

RUNNING HEAD: MAPPING THE ENVIRONMENT

**Enacting Technology-Supported Inquiry Learning through  
Mapping Our Environment**

Bob Coulter  
Missouri Botanical Garden

and

Joseph L. Polman  
University of Missouri-St. Louis

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Correspondence should be directed to: Bob Coulter, Missouri Botanical  
Garden, Education Division, [bob.coulter@mobot.org](mailto:bob.coulter@mobot.org)

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## **Enacting Technology-Supported Inquiry Learning through Mapping Our Environment**

The Mapping the Environment project at the Missouri Botanical Garden is an attempt to foster inquiry-oriented environmental science teaching and learning integrating geospatial technologies. In this paper, we describe the development and design of the professional development activities in Mapping the Environment over the past six years, and the most recent two years of evaluation describing the impact of a greater curriculum development focus on teaching practice. These findings help explain when and how professional development activities for teachers impact reform toward technology-supported inquiry learning in schools (Bransford, Brown, & Cocking, 2000; Edelson, Gordin, & Pea, 1999; National Research Council, 2000).

### **Project History**

The Education Division of the Missouri Botanical Garden initiated Mapping the Environment in September, 1998. In the past five and a half years, the program has evolved in an effort to be responsive to changing contexts, moving from an initial technology-focused effort to bring geospatial tools to the classroom toward its current work exploring the best ways in which geospatially-enhanced inquiry can best support teaching and learning (cf. Feldman, Konold & Coulter, 2000; Polman, 2000).

Initially, Mapping the Environment was conceived as a means of integrating the use of geospatial tools—specifically, geographic information system (GIS) software and global positioning system (GPS) receivers—into explorations conducted at the Litzsinger Road Ecology Center (LREC), one of the Garden’s field sites. Initial funding for the project was provided by the Litzsinger Road Ecology Foundation, a private foundation that owns this field site. Early in the process, the program director hired to lead the project refocused the initiative to support teacher professional development, rather than just field activities conducted on site. This was done under the assumption that changing participating teachers’ classroom practice would be more likely to have lasting impact than one or two isolated field experiences. With generous corporate support from Environmental Systems Research Institute (ESRI), each participating teacher for the past five years has been provided with a site license for ArcView GIS as part of their participation in the program.

The first year focused on applications of GIS and GPS to enhance water monitoring in the middle school science curriculum. A pilot project (Coulter, 2000) was conducted with two high-ability fifth grade students in the 1998-99 school year, leading to the Garden’s first professional development institute, conducted in July, 1999. This two week institute involved teachers from 6 area middle schools and 1 high school enhancing their content knowledge in regard to aquatic ecology, field monitoring techniques, data collection and analysis, and applications of GIS and GPS technologies. Teachers also became members of the “Stream Team” program, run jointly by the Missouri Department of Conservation and the Missouri Department of Natural Resources. This membership in Stream Team provided a wide range of curriculum materials and water testing equipment for teachers’ use. Follow-up support for what was learned in the institute was provided through

classroom visits by the Mapping the Environment project director and through transportation funding provided for field monitoring expenses.

In summer of 1999 uses of GIS and GPS in education were just emerging, and substantive curriculum materials were generally not available. Isolated lesson plans were available through sources such as ESRI's ArcLessons web site, but substantive, sequenced materials that could be adapted easily to other contexts did not exist. Consequently, teachers and their students had to rely on the ArcView software manual and basic training activities with ArcVoyager, a more limited version of ArcView. Bridging this gap to use of the full ArcView program and data sets for the local watersheds proved to be challenging for most teachers. As a result, all participating teachers engaged in field study, but only one of the 7 teachers was able to implement GIS-enhanced study without the direct assistance of the project coordinator.

Building on this first year, an institute was held in summer 2000 focusing on using GIS to enhance studies of seasonal change. Support from the Missouri Coordinating Board for Higher Education (in the form of Eisenhower professional development funds) enabled the program to expand to 16 teachers from different parts of the state, though the majority were from the St. Louis metropolitan region. In addition to GIS training, teachers engaged with the Journey North project ([www.learner.org/jnorth](http://www.learner.org/jnorth)) and received training and certification in specific aspects of the GLOBE program ([www.globe.gov](http://www.globe.gov)). Based on the experiences in year 1, a good portion of the project year focused on the development of appropriate software tutorials and GIS-based curriculum supplements. Working with the teachers and in some cases directly with their students, an introductory module (*A Quick Guide to Viewing Data*) was developed and field tested, as were specific explorations of the Journey North data. While independent implementation was spotty at best, feedback from the teachers strongly suggested that the curriculum module approach would be integral to successful use of GIS in the classroom. Thus, a strategic decision was made to focus jointly on continuing to provide professional development institutes with follow-up support for area teachers and initiate a sequence of instructional modules that would be made available widely to teachers seeking to use GIS in their classrooms. (These modules are now available online at [www.mobot.org/education/mapping](http://www.mobot.org/education/mapping).)

Subsequent Eisenhower funding in 2001 supported Mapping Natural Disasters, conducted in partnership with Southwest Missouri State University's Department of Geography, Geology, and Planning. This institute focused on mapping major natural hazards such as tornados, hurricanes, earthquakes, and volcanoes. As before, virtually all teachers were able to use the various hands-on curriculum materials in their class during the following year, and independent GIS use was at approximately 50% (Gutierrez, Coulter, and Goodwin, 2002). The final cycle of Eisenhower funding in 2002 supported a pilot initiative with the St. Louis Public Schools involving mapping urban trees using the CITYgreen extension to ArcView, developed by American Forests. While 85% of participating teachers reported using GIS with their students (Coulter, 2003), this number may be artificially high due to the casual nature of the question posed by that project's evaluator.

Over the first four years of the project, it became clear to the project director that there was a shift occurring—likely caused by several factors—away from teachers not being able to use GIS for a lack of materials and not understanding the software operations, and toward a new set of challenges. The materials produced specifically for Mapping the Environment as well as other materials such as *Mapping Our World: Geographic Lessons for Educators* (Malone, Palmer, and Voigt, 2003), and refinements made in supporting teachers' learning of GIS have made the early challenges less of a concern. While many teachers continue to struggle with getting their districts to install the software, the act of teachers learning the software sufficiently to support use, and their actually being comfortable using it in the classroom has proven to be considerably less problematic than it once was.

### **Mapping the Environment –The Next Generation**

In the fall of 2001, the Missouri Botanical Garden secured four years of funding from the Howard Hughes Medical Institute's Precollege Science program to supplement continuing funding from the Litzsinger Road Ecology Foundation. Enabled by this additional funding, the project shifted its emphasis away from a singular focus on GIS toward supporting teachers' curricular thinking, enhanced by applications of GIS and other data tools. Since then, the operational vision has been to work with teachers to create a classroom environment that is compelling and sufficiently data rich that the need for the tools (such as GIS) is obvious. Structurally, the program also coalesced around a model that emerged from the first three years of the program operations:

One-day introductory workshops proved to be successful in helping teachers to experience the power of GIS-enhanced inquiry. As expected, these short sessions only led directly to successful classroom change in a few isolated cases. More often, these workshops led to some teachers choosing to enroll in more substantive offerings. Given the inherent limitations of single day workshops, these sessions are intended primarily to enhance teachers' awareness of geospatial tools and allow them to make an informed choice as to whether to pursue more substantive professional development in the use of GIS in their curriculum.

Week-long institutes with two 2-day follow-up sessions held during the school year, first initiated in 2000, continue to be the major program venue. These institutes focus on a specific content area (e.g. natural disasters, ecoregions, science aspects of the Lewis and Clark Trail) and include classroom and field-based explorations and extensive GIS practice.

Leadership Institutes initiated in the summer of 2002 provide a forum in which teachers with experience using GIS in education can work together to develop new project ideas and learn advanced skills needed to support deeper investigations. Each participant spends a significant portion of the 1-week institute developing an individual project, preparing data to be used, and planning for curriculum implementation. Some graduates of the GIS Leadership Institute also work with the project director in teaching introductory programs for teachers and summer programs for students.

**Data Sources and Methods**

For the past two years (2002-3 and 2003-4), the research on Mapping Our Environment has utilized a combination of observational methods and self-report survey research to document:

- (1) teachers' developing ideas and implementation of inquiry science practices from the National Science Education Standards for Inquiry (National Research Council, 2000), including the extent to which their students engaged research questions, collected data as evidence, formulated explanations, considered alternative explanations, and communicated their results (See Appendix for details of survey question).
- (2) teachers' knowledge of and integration of ArcView GIS software for inquiry, and
- (3) evidence of teachers' understanding of the relevant science content (e.g., relationships between adaptations of plants and animals and biotic and abiotic environmental elements).

Data sources include typewritten fieldnotes recorded by Polman during summer workshop sessions and schoolyear followup sessions, curriculum plans developed by teachers, and electronic survey responses from participating teachers. These data are being used to develop profiles of change and implementation of inquiry science utilizing GIS technology.

**2002-2003 Results: Impact of Curriculum Planning and Context on Implementation**

Findings from the participants in Summer 2002 indicated that all teachers exhibited a fundamental grasp of the science content, and most increased their confidence in using GIS as a personal inquiry tool and in their ability to guide students' use of GIS. But change in the classroom during the 2002-2003 encountered some difficulties, as expected. All teachers reported some impact of the professional development on their practice, but there were notable differences in the Leadership institute participants and the standard week-long institute (the theme of which for 2002 was Ecoregions).

Among the 8 participants in the 2002 Leadership Institute, *all* implemented some GIS inquiry during the school year. These implementations varied from a GIS curricular unit provided in a publication distributed at the summer workshop, to use of curriculum modules on storms developed by the Garden, to custom implementations such as an island study with data and maps gathered during the summer workshop and local environmental impact statements utilizing maps and showing data collected by students. Impressively, teachers' expectations for their students carrying out various scientific inquiry practices, as indicated by our survey items (see Appendix) based on the National Science Education Standards (National Research Council, 2000), showed gains from one school year to the next. Specifically, average gains were seen in all of the measures of students' levels of participation in inquiry practices. On a scale where 2 indicated "by the end of the year, students are *given general guidelines or sources* on how to carry out this aspect of inquiry", 3 indicated "by the end of the year, students are *coached* by their teacher in carrying out this aspect of inquiry", and 4 indicated "by the end of the year, students *independently* carry out this aspect of inquiry," the changes were as follows:

- formulating research questions - went from a mean of 2.8 to a mean of 3.4
- collected data as evidence - went from a mean of 2.6 to a mean of 3.0

- formulated explanations - went from a mean of 2.6 to a mean of 3.2
- considered alternative explanations - went from a mean of 2.6 to a mean of 3.0
- communicated their results - went from a mean of 2.8 to a mean of 3.2

We also saw some impact the 2002 summer institute focused on Ecoregions had on teaching practices, but it was more limited. Among the 14 participants in the 2002 Ecoregions summer institute for whom data is available, 11 implemented some new inquiry in their classroom related to ecoregions, including 6 which integrated GIS software, and 5 which did not integrate GIS. On our survey items relating to scientific inquiry practices, the ratings of the Ecoregions teachers actually decreased from 2001-2 to 2003-4. The differences between the student science inquiry practice ratings of Leadership institute teachers and Ecoregions institute teachers is shown in Figures 1 & 2.

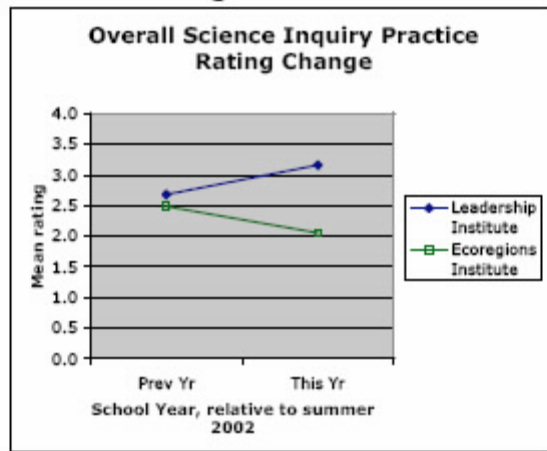


Figure 1: Overall change in student inquiry practices from 2001-02 to 2002-03, as reported by teachers in Summer 2002 workshops

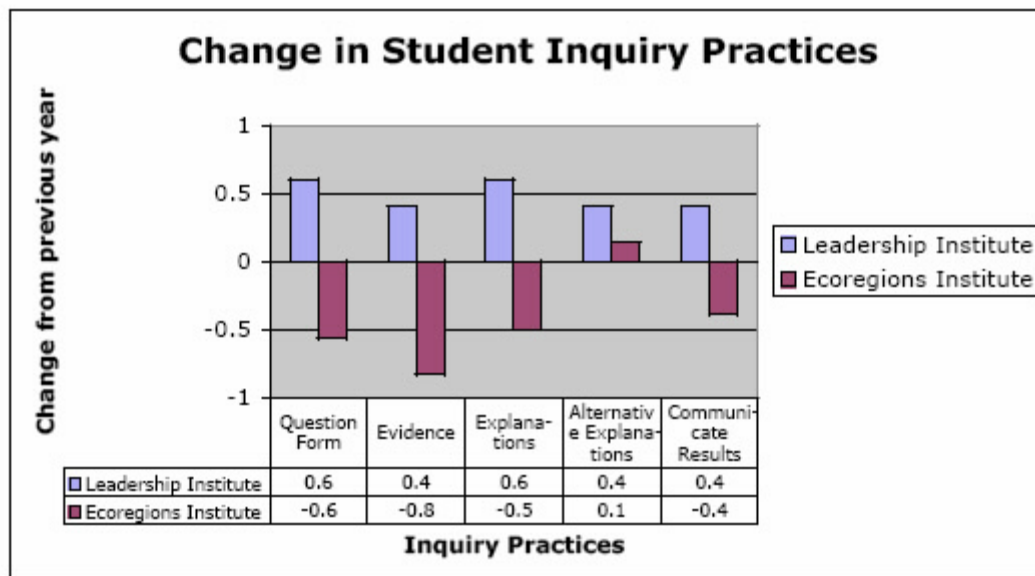


Figure 2: Change in specific student inquiry practices from 2001-02 to 2002-03

### Lessons Learned

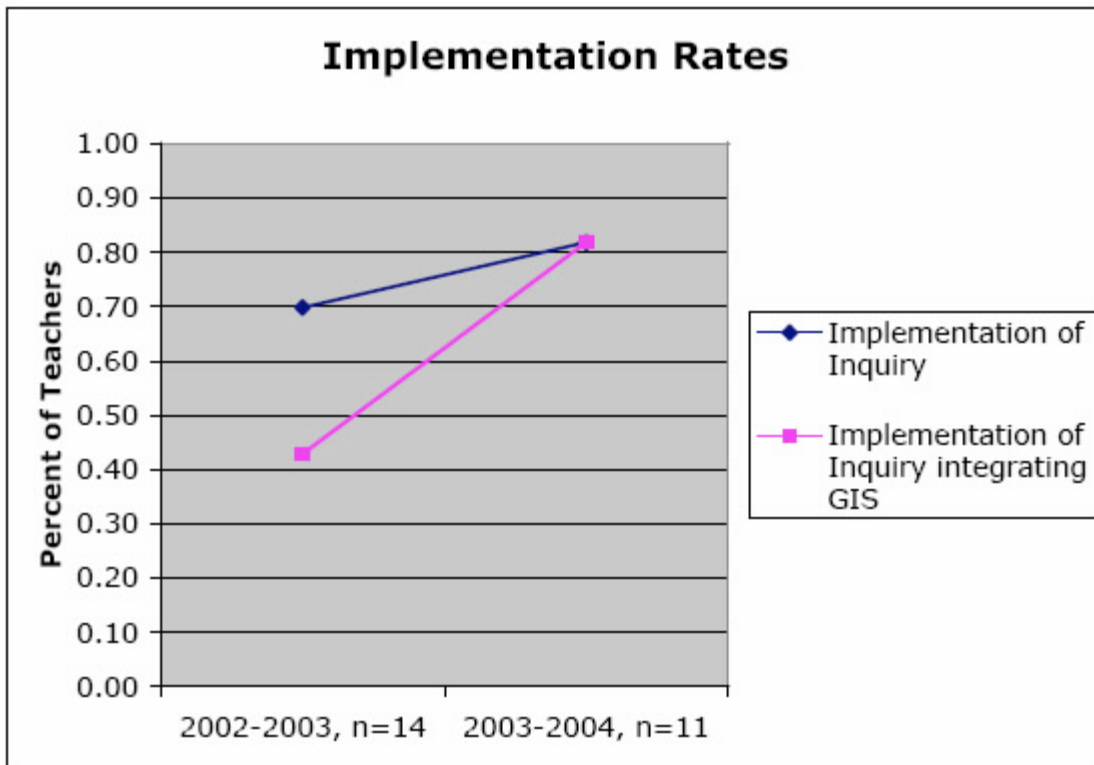
The GIS Leadership participants came into their summer workshop familiar with GIS software, and previously had overcome infrastructure barriers to implementing GIS in their schools. Thus, it was not surprising to find high degrees of sophisticated implementation. The institute during the summer of 2002 focused on learning advanced features of GIS and preparing curriculum materials; the latter proved particularly useful in advancing teachers' levels of sophistication in their implementation of science inquiry. On the other hand, the Mapping Ecoregions institute in the summer of 2002 did not have as much focus on preparing to implement a custom curricular module utilizing inquiry. The teachers worked on a wide smorgasbord of skills, science topics, and activities. At the end of the institute, they had only vague ideas for implementation, and few made significant changes in teaching as shown by survey results. To some degree, this is inevitable, since research on educational reform shows that change usually takes years (e.g., Fullan & Miles, 1992); the Leadership teachers are one or more years into a process of change toward GIS and inquiry implementation, whereas many of the teachers in the other institute were just beginning. Nonetheless, the differences between the two summer institutes, and their outcomes, suggested the importance of teachers preparing curricular resources and plans for specific units which they commit to implementing. In the spirit of design-based research (Brown, 1992; Collins, 1992; The Design-Based Research Collective, 2003), the curriculum development and strategic planning aspect of the workshops was therefore enhanced for the Summer 2003 workshops.

### **2003-2004 Results: Improvements in Integration and Overcoming Contextual Hindrances**

To better support the initiative toward strategic curriculum planning, all teachers in the major 2003 institutes (GIS Leadership Institute and the Science of the Lewis and Clark Trail institute) were introduced to the Understanding by Design model (Wiggins and McTighe, 1998) of "backwards design" for curriculum based on learning goals. After practicing with hypothetical examples, each teacher or team of teachers from the same school were expected to develop a fully articulated plan in the UBD framework, using the UBD Exchange ([www.ubdexchange.org](http://www.ubdexchange.org)). This plan included the overarching understandings the students were expected to develop, the evidence that would be accepted by the teachers that the understandings had been achieved, and the rubric criteria by which the work would be assessed. Following this articulation, specific activity planning commenced.

At the end of the Summer 2003 institute focused on the Science of Lewis and Clark, there was some indication that this changed model had had some impact on the 15 participants. When asked at the end of the institute what they learned and will use in the upcoming year, five teachers noted the curriculum development process utilizing the Understanding by Design framework as a strength of the institute, with a couple noting its relevance beyond the particular content and GIS tools. 13 participating teachers drafted a complete unit plan posted on the Understanding by Design website, incorporating GIS inquiry and resources from the workshop in their curriculum for the upcoming academic year. The other 2 teachers drafted a partial unit plan. These unit plans used resources that they had begun to gather during the course of the week, and most expressed their appreciation for the opportunity to do such curriculum preparation in a supportive atmosphere.

Preliminary results from the 2003-4 school year are also promising. Eleven of the fifteen teachers who participated in the Science of Lewis and Clark institute responded to a midyear survey on their progress so far this year. 5 of 11 had already implemented the curriculum plans they had mapped out during the summer, and 9 of the 11 said they will have completed the unit by the end of the year (i.e., 4 who had not yet implemented their plans had them on the schedule in the spring semester, and only two had had to abandon their plans due to curriculum constraints). In comparison to the 2002-3 participants, the percentage of 2003-4 participants who implemented some form of inquiry related to the Institute increased, as did the percentage of participants who implemented inquiry that integrated GIS technology in the process (see Figure 3).



**Figure 3: Implementation rates for inquiry in any form, and inquiry integrating GIS, by year**

It is notable that 7 of the 11 teachers in 2003-4 still encountered difficulties in installing the ArcView GIS software or accessing it successfully on student workstations; nonetheless, all but one of them had overcome these problems by three quarters of the way through the year, such that they could implement inquiry projects integrating GIS. In 2002-3, 4 of the 5 teachers who encountered technology installation or access problems were unable to overcome them by the end of the year, and consequently did not integrate GIS. We surmise that technology support, or teacher ability to improvise with technology, or both, have led to greater success at overcoming technical obstacles.

## Conclusions/ Future Research Directions

Based on the research conducted to date, there appears to be a definable academic benefit to implementation-focused curriculum planning as a means of supporting technology-enhanced inquiry. As seen in the previous two years' GIS Leadership Institutes and in the current year's Science of the Lewis and Clark Trail program, teachers who engaged in more focused planning created experiences that led to higher levels of student inquiry. Conversely, the Mapping Ecoregions program did not have this focus. Instead, the more general "activity exposure" approach that characterized that institute led to more confused implementation and (potentially) less of a commitment to overcoming the inevitable technology hurdles. The buffet approach did not cohere into targeted programs.

It is significant to note in this context that virtually all of the individual workshop activities within the Mapping Ecoregions program were inquiry-focused; the operative variable appears to be the extent to which teachers were supported in their efforts to translate workshop learning into professional practice. Specifically, the Understanding by Design framework appears to be a productive planning tool, based both on teacher feedback and documented implementation.

Building on this work, additional research is needed to construct a better understanding of teachers' growth paths in supporting geospatially-enhanced inquiry. The spectrum from the introductory workshops through the more content-focused programs and culminating in the GIS Leadership Institute creates something of a continuum. For geospatial tools to become well-integrated into professional practice, it is essential that the path from induction to advanced practice be well understood. We expect that our work with a growing number of teachers who have followed the length of that path will lead to illuminating case studies.

Equally important, the specific contributions of the geospatial tools to student learning need to be better understood. While the implementation rates suggest that teachers find academic value in using GIS with their students, documenting learning outcomes is imperative in light of school accountability requirements. We hope that our work and that pursued by others will contribute to a better understanding of the role these tools should play in students' learning.

## References

- Bransford, J. D., Brown, A. L., and Cocking, R. R. (2000). *How people learn : Brain, mind, experience, and school*. Washington, DC: National Academy Press.
- Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, 2,141–178.
- Collins, A. (1992). Toward a design science of education. In E. Scanlon & T. O'Shea (Eds.), *New directions in educational technology*. New York: Springer-Verlag.
- Coulter, B. (2000). Investigating an urban watershed: How healthy is Deer Creek?. In R. Audet and G. Ludwig, eds. *GIS in schools*. Redlands, CA: ESRI Press.

- Coulter, B. (2003). Mapping neighborhood trees to enhance math and science skills. Paper presented at the American Forests Urban Forestry Conference, September, 2003.
- Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5-8.
- Edelson, D. C., Gordin, D. N., and Pea, R. D. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *Journal of the Learning Sciences*, 8(3/4), 391-450.
- Feldman, A., Konold, C., and Coulter, B. (2000). *Network science: A decade later*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Fullan, M. G., and Miles, M. B. (1992). Getting reform right: What works and what doesn't. *Phi Delta Kappan* (June), 745-752.
- Gutierrez, M., Coulter, B., and Goodwin, D. (2002). Natural disasters workshop integrating hands-on activities, Internet-based data, and GIS. *Journal of Geoscience Education*, 50, 4.
- Malone, L., Palmer, A. M., and Voigt, C. L. (2003). *Mapping our world: GIS lessons for educators*. ESRI Press.
- National Research Council (2000). *Inquiry and the National Science Education Standards*. Washington, DC: National Academy Press.
- Polman, J. L. (2000). *Designing project-based science: Connecting learners through guided inquiry*. New York: Teachers College Press.
- Wiggins, G. and McTighe, J. (1998). *Understanding by design*. Alexandria, VA, Association for Supervision and Curriculum Development.

**Appendix – Student Inquiry Practices Survey Items**

If you teach science or social science subjects, please describe your **students' involvement** in the following aspects of science **inquiry** in the past year, using the following rating scale:

- 0 = not a priority in my class; students have never carried out this aspect of inquiry
- 1 = throughout the year, students are given explicit directions or procedures by their teacher, materials, or other sources in order to carry out this aspect of inquiry
- 2 = by the end of the year, students are given general guidelines or sources on how to carry out this aspect of inquiry
- 3 = by the end of the year, students are coached by their teacher in carrying out this aspect of inquiry
- 4 = by the end of the year, students independently carry out this aspect of inquiry

- a. \_\_\_\_\_ Students are engaged by scientifically oriented **questions** which they seek to answer
- b. \_\_\_\_\_ Students give priority to and collect data as **evidence**, which allows them to develop and evaluate explanations that address scientifically oriented questions
- c. \_\_\_\_\_ Students formulate **explanations** from evidence to address scientifically oriented questions
- d. \_\_\_\_\_ Students evaluate their explanations in light of **alternative explanations**, particularly those reflecting scientific understanding
- e. \_\_\_\_\_ Students **communicate** (in writing and/or presentation) their proposed explanations/results/conclusions.