecological scenarios from multiple viewpoints, rejecting traditional disciplinary boundaries in favor of perspectives of value and valuation, process and governance, and power and inequality (Hirsch et al. 2013). It is important to note that with the term "integrative" we are referring to a process, not an endpoint; the ICON program is integrative, not integrated. Rather than seeking a singular or synthetic approach, it is pluralistic, accepting and embracing the value that accrues from considering a diversity of ways of perceiving and analyzing complex conservation issues (Miller et al. 2008). The integrative framework provides a heuristic for working collaboratively on complex conservation and sustainability issues.

Although the ability to work in teams is indeed critical, on the ground, practitioners often are forced to work with limited resources and do not always have the luxury of crafting a diverse project team; instead, the team may be one person (Adams 2007). The ICON program therefore focuses on creating individuals who have deep expertise in a particular area, broad exposure to other disciplines and epistemologies, and the ability and disposition to think integratively, drawing on necessary resources and combining them in effective ways. Each real-world problem will require its own case specific solution, and that solution will be comprised of a series of negotiations and trade-offs among multiple perspectives and ways of knowing and valuing the world, or the problem.

Building a working understanding of different epistemologies, methodologies, and methods requires broad exposure to them and critical discussion of what they both offer and lack. Because we feel strongly that students should also be experts in a particular area, the ICON program attempts to hold depth and breadth of expertise in balance. The program currently requires that students select a home department, anthropology, ecology, forestry and natural resources, or geography, and complete all of the requirements for the PhD in that discipline, including core courses, elective hours, comprehensive exams, and rigorous dissertation work. Additionally, students must take two core ICON courses. The first of these is a theoretical course that critically examines the theory and practice of integrative engagement. This course is team-taught by faculty members from different disciplines. The second core course, described in more depth below, is also team-taught and challenges students to work in groups and with local stakeholders on a real conservation problem. Research questions and project outputs are coproduced in consultation with community and NGO partners, and students are pressed to understand and incorporate many different ways of knowing the world. In both of these courses, students are taught to critically explore the intellectual, institutional, and practical difficulties of integrative work and to actively seek solutions. In addition to these two core courses, students must take elective concentrations outside of their home departments, ensuring that they have substantial exposure to the biophysical sciences and social sciences, as well as to law, policy, and economics.

Because the literature on interdisciplinary education shows that students tend to fall back into disciplinary silos as they progress through their programs (Hackett and Rhoten 2009), the ICON program also includes a series of integrative mechanisms designed to encourage exchange throughout the program and across cohorts. Students engage in peer review of proposals and manuscripts, brown bag discussions, and reflective collaborative journaling throughout their time at UGA. We also incorporate team-building exercises, such as low ropes course experiences, to foster teamwork, communication, and collaboration. Because of these heavy demands, we realize that students may need an extra semester to finish the program. We believe that this additional time is well warranted and that the demands of the program serve the additional purpose of prescreening applicants so that only the most motivated and likely to succeed actually join the program.

The second component of the triple helix is experiential learning. The experiential learning component was designed to address the concern that there is a divide between academic and practicing conservation scientists and to prepare students to more readily and fully engage with people from different backgrounds around conservation issues. We distinguish experiential learning from other forms of learning by explicit exposure to the struggles that communities and organizations face. Experiential learning in conservation training is crucial because local communities often frame and understand conservation issues in ways that are difficult to prepare students for through codified or didactic forms of learning alone. In part, our strong emphasis on experiential

learning results from the recognition that conservation practitioners often rely less on codified, i.e., explicitly book-oriented, knowledge in their practice and instead rely more on tacit knowledge based in lived experience to make decisions (Pullin et al. 2004, Fazey et al. 2006).

The experiential learning component of the ICON program begins in the second semester core course. In spring 2012, the first cohort of students, working under the auspices of the Coweeta Listening Project (CLP) at the Coweeta LTER in Macon County, North Carolina (https://listening.coweeta.uga.edu/), collaborated with the U.S. Forest Service, county officials, and local community groups to address steep slope development in western North Carolina (Vercoe et al. 2014). The second cohort of students, in spring 2013, teamed with the government of Tybee Island, Georgia and UGA's Vinson Institute to address planning for the sea-level rise that is expected with climate change. These team-based class projects helped students learn techniques of visualization, analysis, and writing, and allowed them to confront issues of ethics, communication, and outsider diplomacy. In the process, students learn negotiation and conflict management skills.

The second major experiential learning component of the ICON program is an eight-week internship with a conservation organization, government agency, or other group identified as appropriate. Through this experience, students gain exposure to skills such as policy drafting, decision making, personnel management, project planning, budgeting, and risk management (cf. Newing 2010, Vincent and Focht 2011) that are not taught in typical academic programs. They also gain an appreciation for the constraints and opportunities that confront conservation practitioners on a day-to-day basis.

The third strand of the triple helix is strategic communication. A fundamental premise of the ICON program is that conservation scholars and practitioners need effective communication skills to negotiate the struggles of translation that occur across disciplines, fields of practice, and languages. Our conception of strategic communication is also based on the recognition that communication entails more than delivering information. Learning to listen is a fundamental component of learning to communicate. This involves training our students to develop an awareness of the dynamics of cross-cultural communication (Sonntag 2003, Gluck and Tsing 2009) and preparing them for active listening that allows them to ask questions in a way that opens lines of communication rather than constricting them, reframing problems in language accessible to all stakeholders (de la Cadena 2005). In a seminar series designed to teach effective communication of science and negotiation of ideas, students develop a set of skills focused on: communicating across disciplines navigating institutional cultures in academia, government, and NGOs; and linking science and policy. Students also learn a variety of specific technical skills, including giving speeches and presentations, preparing materials for a variety of audiences, working with the media, and using media tools, e.g., photography, web pages, blogs, social media. We expect ICON students to incorporate strategic communication elements into their dissertations.

Our strategic communication pedagogy is modeled on the methods of Stony Brook University's Center for Communicating Science. We use improvisational theatre games to train students to connect with their audiences and provide hands-on training in such topics as "Distilling your Message" and "Working with the Media." We have enlisted faculty from the Department of Theatre and Film Studies, as well as communications professionals at UGA, to deliver these workshops, and ICON faculty members lead exercises focusing on listening, communicating across boundaries, and navigating institutional cultures. In another effort that focuses on developing communication skills, we approached experts at MIT to develop a role-playing game that challenges student teams representing different stakeholders to negotiate the number, type, and placement of dams on a river system. Students are provided with guides to their individual characters and stakeholder groups. Each of the three stakeholder groups has different priorities, different knowledge of the river system, and different terminologies for similar concepts. Students work within their groups to propose the placement of dams to meet their needs. Subsequently, representatives of each group come together to try to negotiate dam placement that would satisfy all groups. This exercise allows students to recognize the power of different perspectives, different experiences, different forms of knowledge, and different forms of communication.

Training for agility

With the many paradigms and descriptors that exist for models that fall outside of traditional, discipline-based training, we want to be clear about the differences that an integrative approach offers. We conceptualize our students as "agile scientists" who, although grounded in a specific discipline, should have translational skills that enable them to (a) be conversant across a range of disciplines and knowledge domains, (b) move easily between the worlds of academia and practice, and (c) translate research into action. The agile scientist should be able to understand, value, and evaluate many different kinds of knowledge, critically interrogating assumptions about what types of knowledge count, and he or she should be able to function in situations of incomplete or shifting knowledge, recalibrating and adapting as necessary (Hackett and Rhoten 2009). Perhaps most importantly though, agile scientists must have the instincts to define and redefine conservation issues in ways that avoid the oversimplification to which these issues are often subjected. What makes the agile scientist different is deftness and intellectual dexterity in drawing on different knowledge bases and the ability and willingness to view conservation challenges from multiple perspectives.

An integrative approach holds that it is critical to develop deep expertise in a particular knowledge domain; however, it rejects the artificial boundaries that present disciplines as discrete entities that have become defined in opposition to other disciplines. Rather than focus on the labels that we might apply to ourselves, we focus on different theories, methodologies, and epistemologies and what they bring to the analysis of a particular question or issue. The integrative framework developed by ACSC is a structured way to systematically see through the perspectives of others and to walk through the insights that different knowledge domains provide. Agility is what allows scientists to move easily from one knowledge domain to another, selecting and relating insights where relevant and working with diverse teams, all the while critically examining and appraising the process without automatically foreclosing other approaches. Like athletic agility, agility in conservation and sustainability must also be cultivated.

To become agile scientists, students, as well as faculty, must frequently be placed in situations where they are well outside of their comfort zones. Drawing on the experiences and writings of Liz Lerman (MacArthur Fellow recognized for her work in science-art collaborations), we have begun to incorporate the arts into the training of ICON students. For example, in the second semester core course for the 2012-2013 cohort, the students' first experience of the Georgia coast was through a viewing of paintings of coastal landscapes accompanied by the artist, Philip Juras. We believe that if we constantly encourage students to confront different sets of information from different sources and to evaluate that information according to different frameworks, they will more fully develop the agility we believe is critical to achieving sustainable conservation outcomes (Lerman 2010).

Analysis and assessment

At the end of each year of the program, which is now entering its third year, the ICON faculty meet in a half-day workshop to review experiences and discuss changes for the upcoming year. Data for our assessment exercises are drawn from student reviews of courses, reflective journals that students produced throughout the year, faculty evaluations of student performance, in-person discussions with students, and the results of cognitive flexibility testing conducting by Creativity Testing Services (http://www.creativitytestingservices.com/). Higher levels of cognitive flexibility, by allowing individuals to more easily move between conceptual categories, indicate increased capacity to produce creative insights (Runco and Chand 1995). Although we do not yet know if the higher levels of cognitive flexibility displayed by ICON students were the result of self-selection to the program or of the training program, we believe that as we are able to collect several years of both pre- and post-test data we will be able to determine this. As we begin to graduate our first students, we will also track traditional metrics such as job placement and years to completion. We also hope to be able to evaluate whether higher levels of cognitive flexibility predict career success.

Some of the most important insights to date have come from discussions with students about the program. Throughout the core courses, both students and faculty members displayed various levels of rigidity and flexibility in their abilities to think beyond their own epistemological commitments, becoming defensive and dismissive when feeling that their disciplinary perspectives were threatened. In their reflections, students pointed out that many of the tense moments arose from competing disciplinary desires to either simplify or complicate any particular issue. Although the norm in some disciplines is to remove complexity to achieve an effective solution, to those in other disciplines, such simplification leads to an incomplete understanding of the problem, thereby precluding an effective solution. This realization for many students was a result of thinking through problems integratively and devoting more attention to process rather than endpoint. We believe that the use of the integrative framework so far has helped students more fully understand and account for the complexity of different conservation scenarios, while not being paralyzed by that complexity.

Each year we have introduced key changes to the program. After the first year, realizing the value and importance of the experiential learning component, we increased the time that students spent in the field for the second core course. Similarly, after each year, we expanded and more fully integrated the strategic communication training, and we have further emphasized the arts and other ways of producing and acquiring knowledge about a place, its people, and its conservation challenges. Perhaps most importantly, after seeing several dissertation prospectuses developed, we have created detailed guidelines that help students and their committees better understand how an integrative approach can be taken for a dissertation project, and we have identified a mechanism for ensuring that a representative on each committee will be fully focused on the integrative nature of the project. As the program continues, we will continue to manage it adaptively, incorporating insights and making adjustments every year.

CONCLUSION AND FUTURE CHALLENGES

We believe that the ICON program could be a model worthy of replication, as we have overcome several of the traditional hurdles for inter- and transdisciplinary teaching through the use of the triple helix approach. However, there are many important challenges that have not yet been solved and that give us caution. The physical size of the UGA campus and students' departmental obligations makes community building for the program difficult. We have found that making events mandatory or providing refreshments is almost required to ensure attendance and mixing, particularly between cohorts. Time and budgetary constraints mean that both of those options are sometimes difficult to enact. We have also not yet been able to adequately address issues of university reward structures, departmental obligations for teaching, and tenure and promotion requirements. Though some of the best insights from the first year emerged as a result of having five professors in the class at every meeting, this required overload and pro bono teaching, neither of which is sustainable. A third issue is that many of the nonclassroom activities depend on student labor. For example, critical integrative mechanisms, like the peer-review program for manuscripts and proposals, rely on students to organize them. Although this provides important professional development opportunities for the students, it also means that they can be inconsistent because responsibility for these components changes hands frequently.

Despite these remaining obstacles, we suggest that the triple helix model offers important lessons. We believe that an integrative approach moves students beyond the reification of disciplines toward a more flexible habit of blending theories, methodologies, and insights, and we believe the emphasis on experiential learning and strategic communication will more fully prepare students for the complex conservation scenarios they will encounter in their careers. As elements of the program prove their worth, expanding them to other schools and programs may help train a larger cadre of agile scientists, transforming conservation scholarship and practice.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/issues/responses.php/6197

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LITERATURE CITED

Adams, W. M. 2007. Thinking like a human: social science and the two cultures problem. *Oryx* 41:275-276.

Boden, D., and M. Borrego. 2011. Academic departments and related organizational barriers to interdisciplinary research. *Higher Education in Review* 8:41-64.

Boden, D., M. Borrego, and L. Newswander. 2011. Student socialization in interdisciplinary doctoral education. *Higher Education* 62:741-755. http://dx.doi.org/10.1007/s10734-011-9415-1

Brewer, G. D. 1999. The challenges of interdisciplinarity. *Policy Sciences* 32:327-337. http://dx.doi.org/10.1023/A:1004706019826

Brosius, J. P. 2006. Common ground between anthropology and conservation biology. *Conservation Biology* 20:683-685. http://dx.doi.org/10.1111/j.1523-1739.2006.00463.x

Campbell, L. M. 2005. Overcoming obstacles to interdisciplinary research. *Conservation Biology* 19:574-577. http://dx.doi.org/10.1111/j.1523-1739.2005.00058.x

Clark, S. G., M. B. Rutherford, M. R. Auer, D. N. Cherney, R. L. Wallace, D. J. Mattson, D. A. Clark, L. Foote, N. Krogman, P. Wilshusen, and T. Steelman. 2011. College and university environmental programs as a policy problem (part 2): strategies for improvement. *Environmental Management* 47(5):716-726. http://dx.doi.org/10.1007/s00267-011-9635-2

Committee on Facilitating Interdisciplinary Research (CoFIR), Committee on Science, Engineering, and Public Policy, National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies. 2005. *Facilitating interdisciplinary research.* National Academies Press, Washington, D.C., USA.

de la Cadena, M. 2005. The production of other knowledges and its tensions. *World Anthropologies Network* 1:13-33.

Endter-Wada, J., D. Blahna, R. Krannich, and M. Brunson. 1998. A framework for understanding social science contributions to ecosystem management. *Ecological Applications* 8:891-904. http://dx.doi.org/10.1890/1051-0761(1998)008[0891:AFFUSS]2.0.CO;2

Fazey, I., J. A. Fazey, J. G. Salisbury, D. B. Lindenmayer, and S. Dovers. 2006. The nature and role of experiential knowledge for environmental conservation. *Environmental Conservation* 33:1-10. http://dx.doi.org/10.1017/S037689290600275X

Fitzgerald, L. A., and A. L. Stronza. 2009. Applied biodiversity science: bridging ecology, culture, and governance for effective Conservation. *Interciencia* 34:563-570.

Fox, H. E., C. Christian, J. Cully Nordby, O. R. W. Pergams, G. D. Peterson, and C. R. Pyke. 2006. Perceived barriers to integrating social science and conservation. *Conservation Biology* 20:1817-1820. http://dx.doi.org/10.1111/j.1523-1739.2006.00598.x

Frodeman, R., and C. Mitcham. 2007. New directions in interdisciplinarity: broad, deep, and critical. *Bulletin of Science, Technology & Society* 27:506-514. http://dx.doi.org/10.1177/0270467607308284

Gluck, C., and A. L. Tsing. 2009. *Words in motion: toward a global lexicon.* Duke University Press, Durham, North Carolina, USA. http://dx.doi.org/10.1215/9780822391104

Haapala, K. R., M. J. Hutchins, J. L. Rivera, V. Kumar, A. R. Clarke, T. D. Eatmon, R. A. Harris, M. H. Durfee, J. R. Mihelcic, D. R. Shonnard, and J. W. Sutherland. 2007. Education, research, and training aspects of the Sustainable Futures NSF IGERT project. Proceedings of the 2007 *ASEE North Midwest Sectional Conference.* American Society for Engineering Education, Washington, D.C., USA.

Hackett, E. J., and D. Rhoten. 2009. The snowbird charrette: integrative interdisciplinary collaboration in environmental research design. *Minerva* 47:407-440. http://dx.doi.org/10.1007/s11024-009-9136-0

Hirsch, P., W. M. Adams, J. P. Brosius, A. Zia, N. Bariola, and J. L. Dammert. 2011. Acknowledging conservation trade-offs and embracing complexity. *Conservation Biology* 25:259-264.

Hirsch, P. D., J. P. Brosius, S. O'Connor, A. Zia, M. Welch-Devine, J. L. Dammert, A. Songorwa, T. C. Trung, J. L. Rice, Z. R. Anderson, S. Hitchner, J. Schelhas, T. O. McShane. 2013. Navigating complex trade-offs in conservation and development: an integrative framework. *Issues in Interdisciplinary Studies* 31:99–122.

Kinzig, A. 2001. Bridging disciplinary divides to address environmental and intellectual challenges. *Ecosystems* **4:**709–715. http://dx.doi.org/10.1007/s10021-001-0039-7

Klein, J. T. 1990. *Interdisciplinarity: history, theory, and practice.* Wayne State University Press, Detroit, Michigan, USA.

Klein, J. T. 2008. Evaluation of interdisciplinary and transdisciplinary research. *American Journal of Preventive Medicine* 35:S116-S123. http://dx.doi.org/10.1016/j.amepre.2008.05.010

Lélé, S., and R. B. Norgaard. 2005. Practicing interdisciplinarity. *Bioscience* 55:967-975. http://dx.doi.org/10.1641/0006-3568(2005)055[0967:PI]2.0.CO;2

Lerman, L. 2010. *Hiking the horizontal: field notes from a choreographer.* Wesleyan University Press, Middletown, Connecticut, USA.

Lubchenco, J. 1998. Entering the century of the environment: a new social contract for science. *Science* 279:491-497. http://dx.doi.org/10.1126/science.279.5350.491

MacMynowski, D. P. 2007. Pausing at the brink of interdisciplinarity: power and knowledge at the meeting of social and biophysical science. *Ecology and Society* 12(1): 20. [online] URL: http://www.ecologyandsociety.org/vol12/iss1/art20/

McBride, B. B., C. A. Brewer, M. Bricker, and M. Machura. 2011. Training the next generation of Renaissance scientists: the GK-12 ecologists, educators, and schools program at the University of Montana. *BioScience* 61(6):466-476. http://dx.doi.org/10.1525/bio.2011.61.6.9

McShane, T. O., P. Hirsch, T. Chi Trung, A. Songorwa, A. Kinzig, B. Monteferri, D. Mutekanga, H. Van Thang, J. L. Dammert, M. Pulgar-Vidal, M. Welch-Devine, J. P. Brosius, P. Coppolillo, and S. O'Connor. 2011. Hard choices: making trade-offs between biodiversity conservation and human well-being. *Biological Conservation* 144:966-972. http://dx.doi.org/10.1016/j.biocon.2010.04.038

Mascia, M. B., J. P. Brosius, T. A. Dobson, B. C. Forbes, L. Horowitz, M. A. McKean, and N. J. Turner. 2003. Conservation and the social sciences. *Conservation Biology* 17:649-650. http://dx.doi.org/10.1046/j.1523-1739.2003.01738.x

Max-Neef, M. A. 2005. Foundations of transdisciplinarity. *Ecological Economics* 53:5-16. http://dx.doi.org/10.1016/j.ecolecon.2005.01.014

Miller, T. R., T. D. Baird, C. M. Littlefield, G. Kofinas, F. S. Chapin, III, and C. L. Redman. 2008. Epistemological pluralism: reorganizing interdisciplinary research. *Ecology and Society* 13 (2): 46. [online] URL: http://www.ecologyandsociety.org/vol13/iss2/art46/

National Science Foundation. 2008. *Impact of transformative interdisciplinary research and graduate education on academic institutions.* Workshop Report. National Science Foundation, Arlington, Virginia, USA.

Newell, B., C. L. Crumley, N. Hassan, E. F. Lambin, C. Pahl-Wostl, A. Underdal, and R. Wasson. 2005. A conceptual template for integrative human-environment research. *Global Environmental Change* 15:299-207. http://dx.doi.org/10.0.1016/j.gloenvcha.2005.06.003

Newing, H. 2010. Interdisciplinary training in environmental conservation: definitions, progress and future directions. *Environmental Conservation* 37:410-418. http://dx.doi.org/10.1017/S0376892910000743

Noss, R. F. 1997. The failure of universities to produce conservation biologists. *Conservation Biology* 11:1267-1269. http://dx.doi.org/10.1046/j.1523-1739.1997.97ed05.x

Park, J. 1996. Integrative research and sustainable agriculture. *Agricultural Systems* 50:81-100. http://dx.doi.org/10.1016/0308-521X(94)00050-2

Pickett, S. T. A., W. R. Burch, Jr., and J. M. Grove. 1999. Interdisciplinary research: maintaining the constructive impulse in a culture of criticism. *Ecosystems* 2:302-307. http://dx.doi.org/10.1007/s100219900081

Pullin, A., T. Knight, D. Stone, and K. Charman. 2004. Do conservation managers use scientific evidence to support their decision making? *Biological Conservation* 119:245-252. http://dx.doi.org/10.1016/j.biocon.2003.11.007

Reyers, B., D. J. Roux, R. M. Cowling, A. E. Ginsburg, J. L. Nel, and P. O. Farrell. 2010. Conservation planning as a transdisciplinary process. *Conservation Biology* 24:957-965. http://dx.doi.org/10.1111/j.1523-1739.2010.01497.x

Runco, M., and I. Chand. 1995. Cognition and creativity. *Educational Psychology Review* 7(3):243-267. http://dx.doi.org/10.1007/BF02213373

Sill, D. 2001. Integrative thinking, synthesis, and creativity in interdisciplinary studies. *Journal of General Education* 50:288-311. http://dx.doi.org/10.1353/jge.2001.0032

Schneider, S. H., J. Stoltman, and D. Waddington. 1995. Education and global environmental change. Page 3 *in* D. Waddington, editor. *Global environmental change science: education and training.* NATO Advanced Science Institutes Series, Springer-Verlag, Berlin, Germany.

Sonntag, S. K. 2003. *The local politics of global English: case studies in linguistic globalization.* Lexington Books, Lanham, Maryland, USA.

Tress, G., B. Tress, and G. Fry. 2005. Integrative studies on rural landscapes: policy expectations and research practice. *Landscape and Urban Planning* 70:177-191. http://dx.doi.org/10.1016/j.landurbplan.2003.10.013

Vercoe, R. A., M. Welch-Devine, D. Hardy, J. A. Demoss, S. N. Bonney, K. Allen, P. Brosius, D. Charles, B. Crawford, S. Heisel, N. Heynen, R. G. De Jesús-Crespo, N. Nibbelink, L. Parker, C. Pringle, A. Shaw, and L. Van Sant. 2014. Acknowledging trade-offs and understanding complexity: exurbanization issues in Macon County, North Carolina. *Ecology and Society* 19(1): 23. http://dx.doi.org/10.5751/ES-05970-190123

Vincent, S., and W. Focht. 2011. Interdisciplinary environmental education: elements of field identity and curriculum design. *Journal of Environmental Studies and Sciences* 1:14-35. http://dx.doi.org/10.1007/s13412-011-0007-2

Welch-Devine, M., and L. M. Campbell. 2010. Sorting out roles and defining divides: social sciences at the World Conservation Congress. *Conservation and Society* 8:339-348. http://dx.doi.org/10.4103/0972-4923.78150