Use of Scientific Fieldwork in Designing High Quality Professional Development Programs

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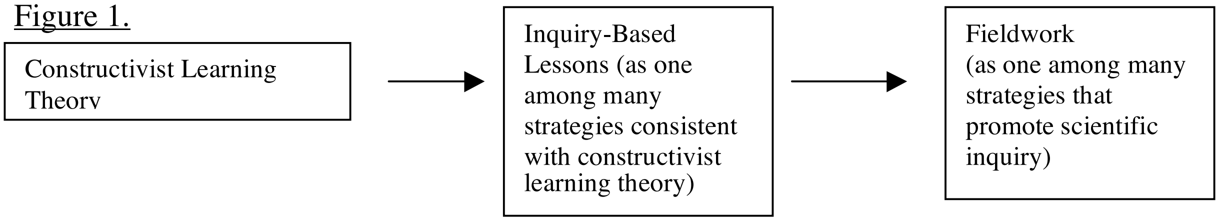
A major component of building high quality professional development programs for science teachers, as defined by NCBL, involves increased attention towards content knowledge. Most program designers recognize, however, that meeting the ultimate goal of increasing student achievement by improving teacher effectiveness involves more than just enhancing teacher content knowledge. As such, appropriate professional development requires program leaders to also facilitate the construction of pedagogical knowledge. By providing learning environments in which effective, research-based pedagogy is taught in the context of science content, it is possible to enhance both types of knowledge (content and pedagogy) while constructing a third – pedagogical content knowledge (PCK) (Shulman, 1986). This third type of knowledge is unique to informed and effective science teachers because it constitutes a holistic and integrated understanding of the most effective way(s) to teach a given scientific concept in particular contexts. It is logical then to assert that the construction and use of PCK is foundational in the development of teacher professionals who are equipped to teach science in general and specific science disciplines. Consequently, many professional development leaders view fostering the conception and growth of PCK as a goal of their programs. Earth-View, an NSF funded three-year project (ESI-9911850) designed to provide North Carolina schools with expert earth/environmental science teachers provides us a model. The primary vehicle for the delivery of instruction centered on the use of inquiry-based scientific fieldwork as a means of constructing content, pedagogical, and pedagogical content knowledge.

Field Work as a Model of Instruction

In accordance with the National Science Education Standards (NRC, 1996) and other reform documents (NRC, 2000; AAAS, 1993, 1997, 1998, 2000), the model for instruction in Earth-View (both for professional development and for student learning) was based on constructivist learning theory and teaching strategies consistent with constructivism. Project leaders chose to design the program for teachers with an emphasis on inquiry activities as a model for what the teachers might then develop for their students, using scientific fieldwork as a core strategy for gathering, analyzing, and interpreting data. Scientific fieldwork in this context is defined as activities performed out of doors that include data gathering and some type of processing of the data to make meaning. The connections among the learning theory and teaching strategies are summarized in figure 1.

Figure 1.



The choice of scientific fieldwork as the core instructional strategy rested on several assumptions:

(1) Textbook science often over-generalizes scientific knowledge and ignores the means by which scientific knowledge is generated; field observations and data gathering give teachers (and students) a more realistic picture of the complexities and uncertainties involved in producing valid scientific information. With a focus on the nature of science, the experience also illustrates the tentativeness of scientific knowledge, the relationship of scientific knowledge to pre-existing theories, and the collaborative nature of scientific discovery.
(2) Fieldwork is highly motivating for several reasons. By working on team assignments, groups of teachers (or students) share tasks and ideas. Working outdoors provides a natural laboratory with infinite variables and interesting challenges.
(3) When focused on data gathering tasks, field work is, by nature, student-centered. Although the instructor facilities the activities, the participants have a great deal of power to make choices of their own and to follow unanticipated avenues of exploration.
(4) The data that is collected during field explorations provides a real world basis for making meaning out of science.
(5) On many occasions field observations result in discrepancies when compared with textbook information, serving as a basis for discussion and providing a glimpse into how science really works.
(6) In summary, fieldwork offers opportunities for participants to take on the roles of scientists and to generate new knowledge (at least new to themselves) in the same way that scientists do.

Methods

A variety of methods were used to collect data, including pre/post tests, a questionnaire, videotaped presentations by teachers, interviews, and classroom observations. Results from the pre/post tests and questionnaire are included in this paper.

Pre/Post Tests. Leaders in the Earth-View project anticipated that the teachers would develop new understandings about earth/environmental science from their experiences in the field, but that those understandings would not necessarily be small items of fact. For that reason, a pre/post test was developed with open-ended items to allow for a broad expression of knowledge. A rubric was used to score each item.

Questionnaire. A questionnaire administered at the end of year I included items that inquired about the teachers' choices of instruction, specifically any use of field exercises with their students. The effect of the teacher's experiences on their choices of instruction provided insight into their pedagogical content knowledge—that is the translation of their content knowledge into teaching behaviors. Project leaders collected qualitative data on the teachers' use of field activities with their students and reasons for their choices. Since the teachers' field experiences were held on the Outer Banks of North Carolina, exact replication of the studies was not expected.

Results

Researchers administered the pre test at the beginning of the program and the post test and questionnaire at the end of the first year. The data suggest the use of inquiry-based scientific fieldwork impacted teacher knowledge constructions. Gains were observed in teacher content knowledge and self-reported teacher practice mirrored program pedagogy. Data were analyzed quantitatively and qualitatively and assertions were made.

Pre/Post Tests

Results of the pre/post tests are shown in Table 1 below. In general the statistical analysis shows that there was a significant difference in the scores on the pre-test and the post-test. The rubric used to score each response included a recognition of examples used to support and clarify the response. Since the teachers collected and analyzed evidence in the field, it is not unexpected to see a difference in their ability to cite examples. That is, in fact, one of the advantages of fieldwork as a means of gaining scientific understanding.

Table 1. Differences in Pre/Post Test Scores

n	Pre-Test M	Post-Test M	Std. Dev, of Pre-Tests	Std. Dev. of Post-Tests	Std. Dev. of Differences	t value	p
16	7.8	13.3	3.5	2.0	4.2	5.24	>.0001

To illustrate how the responses were scored, note the following example:

Question: *Discuss adaptations in the organisms you might find on sound side and ocean side. (Part A-Plants)*

Response that received a score of 1: *Ocean side-more blade like leaves*

Response that received a score of 4: *Ocean side-very limited plant life on shore due to harsh conditions. Small sea oats on dunes (normally human planted). Sound side-no large plants; junkus grass, spartina, have adaptations to salt. Plant must adapt to salt/brackish/fresh water changes with storms. Salicornia-special cells to hold salt.*

Questionnaire

A summary of responses to Item 2 of the questionnaire is shown in Table 2 below. The responses indicate that 17 of the 23 teachers who completed the questionnaire used field activities with their students—either on or near their schoolyards or during off-campus trips. Seven of the types of field trips (of the 13 documented) were translations of field assignments teachers were given during the Earth-View summer project, an observation that confirms long-held notion of professional developers in science that teachers are more likely to implement activities that they actually experience themselves. Such translations also serve an evidence of PCK construction, because teachers used newly formed content and pedagogical knowledge in the development of lessons for use in their particular contexts. Additionally, in some of the field activities, group assignments meant that only one or two people per group collected a certain type of data; in other assignments, every person collected the data. Analysis of the activities teachers used with their students showed that they were far more likely to implement those assignments that every teacher actually completed individually during the summer program. A surprising result was that four teachers actually took field trips to the coast to allow their students to replicate data gathering tasks used in the summer program.

Table 2. Summary of Responses to Questionnaire Item 2

Item: Describe examples of ways in which you have implemented Earth-View ideas/activities with your classes (if you have).			
School Yard Exercises		Off-Campus Field Trips	
Types of Activities Documented	Number of Teachers	Types of Activities Documented	Number of Teachers
Measure of erosional forces	1	Fossil field trip to Virginia	1
*Topographic map development	5	Field trip to New Zealand	1
Field activities (unspecified)	1	*Coastal field trip	4
*Water sampling	2	Stream sediment load	1
*Orienteering activities	2	*Changes due to erosion	1
*Survey techniques	1		
*Documentation of observations	1		
Soil profile	1		

*Activities that closely replicate techniques used in the Earth-View field course

Implications

The major implications lie in the effects of scientific fieldwork on the development of knowledge and skills in teachers and in the changes in their teaching behaviors. Without reference to data sources not mentioned in this paper, it seems apparent that the field experience produced a noticeable increase in knowledge about the coastal environment and human impacts. Responses on the post-test were, in general, much richer than those on the pre-test, especially with regard to supporting evidence (examples).

Implications for teaching are particularly important since the point of professional development for teachers is primarily to improve their ability to affect student learning. The limited information found in the questionnaire shows that 74% of the teachers used fieldwork as a choice of instructional strategy on at least one occasion—and that they most often chose activities with which they had had direct experience.

Lessons suggested by the data include the following:

1. Most apparent is confirmation that field-based scientific studies are effective in promoting conceptual understandings in science. It works for scientists. It works for teachers. Obviously, it should work for students.
2. In order to encourage teachers to use scientific fieldwork with their students, professional developers must provide those experiences for teachers. The knowledge and skills needed to perform meaningful work in the field is not necessarily something that teachers possess from their traditional pre-service and in-service education.
3. In order to increase the chances that teachers will actually translate field activities to their teaching, teacher programs should provide each person with hands-on experience. Observing as a team member does not seem to provide the same motivation.

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