

Field Studies as a Pedagogical Approach to Inquiry

Daniel P. Shepardson, Purdue University

Theodore J. Leuenberger, Benton Central Jr.-Sr. High School, Oxford, Indiana



Field studies are a valuable way to engage students in scientific inquiry. They involve students in planning and conducting their own environmental investigations, allowing them to control their own learning experiences. Pedagogically, this process allows students to generate their own questions, create their own procedures for collecting evidence, and use data as the basis for their explanations. By designing and conducting their own field studies, students learn science in a meaningful context, apply scientific knowledge to local environmental issues, use resources within and around the school, and link classroom science to real-world issues (see Stapp, Wols, and Staukoub 1996, an excellent resource for teachers on planning and integrating field studies and community-based problem solving into the science curriculum). Students who are uninterested in school science because it is not useful or relevant to the real world can be drawn in and engaged, according to Howe (1991).

The first step in an environmental field study should be for students to conduct an environmental site survey. Students start by collecting background information about the local environment to develop an understanding of the conditions and context of the field study site. This step focuses their attention

on the issues and conditions at the site itself. The outcome is a field study well-suited to the site and of local significance.

The TerraServer website (<http://terraserver.microsoft.com>) or a similar site (e.g., Google Earth, <http://earth.google.com>) can be used to display aerial photographs and topographic maps of the site, providing an overview of the land use patterns and landforms. Review of aerial photographs provides insight and clues to environmental problems to be investigated, familiarizes students with the environment, and may define the physical boundaries for the field study. This analysis also provides insight into where monitoring or data collection sites might be established.

The second step is to conduct an on-site survey. The on-site survey is a visual assessment of the environment, providing a closer look at the environmental conditions and potential environmental impacts within the site.

As students collect their field data, they organize and analyze these data, drawing interpretations about the patterns they observe. The field work gives meaning to *doing* science, as well as to the science concepts used to make sense of the world. As the students begin to interpret and analyze their results, scientific resources are used to assist in constructing explanations of the data. To complete the field study, students prepare an authentic product that summarizes the context of their work, goals, hypotheses, procedures, data, and interpretations and explanations. Thus, through field studies, students experience science teaching that promotes inquiry.

Classroom Example: Field Study in a Stream Environment

The following example from Ted's seventh-grade general science course illustrates field studies as an effective, inquiry-based pedagogical technique and culminates with students conducting their own field investigation. The example is designed to follow the integrated Indiana Science Standards.

Ted's class was composed of Caucasian (95%) and Hispanic (5%) students; 48% were girls and 52% were boys. The students came from a wide variety of social and economic backgrounds. The school district draws from a large rural area of mostly agricultural land. Most of the population is employed in nearby Lafayette, Indiana, the site of several industries as well as Purdue University. The science classroom was well equipped with the materials and supplies necessary to conduct inquiry activities. During the activities described

here, Ted used several visuals with the students, including posters on water quality, stream ecology, and land use.

First, Ted introduced students to water monitoring techniques, including the physical, biological, and chemical properties of stream environments. Students then learned about water quality issues using an interactive CD, which defined the different water quality parameters and prepared students in the water testing procedures used in the Green Kit (an inexpensive stream monitoring kit available from a number of educational suppliers).

Next, students engaged in a watershed simulation to practice using the testing equipment and to learn how environmental factors and land use practices might affect stream environments. During the simulation, students conducted the water quality tests at four different locations within a hypothetical watershed. Students used the results of the tests to explain how land use practices in the watershed affected the stream environment.

The watershed simulation prepared students to test for nitrates, phosphates, dissolved oxygen, pH, turbidity, temperature, and *E. coli*. Macroinvertebrates were also introduced as biological indicators. Macroinvertebrates are large (macro) organisms that lack a backbone (invertebrate) and may be seen with the naked eye. Students viewed macroinvertebrate cards for each site and identified the type and number of each macroinvertebrate at that site. Based on this biological data students drew conclusions about water quality at each site. Ted showed the students preserved macroinvertebrate samples to help them recognize the macroinvertebrates they might observe during their stream investigations. These experiences provided students with the foundation for building a conceptual model of stream environments (Figure 5.1).

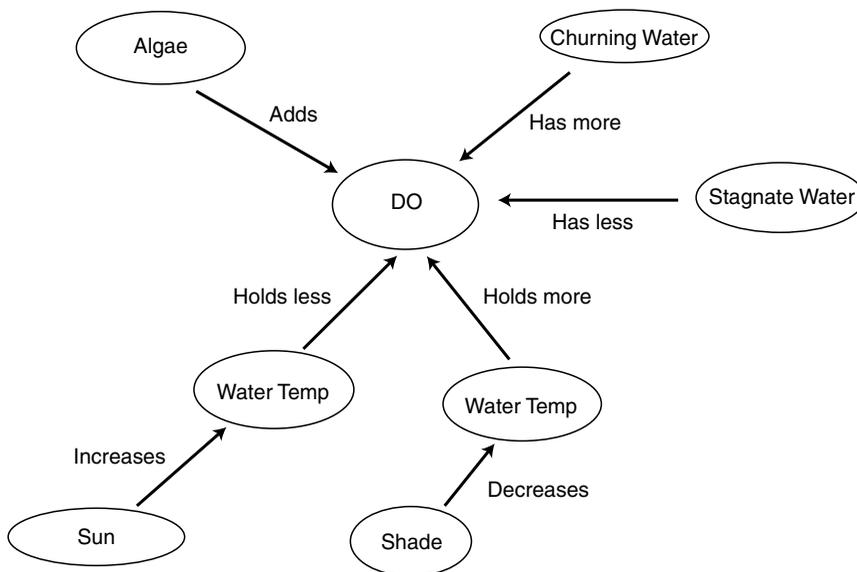
After reviewing the testing techniques and possible environmental factors and land use practices that might affect stream environments, Ted presented students with a site survey of the field study area. An on-site survey would be best, but due to time and transportation limitations, in this case an in-class survey was conducted. Ted showed students an aerial photograph and topographic map of the field study area obtained from the TerraServer website. Within the field study area are found a major stream (Little Pine Creek) that drains farmland and forested areas, with a small, rural community on its banks about five miles upstream; a small tributary (Sugar Run), which begins in a cow pasture and flows through a forested area before entering Little Pine Creek; and a human-made pond, fed primarily by Sugar Run. The students viewed photographs of these areas so that they could get an idea of

to the hypothesis. During the site survey, the students identified two areas of Little Pine Creek that were different. One location showed water moving rapidly over rocks and another showed that water had been trapped in a small stagnant pool.

All students gathered authentic data pertinent to their individual investigations at the site. Later, in the classroom, students presented that data as graphs or charts (types of models) as evidence to support their explanations. Students developed their explanations based on the data, and these were then discussed by the class, where alternative explanations could be presented. This type of classroom conversation generates an authentic argument (see Chapter 1). The presentation and discussion of the individual student investigations gave the class a holistic view of the Little Pine Creek watershed.

Based on their experiences, the students constructed tentative mental models about stream environments. For example, as represented in Figure 5.2, students saw that the amount of dissolved oxygen in the water was affected by the physical and biological parameters of the stream. In this case, riffles add oxygen to the water and cooler water holds more oxygen; algae, through

FIGURE 5.2. REPRESENTATION OF STUDENTS' TENTATIVE MODEL OF DISSOLVED OXYGEN (DO)



photosynthesis, add oxygen to the water. The quality or health of the stream environment was determined by the level of dissolved oxygen. Higher levels of dissolved oxygen support different types of macroinvertebrates (e.g., stonefly and mayfly nymphs); therefore, the stream is healthier.

Teacher Reflection

The highlight for me (Ted) was the variety of interactions that took place among students and with me as they worked through each step of the process. Initially, each question had to be refined, each hypothesis developed, and each investigation transformed into a test of the hypothesis. Some students didn't quite get it the first time. A pair of students presented as their problem, "How will dissolved oxygen affect the temperature of the water?" Here they had included two water quality parameters and no environmental factors. With these students, I discussed the environmental factors that could affect those water quality factors. I helped them see that dissolved oxygen was not an environmental factor that might affect temperature. They amended their question to, "How will shade affect the temperature of the water?" Requiring students to present their ideas provides the teacher with an opportunity to help students develop good thinking strategies and to refine their tentative mental models.

Especially satisfying were the conversations that occurred in the field as students worked with the tests and the investigation site to collect their data. Students were excited about getting outside into the real environment. The physical presence of the testing site either confirmed or altered student ideas. For example, a pair of students had planned to take an *E. coli* sample in Little Pine Creek above and below the mouth of Sugar Run, thinking that the cow pasture at the head of Sugar Run might change the *E. coli* levels in Little Pine Creek. They noticed that the amount of water exiting Sugar Run was very small and realized that perhaps there was not enough water being introduced from Sugar Run into Little Pine Creek to make a difference. After discussing the problem, they decided to test the water in Sugar Run before it entered Little Pine Creek. By making this change, they collected more meaningful data. Some students doubted their original data and asked to collect additional data to confirm or correct their findings. Many learning experiences are available in the field that cannot be duplicated in the classroom.

In the final stage of the activity, students presented their findings and defended their explanations to the class. In one case, a student had hypothesized that dissolved oxygen would be lower in the still water of the pond than in the ripples of the creek. After taking two sets of data, she found opposite results and had trouble

explaining why. Another student observed that the pond water looked greenish and thought perhaps the algae within the water caused the difference, explaining that photosynthesis would contribute oxygen to the pond. Throughout the presentation and discussion of results students gained a deeper understanding of the scientific process and of the biological, chemical, and physical aspects of stream environments. Although students constructed their own understanding, this personal meaning was not constructed in isolation from other students (as suggested by Bishop 1985; Rogoff 1990). I have found that students respond well to appropriate inquiry challenges like the one outlined in this chapter.

Student Reflections

Students overwhelmingly enjoyed doing their field study. A number of students believed that doing the field study matched their learning styles: “I think I learn more doing hands-on learning,” one student said. Conducting the water quality tests in the field made the tests more meaningful. As another student said, “It really helped me learn, because we were actually outside doing the tests ourselves. That is when I finally, completely figured out what my teacher was talking about.”

The field study also helped students develop an understanding about how to design and conduct an investigation. Planning the investigation helped students learn to write a hypothesis that clearly stated the independent and dependent variables. Many of the students noted that the importance of the experience was its connection to the real world. One said, “In the long run it will help us not only in the classroom but in real life.” The experience helped students see the real connection between land use practice and stream quality. It allowed the students to determine if land use practices were impacting Sugar Run, as several students noted: “It showed me if cow pastures would affect the pH in Sugar Run or not” and that “a cow pasture by Sugar Run puts more *E. coli* into the stream.”

Most students thought that developing their own question and investigation was best. Statements by students included the following: “I would rather come up with my own question because it lets you choose what you are going to do and how you are going to do it.” “It challenged me to find answers.” “I would rather make my own up. This is because you get to learn what you want to learn not [what] the teacher [wants you to learn].” This gave students ownership and responsibility in their learning. “If I’m given the question and the investigation, it’s like I’m not doing the work,” one student said.

A few students, however, wanted the teacher to provide the question, as exemplified by the following student statements: “I would rather be given the question and investigation, because it would be less confusing and easier.” “I think we should be given a question because we can pick something really easy, and I think we need to be challenged more.”

Science Educator Reflection

I (Dan) see the interactive CD and watershed simulation as guided inquiry activities, what Windschitl (in Chapter 1) calls *supporting activities*. These activities provided the students with the experiences and knowledge to develop the tentative mental models they needed in order to plan and conduct the water quality tests and organize their information, data, and experiences about the Little Pine Creek watershed. This process is adaptive in that students organize the experiential world based on their tentative mental models (as described by Lerman 1989).

These experiences required students to physically and mentally act on phenomena (as in Piaget 1970) and to interact with members of the community (as in Vygotsky 1962/1986)—other students and the teacher—in order to construct personal meaning (as in Driver and Bell 1986). For example, students physically performed the water quality tests and used their tentative mental models to think and talk about these tests within the context of the environmental factors and land use practices surrounding Little Pine Creek.

The students’ stream investigations not only reflected open inquiry (i.e., they were more learner directed), but reflected what scientists do in the real world to investigate and monitor stream environments. In essence, these students were modeling the scientific process. Windschitl (see Chapter 1) refers to this type of experience as core knowledge-building activities. This is not to say that the teacher takes a hands-off approach but rather, as this teacher did, assists students as needed, providing the type and amount of structure based on individual student needs. For example, Ted provided some students with more guidance than others in developing and framing their questions, and stating their hypotheses. Had he not done so, those students would have floundered in doing the inquiry and learning the science.

Poor inquiries often lead to scientifically inappropriate or meaningless understandings. In essence, these students identified their own questions and designed their own investigations. The students used appropriate tools to collect their data; they then interpreted their data and used scientific knowledge

to explain their results, using data as evidence. They communicated their procedures, data, and explanations to others, creating opportunities for argumentation and the presentation of alternative explanations.

Finally, students were learning about macroinvertebrates as biological indicators of stream quality. Biological monitoring is the study of living organisms for the purpose of determining environmental conditions. In this particular classroom, students were conducting a biosurvey—the identification and quantification of macroinvertebrates. Macroinvertebrates are good indicators of stream quality because they are affected by the physical and chemical conditions of the stream, are unable to move away from pollutants or events that impact the stream, show the cumulative or synergistic effects of pollutants, and vary in their tolerance to pollution. The quality of the stream is determined by the presence and abundance of different macroinvertebrates, using a model that categorizes the macroinvertebrates based on their sensitivity or tolerance to pollution and that results in a numerical rating of the stream. Different types of streams (e.g., rocky bottom, muddy bottom) and different states require the use of different rating systems.

In this way students were addressing the National Science Education Standards (NSES) (NRC 1996) life science standards about populations and ecosystems. Students were learning that the type and number of organisms (i.e., species richness and abundance) found in an ecosystem are dependent on the abiotic factors of that system—in this case, the chemical and physical conditions of the stream. For example, the presence and abundance of stonefly and mayfly nymphs will decline as the level of dissolved oxygen decreases.

Other Field Studies: Invasive Species and Air Quality

Although this classroom example illustrated field studies–based pedagogy through stream investigations, there are numerous biological concepts that may be learned through field studies. Students could conduct field studies to investigate the distribution or ecological impact of invasive species (such as garlic mustard or bush honeysuckle on woodland environments). In such field studies, students could compare the abiotic and biotic characteristics of field plots containing invasive species to plots without invasive species. Such comparisons would lead to data-based discussions about biodiversity, species interactions, and competition for resources such as abiotic factors (e.g., light, water, and temperature), differences in biological adaptations, and perhaps the extinction

of indigenous species because of their inability to compete with invasive species for resources—all of which topics are aligned with the life science standards for Populations and Ecosystems and Diversity and Adaptations of Organisms (NRC 1996, pp. 157–158).

Students could conduct field studies investigating air quality using lichens as biological indicators. Foliose (leafy) and fruticose (shrubby) lichens tend to be found in areas with clean air, while crustose (crusty) lichens can survive in areas of poor air quality. A number of websites describe the use of lichens as biological indicators; a general air quality index is as follows (from polluted to clean air): no lichens, grey-green crusty lichens, orange crusty lichens, leafy lichens, shrubby lichens (Frank, Luera, and Stapp 1996). It is also important to consider the size of the lichens; in general, the larger the lichens the better the air quality. In essence, students identify sampling sites on trees from different field sites and compare the type and quantity of lichens (see Frank, Luera, and Stapp 1996 for a detailed protocol). This leads to data-driven discussions about air quality and environmental degradation, which aligns with the standards for Science in Personal and Social Perspectives (NRC 1996, pp. 166–170, 193–199).

As shown in the classroom examples and in these examples, field studies provide teachers and students with unique opportunities to investigate their local environments in authentic ways. Field studies are data-driven experiences, are extended over time, and use evidence to develop and support explanations. Field studies provide the opportunity for students to learn science and develop inquiry abilities in a meaningful context—the students’ real world.

Conclusion

This chapter described guided inquiry activities used as a means to build students’ knowledge structures or tentative mental models, providing the experience necessary to be successful in their stream investigations. The stream investigations built from students’ tentative mental models to identifying guiding questions. Students defined their own learning by designing an investigation and collecting data to answer their questions and test their tentative mental models. In this way the inquiries were data driven, and the data became central to learning; that is, students formulated explanations based on the data and used scientific ideas to explain the data. These students shared their investigations, data, and explanations with others, supporting science-specific forms of talk (see Chapter 1). The teacher assisted students as needed to ensure that they developed their inquiry abilities and learned science.

The teacher engaged students in the fundamental abilities to do scientific inquiry as outlined by the National Research Council (1996, 2000). This teacher, like many, spent less time addressing the fundamental understandings about scientific inquiry. For example, the notion that different kinds of questions require different kinds of investigations or that technology enhances the accuracy of data collection was not explicitly addressed. This experience did implicitly expose students to the notions that scientific knowledge guides scientific investigations and that scientific explanations emphasize evidence.

