

# University Science Students as Facilitators of High School Inquiry-Based Learning

by

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## Introduction

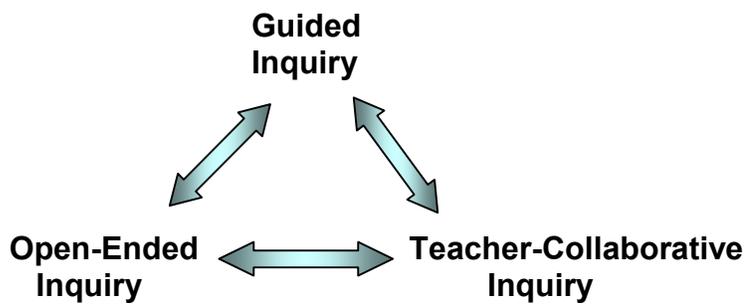
Although engaging K-12 students in original inquiry or research is a cornerstone of current science education reform, efforts to meet this goal face a number of challenges. These include the need to balance content vs. open-ended inquiry while dealing with over-packed curricula and the pressure to prepare students for high stakes exams. Test preparation is an overriding concern of high school science teachers in New York State, where passing a Regents science exam has become a high school graduation requirement (Veronesi and Voorst 2000). For teachers who do find time to include inquiry-based instruction, another challenge is how to find research topics that are appropriate, feasible, and interesting to high school students of widely ranging backgrounds and ability levels. Finally, teachers must grapple with how to balance open-ended inquiry with the need to provide sufficient structure to ensure that the projects will be good learning experiences. All of these challenges can be particularly daunting to teachers who do not have personal experience conducting scientific research.

As defined by the National Science Education Standards, inquiry is both a pedagogical strategy and a learning goal (National Research Council 1996). Students engaged in inquiry-based learning construct their own knowledge by doing: they ask scientifically oriented questions, plan investigations, use appropriate tools and techniques to gather data, formulate explanations from appropriate evidence, evaluate their explanations in light of alternatives, and then communicate and justify their proposed explanations (National Research Council 2000). Although this definition seems quite specific, it embraces a wide range of approaches and has different meanings for different teachers (Keys and Bryan 2000; Llewellyn 2001). The various approaches to inquiry-based teaching can be organized into a continuum that includes three broad categories (D'Avanzo and McNeal 1997):

- guided – the teacher provides the focus questions, then prompts and supervises approaches used by students to address these questions,
- open-ended – the teacher facilitates the process of students choosing their own questions and inquiry approaches, and
- teacher-collaborative – the teacher and students are co-researchers, and together choose questions and strategies to find answers that initially are unknown to all.

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These approaches represent a continuum rather than distinct categories. All three define inquiry in terms of question-driven learning. The distinctions rest on who frames the questions and chooses the appropriate strategies: the teacher, the students, or a collaborative effort in which the teacher and students work together as co-researchers.

Over the past decade, Cornell’s Environmental Inquiry program has been conducting teacher enhancement, instructional materials development, and teacher and student research programs that share the common theme of building partnerships among secondary-level science teachers, university scientists, and science educators to create opportunities for integrating authentic inquiry into classroom science. Through the Cornell Environmental Inquiry Research Partnership (CEIRP), an NSF-funded GK-12 program, we currently are placing graduate and advanced undergraduate science students in local secondary schools as teaching fellows.

The overall goal of CEIRP is for the university fellows to work with middle and high school teachers in guiding student research in environmental sciences. The objectives are for secondary level students to get the opportunity to participate in authentic research, teachers to get assistance in guiding open-ended inquiry-based learning, and the university fellows to gain educational outreach skills and understandings. Currently, CEIRP fellows are working with partner teachers in the following modes:

- Developing and piloting inquiry protocols based on their own scientific expertise,
- Facilitating student research projects using Environmental Inquiry curricula developed at Cornell (e.g. Trautmann, Carlsen et al. 2001; Krasny, Trautmann et al. 2002),
- Adapting traditional lab and field activities to meet curriculum requirements through a more inquiry-based approach, and
- Creating “inquiry moments” in the midst of regular classroom discussions and activities.

CEIRP fellows work with partner teachers to figure out where and how inquiry can best be used to enhance established curricula. In the ideal case, CEIRP fellows facilitate projects that fit the teacher-collaborative model of inquiry teaching, in which the teacher and students work together as co-researchers on genuine research endeavors. The curriculum materials are designed to lead students into research using a stepwise progression, first learning one or

more well-defined research protocols, then using these newly acquired skills to design and conduct open-ended research projects.

### **Objectives**

The overall goal of this study is to determine to what extent and in what ways university science students can enhance inquiry-based teaching in secondary-level science classes. Through CEIRP, university science graduate and advanced undergraduate fellows partner with teachers and help to facilitate student inquiry projects in the environmental sciences. Our objectives are to investigate: 1) ways in which university science students can instill or enhance inquiry-based learning in secondary-level science classes, 2) whether teachers' prior experience with scientific research affects their receptiveness to inquiry-based teaching, and 3) what additional benefits beyond inquiry-based teaching accrue from placing university fellows in secondary level classrooms.

### **Methodology**

This study uses a qualitative approach based on grounded theory, constant comparative analysis, and the case study method (Glaser 1969; Strauss 1987; Patton 1990; Yin 1994). The subjects include 15 teachers who participated in CEIRP in the 2000-2001 school year, 15 more who are participating this year, and the fellows with whom they have worked. Data sources include teacher questionnaires, interviews, and recorded group sessions; classroom observations; a weekly seminar and electronic discussion board for the fellows; and on-going conversations with teachers, fellows, and students.

### **Emerging Findings**

Based on data from the first year and a half of the CEIRP program, we have made the following tentative findings related to the role of fellows and their partner teachers in promoting classroom inquiry.

#### ***1) How can university students instill or enhance inquiry in high school science?***

One of the major challenges we have found in promoting inquiry-based learning is the disparity that exists in conceptions about what inquiry really means. Although we define inquiry broadly as question-driven learning, many of the teachers we have worked with conceptualize it as anything that is hands-on rather than textbook- or lecture-based. Teachers who think that they need to know all the answers are reluctant to encourage open-ended questioning among students. Students, too, may be reluctant to engage in inquiry-based learning because they are accustomed to being told what to do and which answers are correct. Breaking down this sort of conditioning does not occur quickly or easily, and there inevitably are frustrations along the way. However, through working together, CEIRP fellows develop understandings of what types of inquiry will work in particular classes, and their partner teachers gain new perspectives on both content and teaching styles.

Some teachers envision inquiry in terms of "the scientific method," which is seen as a rigid series of steps to be taught rather than an open-ended process of discovery. These teachers tend to be most comfortable with guided inquiry, in which the teacher specifies the question and the research methods that will be used. However, with the guidance of a university fellow, some teachers choose to make the leap to the riskier, less teacher-driven approach of

open-ended student inquiry. In such cases, CEIRP fellows have provided useful guidance to students as they work to frame research questions, form hypotheses, plan experiments, and then analyze and interpret their results. The fellows provide assistance in working with real data, including how to respond to unexpected results, messy data, and uncertain conclusions.

Although we strive to create partnerships that enable open-ended or teacher-collaborative inquiry, time constraints make this an unrealistic goal in many science classes. CEIRP fellows therefore work with their partner teachers to develop and implement a wide variety of both short- and long-term inquiry projects that are designed to meet curricular needs of each class. The classes we have worked with range from basic level to advanced placement. We have found that non-Regents courses provide richer opportunities for extended inquiry but that opportunities exist for infusing inquiry into even the most traditional courses.

In some cases, CEIRP fellows have adapted traditional lab and field activities to meet curriculum requirements through a more inquiry-based approach. This can be as simple as helping students to come up with a research question to add an inquiry focus to an existing project such as water quality monitoring. Or it can mean creating spontaneous “inquiry moments” in the midst of regular classroom discussions and activities. For example, when students are analyzing their water monitoring data, with very little extra time they can be led through a discussion of the potential sources of data variability and bias. Fellows also use informal discussions to get students thinking about questions such as why they are doing this particular activity or how it relates to other topics they have addressed over the course of the year.

Another approach used by CEIRP fellows is to refocus an existing lab so that it approaches a required topic in a way that is more mentally engaging to students. For example, cellular respiration is a fundamental concept in biology, commonly addressed using laboratory exercises related to respiration in whole organisms. This year one of the CEIRP fellows designed two new labs that lead students through investigation of the biochemistry of cellular respiration in muscle tissue, using techniques adapted from those used at the university level (Dearoff 2002). These new labs highlight interconnections between biology, chemistry, and physics and relate these sciences to a topic of interest to students. The students who piloted these new labs were intrigued with the biochemical changes that lead to muscle soreness following intense exercise.

Finally, some fellows have put together lessons specifically addressing various aspects of the nature of science. One of these focuses on the topic of scientific peer review, using as an example the recent controversy about the National Geographic’s publication of an article about a fossil that turned out to be a fake (Gift and Krasny 2002). Another lesson currently under development focuses on precision versus bias in data.

## ***2) Are teachers with a research background more receptive to inquiry?***

We have found that the teachers who are most receptive to open-ended or teacher-collaborative inquiry are those who have had personal experience conducting scientific research (Cunningham 1995; Avery and Carlsen 2001). These teachers may not need help with the research process, but they benefit from exposure to new scientific subject matter and

techniques that university fellows bring to their classrooms. Because teachers don't have time to keep up with current research, it is helpful for them to work with a fellow who can contribute new ideas and approaches.

The teachers for whom the CEIRP program has had the most dramatic pedagogical benefits are those with no previous research experience. For these teachers, the leap to open-ended student inquiry can be intimidating. When CEIRP fellows have led inquiry projects in their classrooms, many of these teachers have reported gaining skills and/or the confidence needed to implement such projects on their own. Several have said that although they had been aware of the value of student research, they would not have taken the initiative to implement it without the guidance of a visiting fellow.

One teacher commented that she previously had been held back in facilitating open-ended student inquiry by her worry that the experiments might fail. Through her experiences in CEIRP, she learned that unexpected results are common in science and can be used productively to make new discoveries rather than viewed as classroom failures. Another teacher told us, "I had downloaded the bioassay curriculum, it looked interesting, and I thought about using it. But then I thought 'If it didn't work, then what?'" When this teacher's classes conducted bioassay experiments under the guidance of a CEIRP fellow, the teacher was able to learn along with the students the ways in which open-ended experiments can get students to wrestle productively with nature of science issues such as data variability, bias, replication, and the need for experimental controls. After working with one or more fellows, all of the participating teachers expressed desire to continue using inquiry-based teaching practices, and some claimed that they had gained the skills and/or confidence needed to implement such practices on their own.

### ***3) What other benefits accrue from placing university fellows in high school classrooms?***

Many teachers have told us that it is useful that fellows bring to the classroom another perspective, an expert opinion, from someone who is not the teacher. They also report that fellows provide a positive role model for their students. Having a female engineer or entomologist working in the classroom sends a powerful message to high school girls about their own potential career options. In some of the rural classrooms in which CEIRP fellows have worked, the fellows have brought multicultural perspectives to students who are not commonly exposed to people with life experiences different from their own.

When the fellows give presentations or engage in conversations about their own research, perhaps more important than the subject matter is the fact that the fellows are communicating their excitement about science. High school students may have a hard time understanding why a fellow is excited about carrying out research on such seemingly esoteric topics as bird droppings or muscle biochemistry, but the excitement is infectious. Participating teachers report that their students relate well to the fellows and get a picture of scientists as real people not too different from themselves. When an undergraduate CEIRP fellow gave a presentation to urban students in New York about his research on Hawaiian volcanoes, one student raised his hand and asked, "Did you always know you wanted to do this kind of work?" This provided the perfect lead-in to a discussion about school and career choices, led by a person who had been a high school student himself only a few years previously.

## Conclusions

Inquiry-based learning takes place in a myriad of ways in high school science classes, and university fellows can help teachers to make the difficult transition to a more inquiry-based or teacher-collaborative teaching style. Infusion of inquiry into traditional classrooms can happen in bold ways, when fellows instigate open-ended research endeavors and help teachers to see the value of granting students the freedom to ask their own questions and wrestle with judgment and decision-making at many steps as they plan and carry out original experiments. It also can happen in much smaller ways such as when fellows lead classroom discussions focused on issues in the nature of science that arise in the course of traditional lab and field activities.

For more information, visit our website: <http://ei.cornell.edu/>.

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