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Challenges and opportunities in transdisciplinary science: The experience of next generation scientists in an agriculture and climate research collaboration

Andrea D. Basche

University of Nebraska-Lincoln, abasche2@unl.edu

Gabrielle E. Roesch-McNally

Iowa State University

Lindsay A. Pease

Ohio State University

Christopher D. Eidson

Ohio State University

Guy Bou Lahdou

Irrigation Consulting Inc.

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Authors

Andrea D. Basche, Gabrielle E. Roesch-McNally, Lindsay A. Pease, Christopher D. Eidson, Guy Bou Lahdou, Mike W. Dunbar, Trevor J. Frank, Laura Frescoln, Lei Gu, Ryan Nagelkirk, Jose Pantoja, and Adam K. Wilke

Challenges and opportunities in transdisciplinary science: The experience of next generation scientists in an agriculture and climate research collaboration

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TRANSDISCIPLINARY SCIENCE

Agriculture in the twenty-first century faces unprecedented challenges from increasing climate variability to growing demands on natural resources to globalizing economic markets. These emerging agricultural issues, spanning both human and natural dimensions, are uniquely formulated, exceedingly complex, and difficult to address within existing disciplinary domains (Eigenbrode et al. 2007; Reganold et al. 2011; Foley et al. 2005; Hansen et al. 2013). Therefore, the next generation of scientists working on these issues must not only be highly trained within a disciplinary context but must also have the capacity to collaborate with others to solve systems-level problems.

To this end, transdisciplinary research continues to grow in the agricultural context. Scientists are encouraged to bridge the social and biophysical sciences in addressing concurrent goals of maintaining high yielding commodities, productive ecosystem services,

and human well-being. This new scientific paradigm is what Collins et al. define as a “knowledge base that can be used to help solve current and future environmental challenges” (2011). Fry (2001) defines transdisciplinary studies as those that reach “a high degree of integration where theories, models and methods merge” across fields. Our conceptualization of transdisciplinarity is the integration of methods, information, and perspectives from several disciplines (Francis et al. 2008) as well as across academic and nonacademic stakeholders (Fry 2001).

We are on the frontier of a transformative era of new science, based on a changing scientific landscape that will demand greater transdisciplinary efforts and team science. As graduate students and junior scholars, we reflect as a cohort on our experiences as part of a large-scale collaborative scientific endeavor. Our perspectives and technical skills are being framed by this new scientific paradigm and will guide our individual and collective contributions to the scientific community as we move forward in our careers. This essay addresses the experience of the graduate students who are working in a unique and transformative transdisciplinary environment. Our goal is to offer examples of successful collaboration, challenges encountered, and opportunities for continued success to future practitioners of team science addressing complex social and ecological challenges.

A COLLABORATIVE PROJECT

The Climate and Corn-based Cropping Systems Coordinated Agricultural Project (Sustainable Corn CAP) is a collaboration of 11 midwestern institutions spanning 9 states. Funded by the USDA’s National Institute for Food and Agriculture (USDA NIFA) in 2011 for a five-year duration, the Sustainable Corn CAP’s objective is to create a functional network of scientists, educators, and extension professionals that facilitate collaborative research and education that focus on mitigating the effects of climate variability on cropping systems in the Midwest. The team is composed of more than 150 members, including 50 principal investigators, more than 40 graduate

students, and various staff and technicians. Scientific disciplines within the project range from, but are not limited to, sociology, agricultural education, economics, climate science, entomology, plant pathology, soil science, agricultural systems engineering, agronomy, and weed science. Therefore, students are a part of a natural experiment—a practical exercise in new research territory—in how the next generation of scientists will be trained and maneuver in a transdisciplinary environment.

Describing advantages of the large-scale project, Mary Ann Rozum, USDA NIFA project representative and national program leader, said,

At USDA, one of our top priorities is sustaining food production in the future. That includes offering improved, more standardized geographic recommendations for farmers on climate change. If we had 20 smaller projects doing their own protocol, it would be far more difficult to compare results. With a large project we can really bracket the climate across the Corn Belt and compare the research. Can you anticipate particular disease problems in warmer or wetter areas? How do we project best management practices across the region? This is new territory for us, but a large project also offers smoother integration of research, extension, and teaching to allow for quicker information dissemination to farmers.

A major directive from the project’s leadership team has been to encourage every team member to take part in activities that put transdisciplinary science into action, such as presenting research and attending integrated meetings. Below, former and current Sustainable Corn CAP students comment on ways that transdisciplinary activities provide the fundamental groundwork for collaboration (figure 1).

Lindsay Pease, a PhD candidate in agricultural engineering at Ohio State University, said,

The field research team has subdivided into smaller working groups based on

Andrea D. Basche is a graduate research assistant in the Department of Agronomy, Iowa State University, Ames, Iowa. **Gabrielle E. Roesch-McNally** is a graduate research assistant in the Sociology Department, Iowa State University, Ames, Iowa. **Lindsay A. Pease** is a graduate research assistant in the Department of Food, Agricultural, and Biological Engineering at The Ohio State University, Columbus, Ohio. **Christopher D. Eidson** is a graduate research assistant in the Carbon Management and Sequestration Center at The Ohio State University, Columbus, Ohio. **Guy Bou Lahdou** is a design engineer at Irrigation Consulting Inc., Pepperell, Massachusetts. **Mike W. Dunbar** is a graduate research assistant in the Department of Entomology at Iowa State University, Ames, Iowa. **Trevor J. Frank** is a graduate research assistant in the Department of Agronomy at Purdue University, West Lafayette, Indiana. **Laura Frescoln** is a graduate research assistant in the Department of Agricultural Education and Studies, Ames, Iowa. **Lei Gu** is a graduate research assistant in the Department of Biological Systems Engineering at the University of Wisconsin, Madison, Wisconsin. **Ryan Nagelkirk** is a graduate research assistant in the Department of Geological Sciences at Michigan State University, East Lansing, Michigan. **Jose Pantoja** is a PROMETEO Scientist in the Department of Life Sciences and Agriculture, Universidad de las Fuerzas Armadas, Sangolquí, Ecuador. **Adam K. Wilke** is a graduate research assistant in the Department of Sociology at Iowa State University, Ames, Iowa.

Figure 1

Entomology graduate student Mike Dunbar (right), agronomy graduate student Andrea Basche (center), and agricultural education graduate student Laura Frescoln (left) participate in a demonstration of climate support tools for producers at the 2014 annual conference. In a voluntary survey of the team at the beginning of the project, all graduate students responded that they valued transdisciplinary collaboration while three-quarters responded that they were pleased with their efforts to engage in transdisciplinary research. Photo credit: Lois Wright Morton.



subject area, and I am a part of the drainage water management working group. These working groups facilitate collective brainstorming, a valuable skill to develop as a young scientist, by bringing together researchers from different universities and fields of study who are researching the same topic with regular conference calls. The groups also allow students to participate as equals with established faculty members and have solidified the importance of cooperation and sharing of information on transdisciplinary projects.

Trevor Frank, master's student in agronomy at Purdue University, noted,

As a new graduate student to the project, I found the annual meeting critical to understanding the 'big picture.' Since researchers normally only meet via conference calls, the annual meeting provided face-to-face interaction and the realization of how much contribution each person puts into the project. Various activities at the conference, such as graduate student poster sessions, table discussions, and social

gatherings, helped me gain a greater understanding of transdisciplinary collaboration, field research concepts, and importance of networking.

Jose Pantoja, a scientist at the Universidad de las Fuerzas Armadas, Ecuador, and a former graduate student in agronomy at Iowa State University, said,

While I worked on the Sustainable Corn CAP, I had the opportunity to interact with scientists and students by sharing initiatives and ideas to improve our work not only in the annual meetings, but also on a day by day basis. I realized the interaction with such professionals was helping improve my communication and leadership skills. That has been of much help to me as I grow in my career. Now that I am back to my home country, Ecuador, I am more capable of leading projects and groups and presenting at conferences to students, agronomists, and farmers. I am sure this would not be that easy if I was not part of this initiative.

PROJECT CHALLENGES AND FUTURE RECOMMENDATIONS

Despite the emphasis placed on the academic integration to address complex social ecological problems (National Academy of Science 2009), a number of challenges associated with the transition to transdisciplinary work remain. We define two major categories of challenges experienced by Sustainable Corn CAP students and propose recommendations for projects in the hope of achieving an improved working model of transdisciplinary team science.

Challenge: Breaking the Mold as Collaborative Pioneers. Although in recent years national funding agencies such as the National Science Foundation and USDA NIFA have moved toward promoting transdisciplinary projects, as pioneering students we observe that the general academic structure does not provide any clear pathways toward integration. Whitmer et al. (2010) similarly recognize both individual and disciplinary obstacles around this type of "engaged" research. On an individual level they note a lack of successful academic models participating in such research. At the disciplinary level, transdisciplinary science requires more time to produce outputs (e.g., multiauthored publications). This is problematic within the current academic framework because incentives for tenure and promotion traditionally place higher emphasis on disciplinary success (Daily and Ehrlich 1999; Goring et al. 2014). Numerous graduate students on our project have established productive research collaborations in spite of such obstacles. One exciting example is the pairing of landscape model scenarios with socioeconomic data, informed by farmer surveys and interview data that explore farmers' adaptive management responses to climate change. This will allow for more realistic predictions of how individual farmer decisions impact regional outcomes, such as water quality and greenhouse gas emissions.

Challenge: Heterogeneity in Student Experiences. Students in the Sustainable Corn CAP come from different disciplines with diverse disciplinary norms concerning methodology as well varying experiences based on length of time on the project (e.g., master's versus doctoral

students) and attend universities in nine different states. Students are also tasked with varied requirements and coursework necessary to hone their specific disciplinary skills and methods. As a result, the path to engage in transdisciplinary research is nonlinear and varies from student to student. Thus, projects with transdisciplinary goals must harness that heterogeneity in a positive way to accomplish something that a single discipline could not achieve. The challenge is to offer systematic opportunities for students to experience the breadth of the project while not compromising individual students' institutional requirements. As a cohort, we developed a "roadmap" for project engagement (http://sustainablecorn.org/About-People/Graduate_Student_Roadmap.pdf) as a vessel to highlight such opportunities.

Recommendation: Define Appropriate Transdisciplinary Training for All Team Members. Principal investigators who serve as advisors to students typically have been trained in a disciplinary subject area. Thus, many of these principal investigators may lack successful models that could fully empower their students to gain experience and training as a transdisciplinary researcher. An explicit recommendation from our experience is that everyone involved—faculty, graduate students, team leadership, and funders—participate in an intentional transdisciplinary training program as part of participation in the project. The outline of a training program should ideally be incorporated from a project's inception. We suggest that this training have broad buy-in from all members of the team but still be flexible enough to accommodate various needs of all mentors and students. A training module should recognize that team science requires different skills than those that most faculty and graduate students generally have the opportunity to acquire. The suggested skills we propose to improve team science collaboration include project management, leadership, interpersonal dynamics, and communication (table 1). Wide participation will help cultivate a culture of successful collaboration and the skills required for team science, therefore hopefully reducing some of the heterogeneity experienced by students. We believe that if academia and the institutions that fund our work are truly

Table 1

Outline of suggested skills for transdisciplinary training.

Training component	Beneficial skills and product outputs for members of Sustainable Corn CAP transdisciplinary team
Scientific training	Disciplinary development (e.g., expert knowledge in research area) Clear training in disciplinary requirements
Team dynamics	Understanding multiple disciplinary frameworks and norms Mutual respect and openness to different disciplinary approaches to scientific questions Facilitation of group process to develop tangible results (e.g., shared analysis, synthesis, and findings)
Communication	Development of shared products to communicate results to stakeholder groups (e.g., research videos, extension publications, and/or education modules)
Leadership and project management	Leadership skill-building opportunities Project management skills to organize group process and development of outcomes Mentoring opportunities (e.g., undergraduate research opportunities)

Figure 2

Sociology graduate student Gabrielle Roesch-McNally (right) exhibits different weed species for a short video production activity at the 2013 annual meeting. Students have participated in activities attempting to work outside of traditional academic silos such as those geared toward communicating science to external audiences. Photo credit: Lois Wright Morton.



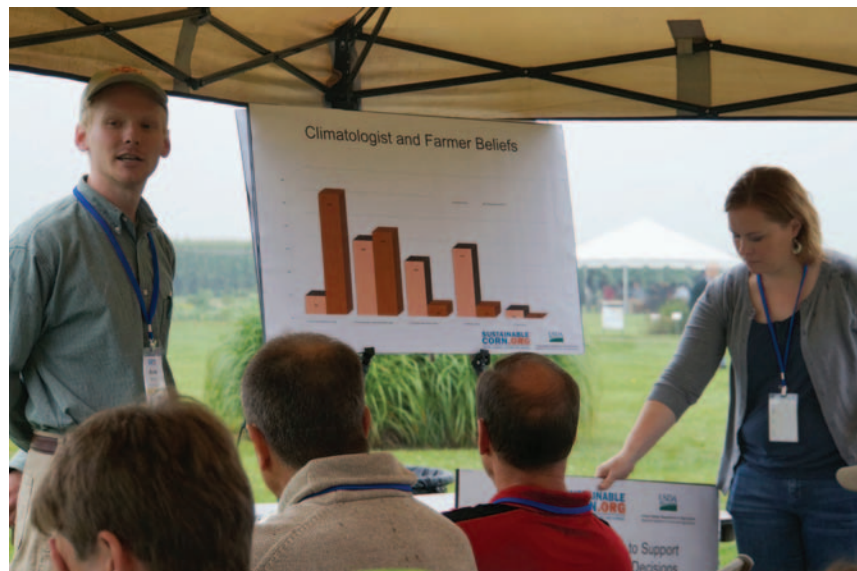
committed to creating a science that solves complex challenges, it will be necessary for such projects to intentionally address additional skills requirements (figure 2).

Recommendation: Create Networks for Communities of Practice. In order to provide more models of successful team collaborations and evolve social norms regarding academic research, we propose that projects explicitly include outside partnerships that can connect students and mentors to transdisciplinary science per the recommen-

dations of Graybill et. al (2006). Romolini et al. (2013) emphasize the need to connect scientists, particularly graduate students, with a strong network in order to better integrate students into the bridge building process between the social and ecological sciences. Whitmer et al. (2010) also suggest that universities hire "professors of practice" from government and industry to help mentor students. The Sustainable Corn CAP continues to work on cultivating such a network through regular communications with our

Figure 3

Sociology graduate student Adam Wilke (left) works with extension coordinator Jamie Benning (right) to present research on climate change communication for a group of Climate and Corn-based Cropping Systems Coordinated Agricultural Project scientists and staff at the 2013 annual conference. Project leadership encouraged graduate students to deliver both oral and poster presentations during regular meetings. Photo credit: Lois Wright Morton.



advisory board, a team of public, private, and nongovernmental organization partners. The education and leadership team, with input from graduate students, facilitated a series of webinars with practitioners from our advisory board to describe their work and as well as the skills needed for the next generation of scientists. We are also in the process of planning a career development retreat to further include input from our advisory board members. A more integrated network between graduate students and nonacademic mentors should be intentionally facilitated in order to share resources, information, and experiences of using science to solve real world problems. This type of network could also help to overcome some of the institutional bias that does not always reward this new paradigm of science (figure 3).

CONCLUSION

It is our goal to inform transdisciplinary collaborations by sharing the successes and challenges we have encountered as well as propose recommendations for future projects. We have observed that participants in team science require new skills and purposeful opportunities to learn that are not generally provided in the current academic setting. We recommend that transdisciplinary

training be an integral component for all members of an integrated team. Further, networks of practice, which include multiple stakeholders outside of academia (such as nonprofit and private sector collaborators), create a better support system for students as well as provide a model of team practitioners solving twenty-first century challenges. Enhanced skill development and access to public and private practice networks will help emerging academics thrive in this new transdisciplinary landscape.

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