National Council for Science and the Environment
Improving the scientific basis for environmental decisionmaking
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NSF Climate Change Education

Creating a Learning Community for Solutions to Climate Change

Proposal # 095-0396

Project Description

Overview: The academic community has been challenged to meet the needs of the future workforce and citizens in general as discourse about climate change has shifted from whether such change is occurring and whether human activities are responsible to the challenges of dealing with ongoing impacts. While faculty have learned how to help students diagnose problems, we, and they, need a different set of knowledge and skills to actually fix them.

A recent CEDD analysis indicates that, around the country, courses about climate change have usually been focused on the scientific background about causes, with only passing references to adaptation and mitigation strategies (CEDD 2008). This is in part because most courses are taught by earth and atmospheric scientists, who are not as proficient in biology, economics, engineering, psychology, political science, and related fields needed to evaluate viable solutions. Information covers too much ground for any one faculty member and is also advancing too fast for textbooks. The interdisciplinary and rapidly evolving nature of climate change causes, consequences, and solutions presents a challenge to colleges and universities as they seek to educate undergraduate students on critical contemporary issues. Yet it is essential that education meets the challenge of climate change: students need to learn not only the causes of climate change, but also how to mitigate greenhouse gas emissions and adapt to changes that are already beginning.

To address this challenge, the National Council for Science and the Environment (NCSE) proposes to create a nationwide learning community called CAMEL (*C*limate, *A*daptation, and *M*itigation *e*-*L*earning). The CAMEL initiative will engage educators and scholars to develop curricular content based on the best available research and on the most appropriate pedagogical methods for enabling students to tackle complex problems. We will:

- Assist faculty at institutions of higher education across the United States as they create, generate, test, and share resources for teaching students not only how to diagnose climate change problems, but also to identify and effect solutions;
- Ensure that materials developed and shared are founded on the best available scientific information and follow the most appropriate educational practices;
- Build a community of researchers, educators, and students engaged in teaching about climate change causes, consequences, and solutions;
- Develop cyberinfrastructure that will support and promote the creation of materials and community; and
- Evaluate the determinants of successful community building using cybermedia.

In order to develop and disseminate innovative undergraduate education that addresses the climate crisis, the CAMEL implementation strategy has five interrelated components: content development, faculty development, community-building, cyberinfrastructure, and program evaluation.

- The content development component will address the shortage of materials available for undergraduates that present a multi/interdisciplinary (geophysical, biological, engineering, ethical, legal, social, behavioral, and economic) treatment of climate change causes, consequences, and solutions.
- The faculty development component will encourage best practices as curricular materials are developed and disseminated.

- The community building component will encompass both face-to-face and online networking of researchers, educators, and students.
- The cyberinfrastructure component will support content development, dissemination of materials, and community building.
- The program evaluation component will assess the effectiveness of the other four components.

The content component represents the core objective of CAMEL: to expand and improve the materials that are available for students at the undergraduate level. Most information about climate change is focused on understanding the phenomena and their causes from a physical science perspective—not on mitigation and adaptation—and is aimed at science majors. Largely missing are materials directed toward the vast majority of undergraduates, especially materials appropriate for educating students about responding to climate change. The focus of the content development component will be to ensure that teachers and students (*a*) understand the causes and consequences of climate change, and (*b*) are prepared to develop solutions relevant to regional and global scales, from the individual to the human population.

The faculty development component will emphasize pedagogies of engagement (e.g., challenge-based learning), inquiry, and assessment appropriate to exploring and understanding complex problems. It will encourage participants in CAMEL to evaluate and report on effective teaching and learning, and promote best practices as teaching and learning tools and methods are developed.

The community building component will foster communities of professional practice at three levels: faculty organized by their topical climate change interests and expertise; faculty organized within specific geographic regions; and a larger national community.

The cyberinfrastructure component will develop electronic resources appropriate to the management of content, development of community, and promotion of best practices. The cyberinfrastructure will also archive decisions, dialogue, rationales, and processes to form a source for subsequent study of what promotes and impedes effective content development and community interactions. The cyberinfrastructure will support opportunities for feedback and comments, providing feedback loops that continuously improve both materials and processes.

The program evaluation component will assess and provide feedback on the effectiveness of the content, faculty development, community building, and cyberinfrastructure components, as well as the integration of all of these components.

Integration strategy: The project PI, coPI's and senior personnel will oversee the project through frequent conference calls and face-to-face meetings. As detailed below, this will include continuous assessment of and feedback to both the individual components and the interactions among those components.

Intellectual Merit: This project will advance understanding through 3 major research objectives. First, we will evaluate approaches appropriate to the successful integration of content and teaching practices:

- What facilitates integration of environmental science research-based content, educational research, and educational practice?
- How can we apply problem-based learning to the climate change solutions challenge?

Second, we will evaluate which norms of content and teaching strategies most effectively inform and motivate various learners about climate change causes, consequences, and solutions:

- How can we develop curricula through a national network of educators?
- How can we integrate qualitative evaluation of process with quantitative analysis of product?

Finally, we will expand our understanding of how learning communities develop and identify the factors that encourage or impede such community building:

- How can we best use cyberinfrastructure for educational community organization?
- How can we produce, evaluate, and disseminate materials such that the community becomes self-sustaining over time?

CAMEL addresses and builds on the educational challenge posed by climate and other environmental scientists, formal and informal educators, and representatives of thirteen federal agencies who developed and adopted "Climate Literacy: The Essential Principles of Climate Science" (CCSP 2009) in which they argue that: "Climate Science Literacy is an understanding of your influence on climate and climate's influence on you and society. A climate-literate person

- understands the essential principles of Earth's climate system,
- knows how to assess scientifically credible information about climate,
- communicates about climate and climate change in a meaningful way, and
- is able to make informed and responsible decisions with regard to actions that may affect climate."

Expanding on this last point, the Climate Literacy initiative has as the guiding principle for informed climate decision: "Humans can take actions to reduce climate change and its impacts." This is our goal: to prepare students who have the willingness and capacity to recognize and take necessary actions (National Academy of Sciences: Rising above the Gathering Storm, 2008).

1: Content Development

Goal: To provide undergraduates with information to become knowledgeable about climate change causes, consequences, and solutions. Becoming knowledgeable extends from being conversant in a common terminology to using the information directly in practical applications.

The first objective of this component will be to draw on climate literacy principles to develop a working framework of curriculum foci related to climate change causes, consequences, and solutions. This framework will serve as an initial prioritization, but will be reviewed continually for currency. The second objective will be to develop teaching and learning resources for these topics.

The topics will include:

- The relevant phenomena as well as the methods that are used to characterize the phenomena (e.g., temperature proxies, insolation, the greenhouse effect, albedo, and carbon absorption by the global ocean);
- The causes of climate change and the conceptual basis of each cause (e.g., fossil fuel use and deforestation);
- The nature of geophysical and biological responses to climate change and their economic, ecological, and sociological consequences (e.g., sea-level rise, shifts in the arrival of spring, temperature-induced shifts of populations to higher elevation and towards the poles, changes in disease patterns, impacts on poverty and human well-being as well as on ecosystem services);
- The scope of climate change solutions and the relative merits of different approaches (e.g., mitigation strategies such as carbon sequestration and reducing reliance on fossil fuels and adaptation strategies such as developing infrastructure for large-scale population shifts);
- The various ways that people can participate in climate change mitigation and adaptation in their personal and professional lives (e.g., shifting individual and societal transportation practices and developing effective policy levers).

These collective resources will provide a common framework on which individual faculty members can draw to develop courses or modules within courses, selecting and expanding on topics that best suit their expertise and the needs of their students. Users of the resources will share their

experiences and propose further modifications and additions to the materials through cyber-enabled and direct exchanges, thereby keeping them up-to-date and expanding potential user options (see Cyberinfrastructure section).

Members of the project leadership team have expertise in climate solutions research and education. Two of the members have forthcoming books on the topic (Bloom, 2009a; Blockstein and Wiegman, 2009), while another (Hassenzahl) has written the climate change and energy chapters in a widely used introductory environmental science text book (Raven et al 2008). Several have been involved in climate solutions education community for some time. For example, Blockstein has organized several National Conferences on Science, Policy and the Environment, including 2003 on education for sustainability (Blockstein and Greene 2003), 2006 on sustainable energy (Blockstein and Shockley 2006) and the 2008 event at which 1350 people convened to discuss climate changes and solutions. At the 2008 conference, Hassenzahl led a half-day workshop on teaching climate change to undergraduates; he also organized for the 2008 Focus the Nation national teach-in, for which he hosted a national coordination meeting. Bloom has taught for nearly a decade a general education course in global climate change that now attracts over 250 undergraduates annually. Likewise, Pfirman has led a co-taught undergraduate climate change course for over a decade (Hays and Pfirman, 1998; Hays et al. 2000), and contributed a chapter to *Climate Change: Picturing the Science* edited by Gavin Schmidt and Joshua Wolfe (who has provided a letter of support; Schmidt and Wolfe, 2009). Faculty Associate McCaffrey is a principal author of the previously mentioned climate literacy principles.

Most of the PIs and some of the faculty associates on this project are also involved in a NASA grant that has just been awarded to NCSE. The goal of the NASA project is to incorporate learning modules based on NASA satellite data into a general education course on global climate change for undergraduates. The NASA grant engages a diverse group of 20 colleges and universities who will be offering such a course using a common textbook, *Global Climate Change: Convergence of Disciplines* by Arnold Bloom, who is a co-investigator on the NASA project and this proposal. The participating faculty members will suggest additions, deletions, modifications, or rearrangements to the modules.

The CAMEL initiative will build upon the NASA project to provide teaching and learning resources for a full range of undergraduate courses and to expand the scope from climate change to climate change solutions. It will also draw on a range of existing resources, including the user-friendly GCM model hosted at Columbia University (EdGCM), the stabilization wedge model at Princeton University, the firetree.net sea-level rise simulator, and the C-ROADS climate decision simulator.

CAMEL will be distinctive in that it will provide teaching and learning resources specifically for undergraduate courses and students. It will focus on solutions-oriented content grounded in the best available expertise and the most appropriate pedagogical practices. For more elementary materials, the CAMEL portal will link to the corresponding topic on K-12 web sites such as Climate Status Investigations (http://www.keystonecurriculum.org/), Climate Change Education (http://www.climatechangeeducation.org/k-12/ecology.html), and the Climate Literacy Network (http://climateliteracynow.org/). For more sophisticated materials, the CAMEL portal will link to existing resources, such as the corresponding section of an IPCC report (http://www.ipcc.ch/), the U.S. Climate Impacts analysis that was just released (Global Change Research Program, 2009), or the corresponding topic on the Encyclopedia of Earth (EoE) web site (http://www.eoearth.org/), which has been created and is hosted by NCSE. NCSE has considerable experience with recruiting, reviewing, editing, and web-publishing scientific material. The EoE site contains almost 5,000 peer-reviewed articles from approximately 1,000 authors and numerous content partners from the community of academic, governmental, and professional scholars.

The content will consist of a broad set of resources that will constitute a virtual toolbox for educators ranging from specific lessons or practices to entire curricula. It will include, but not be limited to, case studies; lectures and presentations; laboratory exercises; problem sets; syllabi; sample criteria for certificates, majors, and minors; experiential learning projects; links; and graphics. These will be enriched through solicited and unsolicited reviews, commentary, blogs, and practical guidance.

The CAMEL portal will differ from other sites by emphasizing visual material—photographs, graphics, and videos—integrated into presentations, case studies, and text. The visual material will also be available for download by instructors for use in their presentations. Students and their instructors will be encouraged to submit additional materials to the topic editors for inclusion on the portal. Climate photographers Joshua Wolfe and Gary Braasch, each of whom has newly published books (Schmidt and Wolfe 2009, Braasch 2009) that illustrate phenomena through climate change-related photographs, will assist in including visual images. Also contributing will be Kerry Tremain, editor and acquisitions manager at the University of California Office of the President, who recently received the Society of Professional Journalists' Excellence in Journalism Award and whose writing was selected for the collection of Best American Science and Nature Writing 2009. Letters of support from these contributors are appended.

Content Implementation Strategy

CEDD members will nominate faculty with relevant expertise to serve as topic editors. Arnold Bloom will have primary responsibility for this effort. Serving a role similar to that of a journal editor, he will identify willing and able topic editors, who in turn will solicit contributors and reviewers for materials on subtopics. Neil Leary, a review editor for the IPCC, will serve as a topic editor. Contributors may receive honoraria once their submission is accepted and may be able to cite their accepted submission as a refereed publication through the e-Scholarship publishing program of the California Digital Library.

While the primary audience for the products of this proposal is faculty members at diverse institutions, students will be the ultimate beneficiaries. Students today are conversant with numerous social networking venues and at ease with tools and approaches that make them receptive to problem-based and collaborative learning approaches. Many of them are extremely engaged in the climate issue. This argues strongly for the direct involvement of students in the development of content. Students will be encouraged (1) to submit content to topic editors, (2) to serve as sounding boards regarding the effectiveness of the materials, and (3) to provide a more diverse perspective than that represented by faculty. Involving students in content development not only ensures that the target audience is reached effectively, but also exposes them to the opportunities associated with education in STEM disciplines. Student participants also influence other students through their social networks. These students will include undergraduates and graduate students in fields related to content, faculty development, or creation and maintenance of a community of practice.

2: Climate education faculty development

Goal: To provide guidance, training, and opportunities for collaboration and communication to faculty members who develop materials consistent with the climate literacy framework.

Co-equal to the need to have the most appropriate and up-to-date content is the need to use this material in a fashion consistent with current knowledge associated with the scholarship of teaching and learning. Simply handing curriculum to college faculty does not lead to meaningful or lasting curricular change. Rather, providing college faculty with (1) stimulating professional development experiences and resources, (2) a professional community of like-minded colleagues, and (3) the time and support to adapt or develop teaching and learning activities for specific classes promotes a deep and enduring investment in curriculum development.

Through face-to-face and virtual workshops, selected faculty members will work collaboratively on developing learning experiences for their students that focus on climate change causes, consequences, and solutions. We want to enable faculty members to build competence and confidence in facilitating student learning in problem- or challenge-based learning settings. Furthermore, we want to help faculty see themselves as designers of learning environments rather than just teachers who cover content (Duderstadt, 2007), especially those kinds of learning environments that enable students to work collaboratively to gather and make sense of evidence and to formulate creative solutions.

Under the leadership and coordination of Jean MacGregor and Karl Smith, workshops and follow-up online support will engage participating faculty members in either developing or deepening their understanding of (1) a curriculum design process that asks faculty to articulate what successful learning would like for their students in a particular educational experience, in terms of what specific concepts/content and perspectives students will know and what specific skills they will develop or strengthen (Wiggins and McTighe, 1998; Pellegrino, 2006); (2) strategies for creating problem-based or "challenge-based" learning environments to motivate and facilitate student engagement and exploration (Bransford, Vye, and Bateman, 2004); (3) methods for promoting reflective, constructive, and productive dialogue and team-work among students (Johnson, Johnson and Smith, 2006; Smith et al., 2005; Smith et al., 2009); (4) specific ways to establish and foster both individual and group accountability, including diagnostic assessments of students' background knowledge and conceptual understanding (Pellegrino, 2006), formative and summative feedback to teachers about learning, meaningful assignments, and student self-assessment (Angelo and Cross, 1993).

3: Climate education community building

Goal: To build a self-sustaining community of educators that advances the teaching of climate change causes, consequences, and solutions.

Global climate change, unlike more traditional topics for college coursework, is interdisciplinary and spans theory, research, and applications. Furthermore, it has become recognized as a pressing problem so recently and is developing so rapidly that it does not yet have the attendant textbooks, materials, educational norms, learning outcomes, and other resources essential to effective teaching and learning. Few faculty have the training or experience to address the breadth of this topic. Consequently, faculty need to be supported (in both face-to-face and electronically mediated communities of practice) as they generate, develop, and review teaching and learning materials. This will mean fostering communities that vary in their geography, demography, and academic missions, as well as diverse disciplinary and professional levels within and across those institutions. The interdisciplinarity, complexity, and distributed nature of the problem, make it a perfect candidate to address through distributed intelligence, i.e. social networking (Shirky, 2008). To that end, a key innovation of CAMEL will be to merge experience with face-to-face faculty community building with now well-established social networking via internet resources to provide the foundation for this community.

A major goal of CAMEL will be to understand how best to integrate educational community building and internet-based networking. This will proceed under the direction of Pfirman, in collaboration with Clay Shirky and participants of the content and faculty development components.

Members of CEDD will serve as the first participants in the CAMEL community, but secondly (and more importantly) as conduits to additional community participants. CEDD members represent their institutions' many and diverse environmental programs and multi-disciplinary faculty. Many of the academic units associated with CEDD already have and are continuing to develop climate change courses and programs or teach classes that touch on climate within the context of a course with another focus. These ongoing courses will be used as test beds for the toolbox being created through CAMEL. Pfirman, for example, will oversee implementation of both CAMEL resources and

social networking approaches in a new course entitled “Climate Solutions” offered for the first time in the spring of 2010 through the Earth Institute at Columbia University. Nicky Phear, a consultant, put together the nation’s first cross-campus climate minor at the University of Montana.

Community implementation strategy

Scientific understanding has often proceeded via groups of people working in different disciplines and institutions who share what they know through both informal conversation and formal publication and critique. These groups are known as “communities of practice” (Wenger, 1998) or “invisible colleges” (Shirky, 2008). New, cyber-enabled social tools offer an unprecedented opportunity for community building. However several separate forces will need to be balanced (much of what follows is based on Shirky 2008): First, participants in the community have to be engaged. Any system for collaboration that does not engage its users will simply be inert, no matter what else is right about it. Enough of the individual participants invited into the community have to find that the environment is sufficiently rewarding that they engage with the existing participants and in turn invite others to join. We are confident that such a community exists and is motivated to participate based on feedback through involvement of CEDD members in the Climate Solutions working group and participation in breakout sessions at annual CEDD and NCSE meetings.

The design constraints on the forum for such a community are that it has to have obvious elements that tell new users where the conversation is occurring and that make it easy to participate. Examples of social forums on the Internet that do this well include Flickr.com and HowardForums.com.

Second, the community has to bridge disciplines. Researchers and educators from a variety of disciplines will have to be willing not only to share their perspectives with others, but to learn from the perspectives of others. Examples of social forums on the Internet that do this well include a variety of wikis, as well as interdisciplinary weblogs such as Crooked Timber and Terra Nova. CEDD both represents and has worked to further this sort of discipline bridging; members of CEDD represent the physical and biological sciences, social sciences, engineering and humanities, as well as interdisciplinary scholars.

Third, the community has to balance open conversation, directed work streams, and refereed publications. A successful communicative forum will have to support the creation of shared work efforts, whether these are joint research projects, surveys of existing environmental information, or the creation of novel instructional tools and materials. It will also have to provide a recognized outlet for publishing the results of this work, in order to reach its intended audience and to gather increasing attention in the wider world over time. Examples of successful uses of this pattern include Intellipedia and the Apache Project, which have many discursive elements while being directed towards the creation and improvement of formal work products. Such a forum does not yet exist for the rapidly growing community of climate educators.

Finally, the community has to start small with a dedicated cadre of participants and grow at an appropriate pace in directions consistent with the group’s goals: we plan to start with a few dozen individuals in the first year, and grow from there. Many of the most successful large-scale collaborations on the internet, such as those leading to the creation of Linux or Apache, two large open-source projects, started with a tiny core of participants and grew over time. This is true of most successful communities, and has more to do with the attitudes and actions of the forum's founders than with any particular form of communal organization or hosting. It is easier to create a large, good community by starting with a small, good community and facilitating its growth, rather than starting with a large, mediocre community and trying to improve it.

This set of constraints means that we need to produce a mix of tools for conversation, for collaboration, and for publishing. Open-ended brainstorming will have to be balanced with directed

work products. The approaches that work in the days of an early, small community will have to be modified or replaced as our CAMEL community grows. The design phase for community support tools will involve mixing strategy and planning with learning by trial and error, with the earliest phase involving the creation of a simple set of tools and a group of a few dozen users as a starting place.

Existing Communities

Several existing programs serve as both examples and potential collaborators for the community development. Here, we discuss how CAMEL will learn from and relate to several salient ongoing efforts in both education and climate change solutions. MERLOT.org has been supporting the creation and dissemination of educational materials for over a decade, and has been highly successful in several areas. A major factor in its success has been a core group of funded developers who seed the various topics, a committed group of unsupported contributors (PI Hassenzahl has served in this capacity for MERLOT, as a member since 2004), and an extensive group of users. CAMEL is designed along these lines, and will include opportunities to both build on and contribute to MERLOT. Our work will be informed by the review of MERLOT found in the *Creating and Sustaining Online Professional Learning Communities*, a review edited by members of TERC.

The Teaching, Learning and Technology (TLT) Group is another example, with which CAMEL will work directly, through Steve Ehrmann, Director of the TLT Group's Flashlight Program for the Study and Improvement of Educational Uses and a consultant on this proposal. TLT is a not-for-profit that supports (and is supported by) about 130 colleges and universities. Its mission is to help them take greater educational advantage of existing technology by providing professional development resources, evaluation tools, online workshops, consulting, and other services. TLT collaborates routinely with many other organizations and associations, e.g., Ascilite (Australia), Association of American Colleges and Universities (AAC&U), Association for Institutional Research (AIR), Association of College and Research Libraries (ACRL), EDUCAUSE, HBCU Faculty Development Network, and the Professional and Organizational Development Network (POD). One of TLT's closest and longest lasting collaborations has been with MERLOT.

Another project that we will learn from and seek to engage is Starting Point, led by Cathy Manduca (http://serc.carleton.edu/introgeo/aboutus.html), which focuses on teaching undergraduate entry-level geoscience. As noted on the Starting Point website, its members are "exploring the ability of on-line resources to catalyze improvements in undergraduate teaching. Our goal is to develop a resource that intimately integrates pedagogy with teaching resources and fully supports a virtual community of educators."

Several (interrelated) communities have developed around climate change solutions. This includes the National Teach-In on Climate Change (formerly Focus the Nation), an ongoing effort to hold simultaneous day-long events at campuses and other locations across the US; the first event involved several thousand faculty, students and others at hundreds of institutions across the country (including several represented by the CAMEL leadership team). Powershift is a youth led consortium that has effectively used blogging, Flickr, Twitter YouTube, Faceook and other internet resources to coordinate activities associated with green energy solutions including a 2009 national conference of more than 10,000 students focused on climate change. Currently, 643 American college and universities presidents have made the commitment to integrate global climate change and sustainability into their curriculum (http://www.presidentsclimatecommitment.org/html/commitment.php). The National Teach-In, Powershift, and the College and University Presidents' Climate Commitment demonstrate that faculty and students are eager to participate in climate-related communities. CAMEL will provide a service to and collaborative opportunities for educational interests of the engaged climate solutions community.Finally, CAMEL will link to several NSF-sponsored educational programs. Timothy Weston, who is an evaluator for the CAMEL project was the lead evaluator for the NSF-SENSER

project. In addition to SENSER, CAMEL will share materials through Project Kaleidoscope, in which CEDD has participated for some time, and will explore opportunities to engage with the DLESE initiative.

4. Cyberinfrastucture component

Goal: To evaluate existing infrastructure and develop novel infrastructure designed to best achieve the goals of the content, faculty development, and community components. Barry Benedict (UTEP CyberShARE Center) and Peter Saundry (NCSE EoE) will direct this effort. Each helps lead cyber-enabled communities of scholars and educators. During the first year they will identify needs and opportunities, and during subsequent years they will develop appropriate infrastructure and a plan to sustain cyberinfrastructure that will support innovation and provide a platform for diverse existing climate education projects.

CAMEL will be supported by the resources of a versatile online web "portal system" which will easily allow participants to create websites (portals and subportals) that integrate a variety of social networking tools with each other and with content and to provide participants with sites where they can:

- jointly create, edit, and disseminate content; and
- share best practices, lessons learned, information, news, questions, and additional resources for consideration by others.

Initially this will be a private space that facilitates posting, collaborative development and editing, discussions, vetting for accuracy, and other tasks prior to release to the public domain. Creation, vetting, and sharing of materials is enhanced in an open source environment, where people are encouraged to contribute, but which permits different levels of review prior to release. This selective review capacity differentiates this environment from the standard wiki approach.

Data required for study of the diffusion of these materials, and hence assessment of community formation, will also be accumulated within the cyberinfrastructure. Promotion of practice will be encouraged through not only providing content (text, graphics, presentations, audio, video) but also placing educational materials and case studies with experientially generated suggestions on how to implement them in different educational settings.

The UTEP and NCSE systems each will support the operation of portals at multiple levels around various categories of topics, regions, and specialties and can have open or restricted membership. Thus, an open portal might address adaptation case studies, a subject of likely interest to all participants, while a restricted access portal might be used in the development stage for a regional community. Portals are ideal means for the highly distributed model we propose. They allow the iterative development of background material and curriculum modules with controlled access and full editing capabilities.

NCSE has tested this approach by creating and utilizing such a portal for the development of the project and for this and other proposal writing efforts. The platform service used is part of a Community of Portals and is connected to the Encyclopedia of Earth. It has the prospect of soon being able to directly integrate the content of the Encyclopedia. Thus educational modules will be developed progressively in a refereed wiki environment.

The Cyber-ShARE system at the NSF-funded *Center of Excellence for Sharing Resources for the Advancement of Research and Education* at the University of Texas at El Paso is built on the open-source PLONE software suite. It permits the addition of existing and specially created modules for various tasks.

As part of the current work funded by NASA through the Global Climate Change Education program (Grant 08-GCCE08-0026), these two platforms are being evaluated. A decision will be made on

which platform or combination of platforms best meets the needs of this project before the work described in this proposal is moved to a wider audience. The NASA-funded project will be a first step for a full life-cycle development of the online model we are proposing. Although limited in extent (i.e., a small number of modules for a single course to be offered at partner institutions), the experience will be sufficient to inform us of the needs of the larger project. The NASA grantee network allows provides opportunities for dissemination both within and beyond undergraduate education.

Our group's experience in using portals for this proposal and other applications and with building cyber-enabled communities will allow us to readily establish the online community in the required dimensions. Development of the portal will be facilitated by the project coordinator who will be based at NCSE.

Assessing dissemination through cyberinfrastructure

A major research goal of the cyberinfrastructure component will be to better understand drivers of and obstacles to cyber-enabled dissemination. There is a considerable body of practice in diffusion research, and since this proposal is intended to understand and support innovation and diffusion through substantial communities of practice, protocols will be developed to assess and model innovation and diffusion of these modules and materials. Of special interest is how electronic networking can enhance individual contact. It has been noted that "…open source projects typically have central contributors who act as catalysts and drivers for the community; people who have bought in and stimulate further contribution by example and enticement. In successful open source projects, these people are present from the beginning, typically among those who start the project." (http://organizationsandmarkets.com/2007/01/11/nature-gives-up-on-open-source-peer-review/). The lack of such individuals appears to have been one of the flaws causing *Nature* to abandon its open-source approach to paper evaluation. Successful and unsuccessful practices from open-source initiatives cited elsewhere in this proposal will be studied for application in this proposed work, with an eye to identifying features to be studied.

Seminal work on enhancement and diffusion of innovation by Rogers (2003) is now embedded within a number of efforts to understand the evolution of electronic communities. One key group with close relationship to the Cyber-ShARE Center is the Collaboratory for Research on Electronic Work (CREW) at the University of Michigan, which has, among other areas, studied the communication links within collaboratories, very similar to communities of practice. In an extensive study, Bos et al (2007) identified seven types of collaboratories, several of which (community data systems, virtual communities of practice, and virtual learning communities) are particularly relevant to CAMEL. CREW's research draws on computer, information, cognitive, and social science, and the Cyber-ShARE Center regularly involves CREW faculty.

5. Content, Faculty Development, Community, and Cyberinfrastructure Component Integration

PIs Hassenzahl, Blockstein and a project coordinator hired for this effort will be responsible for ensuring the effective integration of the four main components. This will take place in a variety of online and in-person meetings, between and among the component leads and members. Component leads and members will interact extensively, with the content component describing need for tools for managing, storing, editing, refereeing, and disseminating materials; the faculty development component describing needs for encouraging and ensuring best teaching practice; the community component identifying opportunities and strategies for community building; and the cyberinfrastructure component responding to all three with options, alternatives, and limitations. The interaction between and among component leaders will be frequent, mutual, and recursive, and will take place both formally and informally.

A particular challenge for the development of communities is establishing a point of contact who can be available to provide direction and support, or guidance on where to seek the same. PI Hassenzahl, particularly during year two when he will be in residence at NCSE and can dedicate about 40% time to the CAMEL project, will meet, telephone, email, and otherwise coordinate with individuals who have created or could create appropriate curricular and educational materials, and could serve as reviewers of materials generated by others.

The integration effort will also be responsible for developing and testing the activities generated through CAMEL, using online student feedback instruments such as Flashlight Online and/or the Student Assessment of Learning Gains (SALG). From this, the integration effort will provide feedback to the components, together and separately, providing encouragement, suggestions, and course corrections.

We will also seek to integrate with other climate education projects funded by NSF and other agencies. We will share our work, invite the leaders of these projects to our national meetings, and offer our cyber-infrastructure as a platform for collaboration. To the extent possible we seek to develop a seamless community of climate change educators.

6. Program evaluation component

Anne-Barrie Hunter, Ethnography & Evaluation Research and Tim Weston, Alliance for Technology, Learning and Society at the University of Colorado at Boulder, will serve as internal evaluators on this project. Both Hunter and Weston have substantial experience with evaluating innovative initiatives in STEM education (Hunter, 2006; Thiry, Laursen & Hunter, 2008; Hunter, Laursen and Seymour, 2007, 2008; Weston and Barker, 2002; Weston, 2004, 2005). In addition, an advisory panel of topic and curriculum experts will serve as external evaluators on this project. Panel members will be kept apprised of progress and will assess the effectiveness of curriculum content, pedagogy and resources as project outcomes. Andrew Jorgensen will be the liaison between the leadership team and the evaluation consultants.

The online community and curriculum development activities are coupled to an evaluation-with-research study that will provide formative and summative evaluation for this project and will also enhance general understanding of how to best promote online curriculum development. Evaluation questions of interest to this project include: How effective are project leaders in implementing and carrying out objectives as an online community? How many faculty members did the project recruit? Did the faculty members who were recruited reflect the diverse disciplinary base necessary to the success of this initiative? Do electronic network activities support uptake and dissemination of pedagogical change? Research questions of broad interest to the STEM education community include: What are the processes of a successful online collaboration to develop innovative curricula? To what extent do faculty characteristics explain or predict who will participate in an online community focused on innovative curriculum development? How do electronic networks support uptake and dissemination of curricular change? We propose a mixed-methods study design that draws on qualitative, ethnographic research methods including participant observation and semi-structured in-depth interviews, as well as quantitative methods, including surveys and social mapping strategies. (Spradley, 1979; Cromley, 1999; Trotter, 1999; Tedlock, 2000; Barab and Leuhmann, 2003; Preece, Abras and Maloney-Krichmar, 2004).

The following table summarizes the proposed evaluation components:

Year	Activities
1	Project design; planning phase: • Participant observation for formative and summative evaluation

2	Nationwide online community participation: • Pre-participation surveys for baseline information • Surveys to gather information on basic measures and formative evaluation • Surveys on webinars, interactive meetings and other online activities
3	• Follow-up surveys for summative evaluation • Follow-up interviews for summative evaluation • Analysis and write up of summative evaluation/article preparation

Qualitative data will be coded and analyzed using standard methods to tag specific concepts, sort, categorize, and count them. Qualitative analysis reveals the patterns, range, and relative weighting of participants' observations. Survey methods capture data from large samples or whole populations. As appropriate, quantitative data will be analyzed using SPSS for descriptive statistics and tests of statistical significance, such as t-tests or one-way ANOVAs, for comparing groups. This mixed-methods approach thus allows us to check and validate results among different data sets. Such triangulation of results across data sets strengthens findings about factors that encourage and/or hinder the success of online communities.

Hunter will conduct participant observations and interviews with project leaders and samples of online community participants. She will be responsible for coding, analysis and write up of all qualitative data. Hunter and Weston will collaborate with project leaders to develop online survey instruments. Weston will be responsible for administering the online surveys and analyzing the survey data. Hunter and Weston will cooperate to produce a final report/or journal article, should project results warrant this.

7. Work plan table

This table outlines the anticipated outcomes of each of the components and the integration effort, along with the personnel contributing to each effort.

Content	Bloom (Lead), Braasch, Hassenzahl, McCaffrey, Leary, Pfirman, Phear, Wolfe	
Year One Outcomes	*Year Two Outcomes*	*Year Three Outcomes*
A broadly accepted yet flexible set of topics that constitute "climate, adaptation, and mitigation literacy"	Working framework of curriculum foci related to climate change causes, consequences and solutions	Virtual toolbox for educators: a range of materials from specific lessons or practices to entire curricula, including case studies; presentations; syllabi; teaching tips, sample criteria for certificates, majors, minors; experiential learning projects; links; and graphics
Content resources identified	New content developed; and new and existing content evaluated and improved	New content developed; and new and existing content evaluated and improved
Content producers identified and recruited	New materials solicited, modified, and developed	New materials solicited, modified, and developed
Topic area editors identified	Additional topic editors and content producers identified	Additional topic editors and content producers identified
Highest priority needs identified for added content	Evaluate content need prioritization	Evaluate content need prioritization
Climate solutions courses modeled	Model climate solutions courses improved	Model climate solutions courses improved

Faculty Development	MacGregor (Lead), Ehrmann, Pfirman, Smith	
Year One Outcomes	*Year Two Outcomes*	*Year Three Outcomes*
Initial norms, standards, expectations to ensure that the content is educationally excellent	Application of modified norms, standards, and expectations to ensure content is educationally excellent	Application of modified norms, standards, and expectations to ensure content is educationally excellent
Methods and potential models for connecting content to pedagogy identified	Methods and potential models for connecting content to pedagogy developed and applied.	Methods and potential models for connecting content to pedagogy applied and improved
Plans developed for regional communities of content development and deployment	Develop and begin to practice guidance, training, and opportunities for collaboration and communication	Continue to develop and practice guidance, training, opportunities for collaboration and communication
Exploration of methods to translate experience in face to face faculty development to cyber-enabled formats	Proposals for establishment and deployment of regional communities, training workshops, other means of community-building submitted	Workshops, webinars and other training and community learning opportunities
Community Building	Pfirman (Lead), Benedict, Blockstein, Hassenzahl, Shirky	
Year One Outcomes	*Year Two Outcomes*	*Year Three Outcomes*
Methods to engage community (educators, practitioners, and students) in content development, deployment and evaluation	Engaged community of educators, practitioners, students in content development, deployment and evaluation	Expanded learning community of engaged and networked climate educators
Network of climate education project leaders	Expanded network of climate education project leaders	Operational network
Community practices piloted through NASA grant development		
Cyberinfrastructure	Benedict (Lead), Saundry	
Year One Outcomes	*Year Two Outcomes*	*Year Three Outcomes*
Evaluation of potential platforms including (NCSE Encyclopedia of the Earth and UTEP CyberShARE Center platforms) to store and disseminate content and support community interactions	Operational platform based on modification of prototype platform(s)	Fully operational platform
Prototype platform based on modification of existing cyberinfrastructure platforms	Presentations and publications on dissemination	Publications and presentations on dissemination
Initial dissemination assessment plan		
Integration	Blockstein and Hassenzahl plus component leads	
Year One Outcomes	*Year Two Outcomes*	*Year Three Outcomes*
Strategic plan	Implementation of strategic	Assessment of integration

	plan	through publications
Initial standards for assessing integration	Share progress and solicit participants at appropriate conferences and meetings	Share progress and solicit participants at appropriate conferences and meetings
Share progress and solicit participants at appropriate conferences and meetings	Identified resources for project sustainability	Project sustainability plan
Program evaluation	Hunter (Lead), Jorgensen, MacGregor	
Year One Outcomes	*Year Two Outcomes*	*Year Three Outcomes*
Methodology to evaluate project with respect to deliverables (educationally sound content), community engagement, group process	Preliminary evaluation with respect to deliverables (educationally sound content), community engagement, and group process	Final evaluation with respect to deliverables (educationally sound content), community engagement, and group process
		Present/publish findings in appropriate scholarly venues

8. Broader Impact

The central goal of CAMEL is networking and to produce supporting faculty and student development of curricular content on an issue of critical importance to the world. The American College and University Presidents' Climate Commitment signed by more than 600 presidents includes a commitment to educate students about their role in the climate change issue (ACUPCC 2009). This project will enable this commitment to be met. A wide range of faculty at diverse institutions are represented through the PIs and the initial set of contributors. Ultimately the outcome of the project will be reachable by all institutions.

CAMEL's impact will be broadened by recording, preserving and disseminating results. The primary outputs of this project will be the materials posted online. The cyberinfrastructure component will maintain these materials in a broadly accessible format. All workshop records (agendas, minutes, and meeting products) will be housed within the cyberinfrastructure developed for the project.

The findings of the research components of this project, in particular on the evolution of content, faculty, and community development will be disseminated through standard academic channels, such as theses, conference presentations, and refereed books and articles. The project will also be promoted and reported in relevant newsletters, listservs, blogs, and other relevant venues.

CAMEL PIs will use project infrastructure to support the development of regional collaborations of climate researchers and educators. In turn, contributions from regional networks will enrich the collection, creation, review, and dissemination of the CAMEL toolbox. Climate change has disparate regional impacts, requiring locally-specific adaptation strategies that will be integrated into CAMEL as student learning opportunities through case studies and student networking.

Several strong connections with regional collaborations are well represented by members of the project leadership team:

- For the past four years in Washington State, MacGregor has provided leadership in the Curriculum for the Bioregion initiative (based in the Washington Center for Improving the Quality of Undergraduate Education at The Evergreen State College). This collaboration has built a network of over 700 faculty members at 32 participating campuses engaged in the integration of environmental and sustainability concepts and practices across a broad array of lower-division, general education college classes.

- Benedict has been active in the binational US / Mexico border region, which includes numerous institutions on both sides of the border, with extensive experience in border environmental policy issues. It will be centered at UTEP, which has been part of the Southwest Consortium for Environmental Research and Planning (SCERP) since its inception fifteen years ago.
- Pfirman has provided leadership for several ongoing efforts in the New York/Hudson area: Columbia University's Earth Institute and the Environmental Consortium of Hudson Valley Colleges and Universities, which both shares curricula about the region and runs a faculty development program called River Summer (Pfirman is the PI of that program).
- Hassenzahl is the Education Component Lead for the Nevada System of Higher Education's five-year NSF EPSCoR grant to develop climate change research and education infrastructure. Through this, Nevada is partnering with Idaho and New Mexico NSF EPSCoR project teams in a tri-state consortium that will include climate education development.

We expect to seek separate funding to engage these and other regional communities into this project to develop regionally appropriate and pedagogically sound content using the template we have established.

This project is consistent with and will be integrated with an NSF supported effort to Mobilize STEM Education for a Sustainable Future. MacGregor is a co-PI and Blockstein and Pfirman are advisors on that project.

9. Results from prior NSF support

Barry A. Benedict:

- PI/PD Louisiana NSF EPSCoR Program 1992-1996, Created a network of competitive clusters and successful minority outreach. 1992-6 ~$6,000,000
- Co-PI, MSP Program, UTEP, 2003-2005, Implemented relationships with local high school teachers
- MIE Program, Institutionalized UTEP programs and facilities through the grant, 2003-5

Arnold Bloom

- PI IBN-03-43127 Global change & nitrate assimilation 2004-08 $585,000
- PI IOS-08-18435 Photorespiration & climate change 2008-11 $532,922

Photorespiration in C_3 plants dissipates over 25% of the carbon fixed during photosynthesis and, thus, has been viewed as a wasteful process, a vestige of the high CO_2 atmospheres under which plants evolved. We have discovered that plants require photorespiration to convert nitrate, a major source of nitrogen, into proteins. This provides a new interpretation for plant responses to rising atmospheric CO_2 concentrations as well as a new interpretation for the observed distributions of plant species. Resulting publications include: Bloom *et al.* 2004; Cousins and Bloom 2004; Rachmilevich, Cousins, and Bloom 2004; Bloom 2005; Epstein and Bloom 2005; Goodstal *et al.* 2005; Volder *et al.* 2005; Bloom 2006a, b & c; Bloom, Frensch, and Taylor 2006; Rost and Bloom 2006; Bloom 2009 b, c, & d; Foyer *et al.* 2009; Volder *et al.* 2009.

David Hassenzahl

- CoPI HSD-0527664, Managing Highly Uncertain Risks, 2006-7 $125,000

Grant to develop novel approaches to assess and manage highly uncertain risks. This effort resulted in several publications framing uncertainty as a management concern: Hassenzahl et al 2007, Goble et al 2007, and Hassenzahl 2006a & b.

- Education Component Lead NSF 0814372 Nevada Infrastructure for Climate Change Science, Education, and Outreach 2008 - 13 $15,000,000

This is a Nevada-wide grant to develop climate change infrastructure and education. Hassenzahl has been involved in K-12, Undergraduate and Graduate Education activities, beginning in September 2008. Accomplishments to date include a climate education conference at UNLV, awarding of multiple grants to undergraduates to do STEM and climate change research, awarding of multiple graduate

fellowships in climate change research, development of a program to educate cohorts of middle school teachers in climate science and education (the first cohort convenes July 2009), and establishment of a renewable energy minor for undergraduates.

Jean MacGregor

- Co-PI DUE0732521 Toward a National Endeavor to Marshal Postsecondary STEM Education, Resources to Meet Global Challenges: A Planning Proposal 2007-9 $99,733
- Co-PI DUE 0744106 and DUE 0849925 Engaging Critical Advisors to Formulate a New Framework for Change: Expansion of "Toward a National Endeavor to Marshal Postsecondary STEM Education Resources to Meet Global Challenges". 2007-10 $660,109 and $32,000
- CoPI DUE 0849934, In Support of Mobilizing STEM Education for a Sustainable Future 2008-10 $99,990

Stephanie Pfirman

- CoPI 0723343 Standard Grant, An IPY Symposium: New York and Polar Research - A Partnership Spanning the Centuries 2007-8
- Co PI 0806509 Continuing Grant Collaborative Research, NYC International Polar Weekend 2008-10
  - Over 10,000 visitors have participated in this public outreach program at the American Museum of Natural History in 2007, 2008, and 2009.
  Publication: Pfirman, S., Turrin, M. and MacPhee, R., "New York City International Polar Weekend at the American Museum of Natural History", Eos Trans. AGU, 89(53), Fall Meet. Suppl., Abstract ED32A-07 (2008).

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