HAMPSHIRE COLLEGE CENTER FOR SCIENCE EDUCATION

FINAL REPORT ON ACTIVITIES SUPPORTED BY DEPARTMENT OF ENERGY GRANT NO. DE-FG02-06ER64256 -September 30, 2009

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Introduction

Hampshire College's Center for Science Education (Center) focuses on teacher professional development, curriculum development, and student enrichment programs. The Center also maintains significant research programs on teacher change, student learning and instructional effectiveness. The Center's work is devoted to promoting learning that persists over time and transfers to new situations in and out of school. Our projects develop the implications of the increasing agreement among teachers and researchers that effective learning involves active concept mastery and consistent practice with inquiry and critical thinking.

The primary objective of the Center is to help strengthen the pipeline of U.S. students motivated to pursue postsecondary study in STEM fields. The Center pursues this objective by fostering an educational environment in which science is taught as an active, directly experienced endeavor across the K-16 continuum. Too often, young people are dissuaded from pursuing science because they do not see its relevance, instead experiencing it as dry, rote, technical, and, too often, intimidating. In contrast, when science is taught as a hands-on, inquiry-driven process, students are encouraged to ask questions grounded in their own curiosity and seek experimental solutions accordingly. In this way, they quickly discover both the profound relevance of science to their daily lives and its accessibility to them. Essentially, they learn to think and act like real scientists.

The Center's approach is multi-faceted: it includes direct inquiry-based science instruction to secondary and postsecondary students, educating the next generation of teachers, and providing new educational opportunities for teachers already working in the schools. Funding from the Department of Energy focused on the last population, enabling in-service teachers to explore and experience the pedagogy of inquiry-based science for themselves, and then to take it back to their classrooms and students. The Center has demonstrated that the inquiry-based approach to science learning is compatible with existing state curriculum frameworks and produces students who understand and are positively inclined toward science.

Funds from this Department of Energy grant supported three projects that involved K-16 science outreach:

1. *Teaching Issues and Experiments in Ecology (TIEE).* TIEE a peer-reviewed online journal and curriculum resource for postsecondary science teachers.

2. *The Collaboration for Excellence in Science Education (CESE).* CESE is a partnership with the Amherst, Massachusetts school system to foster the professional development of science teachers, and to perform research on

student learning in the sciences and on teacher change. The project draws on Hampshire's long experience with inquiry-oriented and interdisciplinary education, as well as on its unique strengths in cognitive science. The project is run as design research, working with teachers to improve their practices and studying student and/or teacher outcomes.

3. *Day in the Lab - Hampshire College Science Faculty Outreach*. Grant funds partially supported and contributed decisively to the expansion of the ongoing science outreach activities of the School of Natural Science. These activities are focused on local districts with large minority enrollments, including the Amherst, Holyoke and Springfield Public School Districts, and the Pioneer Valley Performing Arts Charter School.

Each of the three projects supported by the grant met or exceeded its goals. In part, the successes we met were due to continuity and communication among the staff of the programs. At the beginning of the CESE project a science outreach coordinator, Paul Bocko, was recruited. He worked throughout the grant period on CESE outreach efforts along with Laura Wenk, a senior researcher and curriculum director on the project. Additionally, Professor Wenk and an undergraduate student conducted research on teacher change. Mr. Bocko acted as a liaison among Hampshire College, the school districts, and a number of local businesses and agencies, providing organizational support, discussion facilitation, classroom support for teachers, and materials purchase. His presence in the schools kept teachers engaged and supported. He also brought the Pioneer Valley Performing Arts Charter Middle School into the project. Mr. Bocko worked closely with Robin Marion, the educational outreach coordinator at Hampshire who oversaw the *Day in the Lab* program. Together, they have ensured the continuity of support to the schools through the use and placement of student interns. Finally, Professor Wenk and Mr. Bocko worked with the Hitchock Center for the Environment to bring the two science professional development efforts in Amherst together. The joint development of workshops for elementary teachers was extremely successful.

A major reason for the successes of the CESE program was the strength of the teacher outreach team and the sheer number of hours spent building relationships, talking about teaching and learning, planning projects, developing curriculum, and working with experts throughout the Valley. The comparison of accomplishments with initial goals and objectives is broken down below in terms of the three projects that were supported by the grant.

Faculty Testimonials on TIEE

General Comments:

"While other education publications do sometimes include an ecological component, it is rarely in depth and usually more environmental than ecological. TIEE has been of great benefit with its focus, breadth, and depth."

"I have used several and they all work great. It takes me many days to put together similar exercises on my own, so when I find one on TIEE that matches my needs it is a great help."

"TIEE was a great resource for me when I first started teaching at an undergraduate college, and it is a resource I turn to now and then."

Teaching Ecology Comments:

"It's so important to have ideas that are discipline-specific. I know I should incorporate active learning in my classroom, but so many of the models are hard to apply to ecological systems. TIEE has really helped with this."

"This is my first semester teaching Ecology after 25+ years of teaching at the undergraduate level. TIEE is excellent, and I have gained many insights and ideas already from the back issues."

"I have taught ecology labs at the undergraduate level both in a community college setting and at a 4-year liberal arts college, and I have not found any other single resource as valuable as TIEE for sharing ideas."

"Ideas about teaching ecology in a student-centered way, opportunities to publish about teaching ecology, and aspects of lessons that scaffolds learning more difficult concepts and skills are provided in TIEE and not in any other format I know of."

"TIEE provides ideas for how to approach subject matter. There are also ideas on how to structure assignments to teach specific skills (e.g. data interpretation). The quality of the ideas has been great and is easily adaptable to lower level or upper level undergraduate teaching."

Proposed Goals and Outcomes Achieved

Teaching Issues and Experiments in Ecology (TIEE)

TIEE is a peer-reviewed journal designed to improve college ecology teaching and has been published electronically since 2004 with primary support from the National Science Foundation (NSF). The current grant supported the Managing Editor who supervised article submission and review. In 2009, with publication of Vol. 6, the TIEE collection included 19 Experiments and 24 Issues plus 12 research papers published by over 70 authors.

In 2009, TIEE editors requested that the Ecological Society of America (ESA), which presently hosts TIEE on its server, assume full publication of TIEE and an ecology education journal. Although a large percentage of ESA's members are college or university faculty who regularly teach ecology courses, ESA does not publish a journal in which faculty and other ecology educators can publish –and read– the latest teaching ideas and research in the field of ecology education. This is in contrast to almost all U.S. national biological, chemical, geologic, physics, mathematics and other scientific societies. The ESA's Publication Committee fully supported the request that ESA published TIEE; recently, the ESA Governing Board allowed publication of Vol. 7.

Assessment Methodology

To get input from the ESA education community about whether TIEE is a valuable resource for them and why, ESA Education Director Teresa Mourad sent a survey to the education section in September, 2008. Members were given two weeks to reply on "Survey

Faculty Testimonials on TIEE

Compared with Other Sources Comments:

"It is more focused than EcoEd.net."

"While other journals may address these topics from a "science" perspective TIEE is the only journal to address it from an ecological perspective."

"While other publications have articles on teaching techniques and approaches, and may occasionally have ideas for actual in-class activities, the TIEE collection is the only peer-reviewed collection of activities that I know of that connects directly to the concepts and issues that I teach in my ecology classes."

Accessibility Comments:

"It is accessible, and provides a venue for resources that are not easily distributed by other mechanisms. I use it, and I recommend the site to k-12 science teachers with whom I work."

"When I am looking for an active learning exercise to go with an ecology concept that I am teaching, TIEE is the first place I go. To my knowledge, there is no other free (this is important) online (equally important) source for high-quality, peer reviewed teaching tools."

Research Articles and Scholarship Comments:

"The research section is important since education research usually is a small portion of other journals. Instead, TIEE serves as a comprehensive site almost exclusively for publishing and reading peer-reviewed ecology education literature."

"The ASM has seen the significance of education research and has captured a chunk of this publication market. ESA has an interested membership that wants to 1) improve their teaching, 2) assess their teaching, and 3) publish their results. We have seen this in the success of this year's ESA meetings."

Monkey." The survey was also posted on TIEE during this period.

Results and Discussion

Seventy one ecologists responded to the survey. Nearly 90% said they used TIEE. Of the original three sections (Issues, Experiments, and the reference Teaching section) Experiments were used most (by 70%) followed by Issue Figure Sets and Issue Data Sets (both were used by about 60% of respondents) and the Teaching section (about 45%). Thus each component is well used. More than 25% said they had made use of the Research papers; we consider that a good response because this component was only added in Volume 5, published last year. To assess submission potential, we asked if respondents were interested in submitting to TIEE in the future. More than 60% said "Yes" and an additional 37% said "Maybe." This interest in submission plus the great number of ecology talks and posters given at the 2008 ESA meeting indicates that many ESA ecologists are potential authors for TIEE. Finally, to address the issue of whether TIEE performs a service to ESA members not available to them elsewhere, 96% said "Yes."

Written Responses

The survey gave ESA members the opportunity to add comments if they wished, and many did. These responses are separated into several sections: 1) General Comments: members express their enthusiasm and gratitude for TIEE and that they hope it will continue to be published. 2) Teaching Ecology: why TIEE is so valuable for teaching ecology in particular is explained in these quotes. Reasons include the critical importance of student-active examples that

are specifically ecological, value for faculty at small colleges and community colleges, focus on teaching specific skills in ecology (e.g. working with data and figures), depth needed for upper level courses, a range of ecology experiments to choose from, and the free and easy availability of the website. 3) Compared with Other Sources: it is clear from these comments that respondents find an ecology-focused education publication very important, the peer-review aspect is critical, and that there is no other source that provides what TIEE does. 4) Accessibility: while numerous comments mention the value of ready access, the comments here describe the importance of an easily accessed, free, peer-reviewed electronic resource that is useful and that faculty trust. 5) Research Articles and Scholarship: these ecologists describe the critical value to the ecology education community of the scholarship that TIEE supports and fosters. The very high quality of the articles and the importance of an ESA supported venue for scholarship and specifically for research practitioners (faculty who do research on their teaching) is noted.

Conclusion

We believe that this survey provides ample evidence that TIEE is a unique, much valued, and highly respected ecology education publication for ESA members. Some respondents literally beg ESA to continue publishing TIEE. Especially noteworthy is the diverse community that TIEE serves (e.g. community college teachers to professors who work with upper level students; faculty who have labs and others who do not), which was an original goal. TIEE was also designed to foster ecology education scholarship. The peer-review process plus the new research section fulfills this mission.

Primary Staff: Charlene D'Avanzo, Professor of Ecology

Collaboration for Excellence in Science Education (CESE)

In 2002, CESE was created as a vehicle to foster an educational environment in which science is taught as an active, directly experienced endeavor. For the current period, CESE research focused on the Amherst, Massachusetts Regional Public School district (ARPS), with additional efforts at the Pioneer Valley Charter Middle School (PVPA).

We succeeded in establishing a strong and enduring partnership with the Amherst school district, its middle school science faculty, the elementary science coordinator, and approximately one third of the elementary classroom teachers across the district, as well as with middle school teachers at PVPA. CESE efforts resulted in the construction of greenhouses at two middle schools, solar panels and weather station at the Amherst Regional High School, new science curriculum in grades K-8 co-developed by project staff and classroom teachers, two years of workshops on teaching and assessment, and

the development of common laboratory rubrics at ARMS, among other personal goals of many of the teachers involved.

During the grant period 56 teachers in eight schools (five elementary schools, the middle school, and high school in the Amherst Regional Public Schools, plus a local performing arts charter middle school) were exposed to the CESE program and curriculum. We had more than 140 workshop contact hours over two years to teachers with more than 1200 students. In addition to its direct service benefits, CESE is structured to generate research data on the implementation of conceptual or inquiry science in the schools under the constraints of high stakes testing.

Although initially interested in looking at student outcomes, the Amherst teachers were feeling beleaguered by pressure from a parent group and the school committee to challenge students. Rather than see this project as an ideal way to demonstrate the ways that they were challenging students in thinking scientifically, teachers were reluctant to have data collected on student progress. This led to a very interesting line of research on teacher change. During the grant period, a substantial data set on teacher's understanding of inquiry science and their sense of their ability to implement it was generated. A Hampshire College undergraduate worked with Professor Wenk on the first round of research, generating a senior thesis on the study. He and Professor Wenk continued the interview study and will be continuing their collaboration in analyzing and disseminating their findings. CESE also resulted in an ongoing partnership that will continue beyond the grant period, involving Hampshire College faculty and students in the schools.

Detail of Work

We began working with ARMS teachers in the Spring of 2007 and continued through September 2009. We began by developing the idea for inquiry projects solving real problems in the school and community to be implemented beginning in the Fall of 2007. We met 2-3 times each semester to discuss their goals for science teaching, inquiry science, teaching conceptually, mapping ideas, etc. Our discussions would be followed by dinner and less formal work on their teaching.

Much of the project work in the ARMS classrooms has focused on climate change, energy, and food production. Teachers developed inquiry-based projects that aligned with state standards (as articulated in the Massachusetts Curriculm Frameworks). In one example, 8th grade students read and wrote about the role of CO_2 from fuel combustion in global warming, and completed research on the transportation of specific foods to their cafeteria. Each group took one food product, found out where it was grown, processed, packaged, and distributed. They examined student consumption of the food, and investigated alternatives that would result in decreased CO_2 production (from dropping the product to finding local or regional alternatives or concentrated products

that could be prepared at school). In another example, 7th grade students grew salad greens in a cold frame built with funds from the grant. They studied plant growth, measured production, and served the greens at the school.

In addition to the project work, which put teachers in contact with local farmers and farm-to-school experts, we worked with teachers on challenging all students. In so doing, we not only thought about challenging projects, but also about highlighting complex ideas and using a metacognitive approach to support all students as well. We helped teachers teach students to:

1. Describe in words and pictures their own mental models of how/why things work and to use evidence and argument to improve their models.
2. Develop concept maps to understand the relationship among ideas.
3. Develop their own hypotheses for experiments or explanations of everyday events.
4. Write science lab reports that follow the nature of science. (And we worked with teachers on how they might assess their new lab reports).

In the Spring of 2008, we added teachers from the PVPA to our outreach efforts in response to some ideas held by the ARMS teachers. ARMS teachers felt constrained by the breadth of standards in science and feared they could not integrate another project into their curriculum. They also felt their situation was drastically different in this regard than it was for teachers in charter schools, who they saw as more privileged. We made the decision to extend our program with the hopes of eventually bringing teachers and students from very different systems together. The ability to share data students had collected and curriculum ideas teachers had developed might save classroom and preparation time in ways that make the project more appealing to teachers.

In fact, PVPA had the same fears about integrating projects with such a wide curriculum. Their response was to ask us to work with them to articulate their ideas of what is "essential" in their curriculum and to identify important overarching understandings that cut across their curricular goals. Then, we worked with them to develop projects to strengthen their more focused curriculum, and engaged with them on many of the same strategies discussed with ARMS teachers.

In the Fall of 2008, we began working with 6th grade ARPS teachers to better understand the science concepts in their new 6th grade curriculum on Earth, Sun and Moon, to develop hands-on activities, and the pedagogies that would support them in the classroom. We created a series of four workshops to support exploration and curriculum development, and then created kits for their continued use in the classroom.

In the Summer of 2009, we held two 3-day workshops for K-6 teachers in ARPS on inquiry science and integration. In these workshops we modeled:

1. Introducing new units by asking important questions.
2. Describing in words and pictures their own mental models of how/why things work and to use evidence and argument to improve their models.
3. Develop their own hypotheses for experiments or explanations of everyday events.
4. Designing experiments to help answer the questions.
5. Supported teachers in developing curriculum on their own standards that would teach students to engage with these ideas in science.

Assessment

We regularly asked teachers to evaluate sessions so that we could adjust our work with them. The responses were overwhelmingly positively about our work. The ARMS teachers found the regular dinner discussions throughout the school year to be supportive and were appreciative of our focus on their goals. The elementary teachers had positive responses to the school year (6^{th} grade) and summer (K-6) programs. They saw that teaching and learning could be more effective, more lasting, and more personally satisfying. They showed clear ability in developing concept-driven, inquiry-oriented curriculum. Student writing and project work showed an increasing ability to use science concepts in inquiry projects, and virtually all students showed gains on the pre-post content assessment.

Although still in progress, the research on teacher change is beginning to point to some clear misconceptions about what inquiry science is and what it means to teach by inquiry –misconceptions that could be an important factor in teachers' failure to implement inquiry approaches in their classrooms. That is, many teachers see inquiry as motivating, but do not understand it as effecting what students learn or how likely they are to transfer their ideas to new settings. We were not able to collect data on their students to examine the real impact of the inquiry projects on learning science ideas, but there is much support in the literature for improved transfer when students learn in problem-solving situations as compared to traditional lecture settings.

Of course, the lack of understanding about the science of learning is only one of the difficulties in implementing inquiry science projects. Teachers in ARMS perceive real constraints from the breadth of teaching standards and from the MCAS testing. What is interesting is that PVPA teachers have the same constraints and share some of the same misconceptions about what students could gain from doing inquiry, yet they were much more open to doing projects in the classroom.

Primary Staff: Laura Wenk, Senior Researcher and Curriculum Director of the Hampshire College Center for Science Education; Paul Bocko, Science Outreach Coordinator; Robin Marion, Education Outreach Coordinator; and we had help in summer sessions from Ted Watt and Helen Ann Stepton from the Hitchcock Center for the Environment.

Science Faculty Outreach – Day in the Lab

Funds from the current grant enhanced and partially supported the ongoing science outreach activities of the School of Natural Science at Hampshire. The following activities were supported:

Day in the Lab (Fall) and *Girls Day in the Lab* (Spring) each bring approximately 130 middle school students from Western Massachusetts to the Cole Science Center for a day to participate in hands-on laboratories led by Hampshire faculty, staff and students. The lab days are designed by the Center for Science Education, the Women in Science Program, and the School of Natural Science to encourage young women and minority students to think about careers in science. Under supervision by Center faculty and staff, students offer lab experiences to middle-school students, as well as labs and workshops for teachers and parents that introduce inquiry-based teaching models.

Throughout the period of the grant, from 50 to 80 Hampshire students volunteered each semester to help organize the program or to lead hour-long labs on a wide range of topics in physiology, genetics, chemistry, physics, math, engineering, and anthropology. These events are a valuable experience for the college students involved, and over the past two years volunteers' numbers have increased more than 25%. *Day in the Lab* inspires students to further their own explorations in the sciences and science education, and deepening their commitments to community service.

> *NS 288: Inquiry Science Teaching in Secondary Schools* - The course provided support and an academic context for Hampshire's science outreach activities. Students examined and evaluated science curriculum materials designed for inquiry-based teaching. They chose one of three projects – physics, chemistry, or biology– and worked in teams to develop, implement, and improve activities that support both content learning and inquiry. Projects focused on concrete issues of interest to students such as health, food, and assistive design. A major component of the course had students teaching the activities in local urban schools during a three week period. Many reported that the classroom teaching opportunity helped them understand what it takes to teach science through the inquiry method and enabled them to strengthen their confidence and skills in science and teaching generally. Students in the course were also expected to participate in the *Day in the Lab* program described above.

Primary Staff: Nancy Lowry, Professor of Chemistry and Laura Larsen, Science Outreach Coordinator.