Ms. Idoni's Class

Every year in the spring, Ms. Idoni's biology class conducts a full and open inquiry. The inquiry takes several weeks of class during the semester, so students have ample time to conduct their investigation. Ms. Idoni begins the inquiry by taking the students on a field trip to an environment where she is relatively certain their interest will be engaged. All year, students look forward to this experience. It is a tradition with Ms. Idoni and the students have heard that it is hard work, but something they will really find interesting.

Earlier in the school year the students have had many opportunities to learn and practice the inquiry skills they will need to conduct a full inquiry. Ms. Idoni has used a series of "invitations to inquiry" (Mayer, 1978), which are short teaching units designed to give students small samples of the process of inquiry. Each sample has a blank the students are invited to fill, for example, the plan of an investigation, a way to control one factor in an experiment, or the conclusion to be drawn from a set of data. Each "invitation" focuses student learning on one or two abilities of inquiry. Participating in the series of invitations over the year has equipped Ms. Idoni's students to identify questions that can be investigated, design appropriate investigations, gather data, interpret data, consult sources such as the Web for additional information, and draw definable conclusions — all of which will be called on in the full inquiry they are now beginning.

Before starting inquiry, Ms. Idoni makes plans for how to assess students' learning on an ongoing basis. She will ask each student to keep a journal through the inquiry. Because she is most interested in emphasizing the development of inquiry abilities, Ms. Idoni will have the students organize their journals according to a slightly modified form of the fundamental abilities as described in the *Standards.* The categories Ms. Idoni will use are:

- Questions and scientific ideas that guide the investigation
- Design of the investigation
- Technology and mathematics for the investigation
- Use of evidence to present explanations
- Alternative explanations
- Conclusions and defense of explanations

As students record their observations, Ms. Idoni will review their journals and ask more specific questions about scientific concepts that underlie their explanations, how technology helps them, what evidence they are collecting, if they have the best evidence and explanation, what other ideas they have heard, and if they have the strongest conclusions.

Ms. Idoni sets the stage for the field trip by explaining to the students that for most of the year their biology class has studied ideas and conducted laboratories that scientists and educators think that all students should know and experience. Although these experiences provide a foundation, now the approach will be different. They will have the opportunity to study something about the environment that they find interesting. "The field trip will help you decide what question you want to pursue." This year, Ms. Idoni has decided to take the students to a lake in the city park. When they arrive at the lake, Ms. Idoni asks the students to simply walk around the lake, to observe the lake, and to think about questions that they may be interested in answering. She asks them to record the observations and questions in their journal.

The next day's activity centers on the students' observations and questions. Ms. Idoni approaches these discussions with caution. She is sensitive to the balance between sustaining the students' interest and enthusiasm and the critical elements of a successful scientific inquiry for 10th graders. A critical aspect of successful inquiry is having students reflect on the ideas and scientific concepts that guide the inquiry. Also important is a knowledge base to support the investigation and help students to formulate an appropriate scientific explanation. Students' current concepts of the aquatic environment will shape, and may limit, their questions and ultimately their inquiry. So, after an initial class discussion, Ms. Idoni knows she will rely on small groups, brief reports on progress, and cooperative learning for the investigations.

Student questions begin with issues such as: Is the lake water safe to drink? Can people swim in the lake? What kinds of plants and animals live in the lake? How have humans changed the lake? As the discussion continues, it becomes clear to Ms. Idoni that the students are most interested in change and stability in the lake and, in particular, the influence humans have had on this environment. It also is clear that students have ideas about how the lake changes: the temperature changes daily and with seasons; there was more dirt since a recent rain; some small organisms could be seen; and, in some places, there were different smells associated with the water. Ms. Idoni probes the students about their observations and reminds them to make entries in their journals. What important aspect of the lake do they want to investigate? What kinds of human influences are of most interest? "Pollution" is the term Ms. Idoni hears first and most consistently. She thinks it is essential to clarify the students' understanding of pollution and in particular the possible sources of human pollution in the city lake. She asks the students to discuss in small groups what they mean by pollution for the city lake.

Over several class periods, they struggle with the issue of normal change, what counts as pollution, and possible human influences. Ms. Idoni lets the students grapple with these issues, which seem to center on one major idea: as living and non-living elements of an ecosystem interact, they change. Any study of changes in an environment, such as the city lake, must begin with an analysis of the patterns of change under normal circumstances. Students realize they have to understand the natural functions of the interactive system before tackling the more complex question of the impact of human actions, in particular, their notion of pollution. At this point Ms. Idoni realizes she already has her final assessment: she will suggest that something has polluted the lake and the students will have to apply what they have learned to this new problem. But, for the time being, she must wait and let the students pursue their questions and investigations.

After hearing the results of small group discussions, Ms. Idoni facilitates a large group review of ideas and helps students identify an overarching question for the class to pursue in the investigation. The class decides on a general question: *Is city park lake polluted? If so, how have humans influenced the pollution?* The class decides to approach the inquiry by first establishing a baseline of data about city lake and then determine if the lake is polluted. Students realize that many factors affect water quality. With help from Ms. Idoni, they decide to organize their work, and so themselves, to focus on three kinds of factors: physical, chemical, and biological. The group investigating physical factors is interested in temperature, color, limits of light penetration, and amounts and types of suspended particles. The chemical factors group wants to learn about pH (which they have measured in various classes in past years and suspect might have something to do with a lake's "condition"), and amounts of oxygen, carbon dioxide, phosphates, and nitrates. The biological group wants to investigate the numbers and kinds of organisms.

Students decide to design the inquiry as follows. Each group will gather data for a period of two months, reporting all results to the other groups on a regular basis. Each group also will report about their ideas and what their library and computer searches suggest about the potential influence of the factors they are studying on the quality of city lake.

Ms. Idoni is very pleased with the way the class investigation is taking shape. Although she knows the students will still struggle with the question of how to determine what counts as pollution, and especially the human influence, she lets this issue remain unresolved. In fact, knowing it will emerge on its own, she doesn't bring it up.

Ms. Idoni is especially aware of three things. First, she keeps a mental list of the inquiry abilities for grades 9–12 and notes which abilities the students are engaged in as the inquiry progresses. Second, she recognizes that students are using what they have learned of physical and life sciences earlier in the year, especially the fundamental understandings associated with the life science standard on the interdependence of organisms (see Table 3-5). Finally, Ms. Idoni sees that this entire inquiry is providing ample opportunities for all students to understand several parts of the standard on science in personal and social perspectives, especially those associated with natural resources and environmental quality.

As the students begin organizing their group investigations, they easily and quickly recognize that the use of various technologies will improve data gathering and mathematics will improve the summary and presentation of data. For example, they decide to set up temperature probes and record data directly into computers, and to use Hach oxygen test kits, a pH meter, a Millipore environmental microbiology kit, and common items that help them gather samples for examination in the science classroom.

Ms. Idoni schedules periodic meetings in which the students share data they have collected and present what they understand about the influence of various factors. With time, students begin to realize that the factors interact. In one discussion, for example, the physical factors team suggests that temperature determines the number and kinds of organisms, The chemical factors team reports that the numbers and kinds of organisms influence how much oxygen and carbon dioxide are present. In one highly energized session, the students realize that an investigation of water quality is a search for relationships among physical, chemical, and biological factors.

In the process of data analysis, student teams review their findings, look at ranges of data and trends over the period of study (it is spring), and determine what is appropriate to consider and how to deal with anomalous data. During their group work, Ms. Idoni moves from group to group and asks questions, such as "What explanation did you expect to develop from the data?" "Where there any surprises in the data?" "How confident do you feel about the accuracy of the data?"

After two months, the groups present their data and their explanation of the specific effect the factors they studied have on the lake and if the effect would count as pollution. As students listen to the different groups, they recognize and analyze alternative explanations and models for understanding stability, change, and the potential of pollution in the city lake. They review what they know, weigh the evidence for different explanations, and examine the logic of the different group presentations. They challenge each others' findings, elaborating on their own knowledge as they help each other learn more about their particular factors. Slowly, they form the view that all factors have to be considered in any explanation for pollution of the lake.

To Ms. Idoni's surprise and pleasure, the students decide that they want to synthesize the data and formulate an answer to their guiding question. Their observations and explanations continually expand; they find they have to consider factors they did not originally think were important, such as season, rainfall, and the activities of domestic animals.

As they compile all of the evidence and begin the difficult task of answering their question, they realize they must first address the question: "What counts as pollution?" The students decide that they will use coliform bacteria because of what they learn in their reading. The literature points out that water can look, taste, and smell perfectly clean and yet be unsafe to drink because it contains bacteria. This eventually becomes the students' operational definition of pollution. They learn that coliform bacteria live longer and are easier to detect in water than bacteria that cause disease. Their presence is considered a real warning signal of sewage pollution. If coliform bacteria are *not* present in city lake, then, the students reason, the answer to their question is that the lake is free of pollution — at least by their operational definition of human pollution.

Working across groups, the class compiles their respective reports and prepares one major summary of their inquiry. They also include summaries of their respective results. The reports are excellent. Students capably describe procedures, express scientific concepts, review information, summarize data, develop charts and data, explain statistical procedures they used, and construct a reasonable and logical argument for their answer to the question, "Is city park lake polluted?" "And, if so, what is the human influence on the pollution?" The class concludes that, even though city park lake experiences variations and changes in many factors, it is not polluted.

For the final assessment, Ms. Idoni presents a new problem and asks each student to prepare a report describing how he or she would investigate the problem. Here is the problem: over several weeks there is a massive fish kill in the lake. Everyone suspects pollution — of some sort. But, no one knows exactly how to investigate the problem. The one thing they have discovered is that coliform bacteria have *not* been found in the lake. Students are to propose an inquiry that might be used by the City Council to address this problem.