5. SUPPORT FOR THE NEXT GENERATION OF RESEARCHERS | Sanford Eigenbrode and Timothy Martin

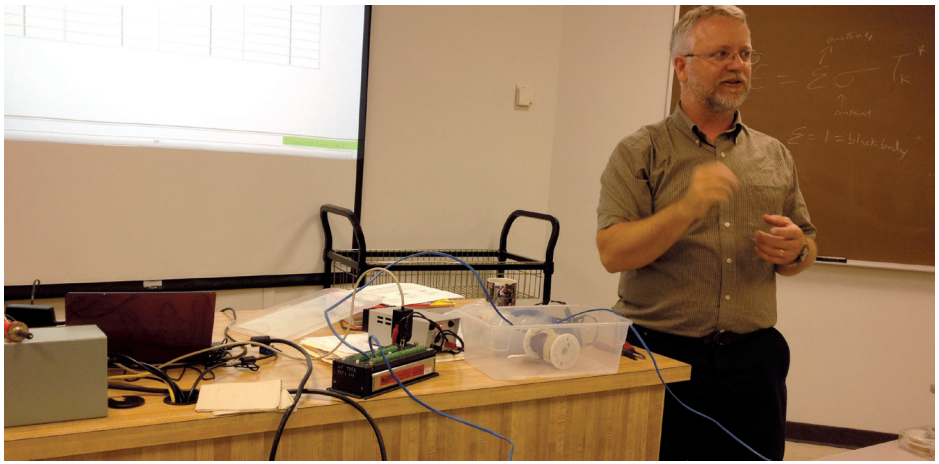
Rationale

Large collaborative projects addressing SES will doubtless remain a significant component of the global research agenda. To support this agenda, the new generation of researchers must be prepared to function effectively within such projects. The need to incorporate collaborative and interdisciplinary skills into graduate education is well recognized (National Research Council 2014, National Academy of Sciences 2004, Wagner et al. 2012), but large SES projects present additional challenges associated with their size, disciplinary breadth, complex structures involving multiple interacting teams and institutions, and their extended geographic scope. Within such projects, there are unique opportunities, if not obligations, to impart the needed skills and understanding to participating undergraduate and graduate students, postdoctoral associates, and other early career professionals.

Education within large SES projects includes imparting rigorous disciplinary expertise as well as the capacity for contributing to the cross-disciplinary effort. Participants and trainees alike must understand their own work in the context of the project as a whole. They must also understand the principles and assumptions of various other disciplines to enable required collaboration. This entails additional time and effort (i.e., transactional costs; see Section 4, Enabling Participant Success) that can challenge students and mentors. Project-wide commitment to addressing these mentoring challenges is essential. During conception, proposal development, and initiation (Phases I and II), it is important to determine your project-wide commitment to education for collaboration. This is a philosophical and pedagogical issue that must be explicitly addressed by your faculty team to find agreement in general terms and in the specific interdisciplinary skills, approaches, and expectations for graduate students and others within the project. Furthermore, many federal programs require an explicit educational component within the proposal. Evidence of careful thinking about the educational culture and expectations will help your proposal to be successful.

Attention to incorporating cross-disciplinary dimensions into graduate education benefits your project and your graduate students. Post project surveys of graduate students of our projects indicate that their competitiveness in the job market has been enhanced by experience with collaboration gained as part of their training.

Determining project-wide commitment may not be straightforward. Very large projects can include multiple types of integration, from multidisciplinary to transdisciplinary, occurring simultaneously across the project (Morton et al. 2015). This diversity has implications for student training. If some components of the project are more independent for technical reasons, you and your leadership must decide if there can be different expectations for integration of students working in these components versus others, and if so, develop the rationale and protocols for providing and enforcing those expectations. In addition, a large, multi-year project will typically support students to different degrees ranging from full support throughout their programs to partial support, for one year or less. What are the expectations of integration across disciplines for students with these different levels of support? These are issues you and your team will have to address explicitly. Full integration of all associated students will benefit your project's culture of collaboration (see Section 3, Creating a Culture of Collaboration). Indeed, today's students are often highly motivated to participate in collaborative efforts and their enthusiasm can greatly assist in elevating your project's *esprit de corps*. Often, students can lead the way to deeper and more creative integration if given opportunities to do so. On the other hand, draconian enforcement of expectations for integration that are inappropriate for all students will incur reluctance, confusion, or resentment. Whatever is adopted must have flexibility that considers different levels of motivation among students for interdisciplinary training. Each project differs and you must find the right balance for yours.



USDA-NIFA sponsored PINEMAP project director Tim Martin in the classroom.
Credit: Carlos Gonzalez-Benecke

Implementing the Educational Approach for your Project

With your project-wide commitment and policies established, efforts to implement them will begin with recruitment and continue to graduation and beyond. How student positions are described and the expectations and goals for participation in recruitment materials can attract students with the varied interests that match your needs and training objectives. Our experience has been that today's degree aspirants are often committed to transdisciplinary principles and their importance for addressing SES issues, and will have been attracted to your project because of the opportunities it presents for acquiring these skills. Be explicit about these opportunities.

USDA-NIFA sponsored Sustainable Corn project graduate students with their major professor and project PI, Warren Dick, the Ohio State University, celebrate the completion of their research and graduation. Credit: Anonymous

Throughout the project, be purposeful in providing structured opportunities for students and acknowledging their respective contributions. Skills and capacities to consider as goals for the educational component of your project include:

- Budgets and budget management
- Navigating different institutions
- Grant writing and reporting
- Data sharing for integrative publications and outputs
- Attribution of credit in collaborative publications and other outputs
- Collaborative skills and cross-disciplinary communication
- Networking and team building skills
- Oral and written communication to lay audiences
- Stakeholders, disciplinary or interdisciplinary peers (or combinations of all of these)
- Use of virtual communication tools including webinars, blogs, and web pages.

For large projects addressing SES, this skill set should include the capacity to place individual research activities into the broader, project-wide, interdisciplinary context of the project as a whole. In one of the CAP projects informing this primer, student presentations at annual meetings included presentation templates with the requirement, "place your work into the context of the project-wide logic model." Project-specific coursework, workshops, and student seminar series are essential for the students and can become key integrating elements of your entire project.

Components of incorporating education into your project throughout its phases are listed in Table 5.1. Resources and ideas for these approaches are described in the following sections.

TABLE 5.1

COMPONENTS OF SUPPORTING THE NEXT GENERATION OF RESEARCHERS PREPARED FOR SUCCESS IN LARGE SES COLLABORATIVE PROJECTS

	PHASE I PROPOSAL	PHASE II GETTING STARTED	PHASE III PERFORMING	PHASE IV FINISHING STRONG
Designate an education lead among the co-PI and resources to support educational activities, retreats, training and to ensure educational goals, protocols, etc. are completed	x	x	x	x
Establish project-wide expectations for involving students in cross-disciplinary, project-wide activities	x	x		
Communicate expectations and guidelines for cross-disciplinary education to all mentors		x	x	
Encourage and enable co-mentoring	x	x	x	
Develop and provide specialized coursework, workshops, immersion experiences	x	x	x	
Involve students and postdocs as feasible in all aspects of project planning and execution	x	x	x	x
Involve students in interdisciplinary teams or activities		x	x	
Conduct annual student retreats or workshops		x	x	
Conduct exit interviews for each student and postdoc as he or she leaves the project			x	x
Design and execute undergraduate research experiences	x	x	x	
(optional) Design and produce K-12 educational activities and materials	x	x	x	x

Your education team

Consider identifying a PI with a primary responsibility to coordinate educational aspects of the project. Some of our projects have PI's specializing in agricultural education or a similar discipline, training students in these areas, and conducting research related to this dimension. One of our CAP projects had an education team that worked to coordinate K-12, undergraduate, and graduate educational activities.

USDA-NIFA sponsored REACCH graduate student, Jackie Chi, working with undergraduate summer interns. Credit: Shelly Pressley

Coursework and workshops

Large projects can and should provide specialized coursework, workshops, or immersion experiences for graduate students to help them acquire interdisciplinary and specialized skills related to the project. Sometimes, coursework on ethics will be required by the funding agency, but if not or if such coursework is not accessible, specialized courses can be developed. Ethical considerations are often visible in transdisciplinary projects because of the potential conflicts inherent to working with stakeholders. Authorship issues and collaborative responsibility have become significant in large projects where project conception, execution, data, and presentation depend upon many contributors. Other sorts of project-wide coursework may focus on common skills such as GIS, working with climate outputs, or utilizing data uploading, tagging, accessing, and manipulation expected of all project participants.

Fostering dialogue through improved communication, awareness, and skills

One of the most challenging aspects of interdisciplinary collaboration is communicating across the sometimes obscured intellectual divides among disciplines, especially those that exist between biophysical and social sciences or even within the social sciences (Lélé and Norgaard 2005). A formal workshop-based approach that illuminates these divides and facilitates greater understanding among collaborators (Eigenbrode et al. 2007) has been used successfully by a number of interdisciplinary teams, including many involving graduate students working together in collaborative teams (**http://toolbox-project.org**). Within one of the NIFA-funded climate CAPs, this so-called "Toolbox" workshop method was implemented for all students and postdocs at project inception. Subsequently, a student team generated a follow-up, project-wide workshop to promote improved interdisciplinary communication. Targeted courses and workshops can also focus on specific interdisciplinary collaborations (e.g. Wagner et al. 2012).

USDA-NIFA sponsored PINEMAP undergraduate interns (left) working on a group project. Credit: Left: Jason Vogel

Participants in USDA-NIFA sponsored PINEMAP's undergraduate fellowship program were paired with graduate students for summer research (left) and took an online course in experiential science education and delivered lessons to middle schools in their hometowns (right). Right: John Seiler

Graduate student teams or team projects

Interdisciplinary training of graduate students can be facilitated through student teams. Such training can range from short-term activities focused on generation of an interdisciplinary research, extension, or education product to establishing formal graduate student teams to address particular integrating objectives within the project. The most thoroughly integrated form of such teams consists of teams of PhD students recruited simultaneously to work together throughout their programs, from generating interdisciplinary dissertation level questions to executing the research and producing jointly authored dissertation chapters and publications (Bosque-Pérez et al. 2016). Although this level of integration presents significant logistical, conceptual, and educational challenges, it successfully has produced students who are extraordinarily well-prepared for careers in integrated collaborative science capable of addressing significant SES questions and challenges.

USDA-NIFA sponsored REACCH graduate students at a two-day retreat in 2012. Credit: Anonymous

Involving students in all project activities

In addition to coursework, workshops, and other interventions to help students acquire needed skills, opportunities to be as involved as possible in project operation should be provided. There will be natural student leaders who are able to contribute substantively without compromising their own research programs. Consider having student members of project sub-teams and committees, as appropriate. Allow them to make the project their own. Our projects have all benefitted from energetic, committed, and capable students. Formalize this involvement and celebrate it with internal awards and other recognition.

Mentoring and co-mentoring

Your project participants all serve as mentors to students, through example, instruction, or both. It is important to recognize that role and its expectations, and to provide resources to help participants to be effective mentors. One possibility is to engage students and mentors in a discussion of the "T-shaped" individual and curriculum and the approaches to achieving optimal breadth and depth in career (Uhlenbrook and de Jong 2012).

Graduate students working together as part of formal co-mentoring activity. Credit: Anonymous

The mentoring and co-mentoring roles of all participants should be acknowledged frequently during project execution. In addition, if you will have defined cohorts of students and postdocs, it can be useful to charge senior cohorts with some responsibilities for helping those coming into the project. Students can be directed to resources to help with co-mentoring. Most will value this training in preparation for responsibility as mentors in their own careers. Because of its importance, many universities have internal documents on mentoring that can be accessed and shared in part with students (also see Handelsman et al. 2009 and **https://uwpress.wisc.edu/books/4702.htm**). Work groups or objective teams within a project can be encouraged to recognize the importance of mentoring as part of the work they carry out, and good mentoring can be modeled by co-PIs and rewarded and recognized when it is done effectively within a team.

Graduate students preparing to present their research at a formal meeting (NWWBC).
Credit: Anonymous

A kindergartner learns about earthworms from USDA-NIFA sponsored REACCH project personnel during a classroom visit.
Credit: Jodi Johnson-Maynard

Assessment

Project assessment activities, organizational meetings, reporting, and outreach aspects of the project can benefit from explicit and deliberate acknowledgement or reiteration of educational philosophy and goals of the project and whether these are being met. When students and postdocs exit the program, it is important to conduct an exit interview that includes questions about the educational experience, disciplinary and interdisciplinary skills and knowledge acquired, sense of engagement with the project, expected impacts of the training, and participation on career aspirations. Data from these surveys can be used to modify and improve educational activities. Ideally, students can be tracked for later assessments, for example, one year after departing the project.

Resources for Imparting Interdisciplinary and Transdisciplinary Skills

Approaches to mentoring students to improve their capacity for interdisciplinary research have been outlined in several publications (Nash 2008, Repko 2008, Stamp et al. 2015); some interdisciplinary SES projects have successfully utilized these and other sources as part of interdisciplinary mentoring in workshop or short course settings (Bosque-Pérez et al. 2016, Stamp et al. 2015).

Undergraduates: Learning and Internship Opportunities

The large scope and integrated nature of very large SES projects provides an ideal platform for involving undergraduates through research internships. You may choose to include this in your project design. In one of our large CAP projects, funding was included to bring approximately 12 students into the project for 9-week internships each summer associated with specific teams or co-PI programs. A total of 72 students were recruited through a competitive process at the national level. Unlike typical internships or NSF REU placements, the CAP internship introduced students to the disciplinary breadth of the project to help them acquire skills such as interdisciplinary collaboration and communication. The internship succeeded in helping students appreciate applied science, assess their interests in and preparedness for graduate school, understand complex systems, and work on outreach or extension related activities. Many continued on to advanced degree programs. In the particular CAP where this was employed, the interns became an important integrator helping the entire project to appreciate work ongoing during the summer months across disciplines and institutions. Interns were embedded in specific objective teams, but also met weekly to discuss their work and the interdisciplinary skills and challenges they faced. Intern symposia were project-wide events that brought together their mentors and other project personnel, with opportunities to see the breadth of work and integrating opportunities.

K-12 Education: Teacher Training, Curricula

Some very large SES projects have invested resources in developing high school or elementary school curricula that draw upon the background and ongoing work of the project. Examples include a tri-state (WA, ID, OR) climate change and agriculture high school curriculum developed over four years with input from high school teachers during a one-week immersion course in each project year (**https://www.reacchpna.org/education/secondary-curriculum**). The processes of developing and assessing educational materials can also provide opportunities to engage project researchers in educational activities, and can also be leveraged as platforms for educational research (e.g. Monroe et al. 2016).

Director's Role

As project director, you may encounter mentors or students who are resistant to allocating student time to acquiring collaborative skills or participating in interdisciplinary activities designed to build these skills. There may be apparent tension between educational and other goals of your project. You will need conviction and commitment to project-established educational objectives and means to achieve them. Be prepared to articulate these compellingly as part of your leadership role.

Take Away Messages:

- Preparing students for effective participation in large SES-focused projects is consistent with anticipated needs for such projects in the future.
- Involving students in very large SES-focused projects provides unique opportunities and presents unique challenges.
- Establish a project-wide commitment to balancing disciplinary and interdisciplinary education and enforce this commitment.
- Identify an education leader among your co-PIs.
- Remember that all participants have mentoring roles to varying degrees and help everyone to develop mentoring and co-mentoring skills.
- Incoming graduate students have an increasing appreciation for and interest in the importance of transdisciplinary projects and actionable research.
- Take advantage of existing resources for training students for interdisciplinary careers.
- Outgoing students with cross-disciplinary skills have improved career opportunities.
- Large SES projects provide an opportunity to expose undergraduate students to cross-disciplinary collaboration and communication.
- Consider directing resources to K-12 education, which can involve all participants and increase project impact.
- The director articulates and inspires the team in achieving its educational goals.

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