# ASSESSMENTS AS TEACHING AND RESEARCH TOOLS IN AN ENVIRONMENTAL PROBLEM-SOLVING PROGRAM FOR IN-SERVICE TEACHERS

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## ABSTRACT

A scenario-based assessment tool used in two environmental geoscience in-service programs for middle school and high school teachers served both to guide instructional techniques and as a method to evaluate the success of the instructional approach. In each in-service program the participants were assessed at an initial meeting to determine their understandings of environmental problems. The assessments included a hypothetical watershed scenario in which participants had to choose water quality monitoring sites, monitoring parameters, and provide justification of their choices. The results of these pre-assessments provided staff with an understanding of participant misconceptions that could be addressed specifically in program activities. In each program the participants were given the same assessment after participating in the workshops and this revealed significant shifts in certain areas of their understanding of watershed quality concepts and monitoring approaches.

Good assessment scenarios are complex and are based on accurate information or data that are used to answer a question or prompt. They are particularly revealing and valuable because they ask students to make decisions by applying their understandings using information or data. Development and use of scenario-based assessment in this program came about only because of genuine and sustained cooperation between science education faculty and geoscience faculty. This highly beneficial collaboration was key to providing quality training to participating in-service teachers, and development of a synergistic teaching and learning environment.

Keywords: education - assessments; assessments - scenarios; education - in-service; education - inquiry learning; education - issues-based learning; environmental geoscience

## INTRODUCTION

To most of us who teach in the geosciences, assessment refers to the tests and assignments we use to assign grades to students. Well-designed assessments, however, can be much more useful both in terms of the information they provide about student learning, and as tools to improve teaching. In addition to determining how much improvement in students' understandings is accomplished through a class, assessments can be used to determine the initial understandings of the students, any misconceptions about the topic that exist, and how the student thinks about a topic. All of these pieces of information can be used to design more effective instruction. Just as a research endeavor begins by first determining the state of previous research on that topic, an initial assessment of students' understandings is necessary to provide quality and efficient instruction (Voska and Heikkinen, 2000). However, producing a good instrument to assess students' understandings of earth science concepts, problem solving abilities, and thought processes is a challenge for which most geoscientists are ill-trained and unprepared.

Much work has taken place at Purdue University to incorporate sound educational practices and educational research into existing and new geoscience classes (e.g., Harbor, 2000; Trop, et al., 2000; Krockover, et al. 2001). One of the most productive approaches has been cooperative work between faculty in the Department of Earth and Atmospheric Sciences (School of Science), and the Department of Curriculum and Instruction (School of Education). This cooperation between science faculty and faculty in science education seems obvious, and is especially appropriate in environmental geoscience classes because of the strong (public) education component in all environmental issues, and because of the environmental emphasis of earth science classes taught expressly for education majors. This collaboration has also extended to joint projects to develop geoscience based educational programs for in-service and pre-service teachers.

In this paper we describe an assessment used in two programs for middle school and high school teachers held at Indiana University/Purdue University at Indianapolis (IUPUI) and at Purdue University's main campus in West Lafayette, Indiana. These two programs were similar in content and identical in the way they were assessed, so results from both are combined in this discussion. In each program, the participants were assessed at the initial meeting to determine their understandings of environmental problems related to a hypothetical watershed. These assessments were compared to teacher assessments completed after participating in the workshops, to determine how their understandings had changed. We also used the information about teacher understanding gained from the assessment in modifying workshop activities specifically to address teacher misconceptions.

## BACKGROUND

Over the past twenty to thirty years, environmental issues and problems have become more important in geoscience classrooms. To understand and solve environmental problems people need to have an understanding of the geologic processes that take place in the near-surface environment, and thus, there is clear rationale for including geoscience material in environmental courses. Geology departments are including more environmental classes in their curricula (Ulanski, 1995), and in some cases are creating new majors with a specific focus on environmental geosciences. Purdue University's environmental geoscience major, developed in 1993, includes a capstone investigative class for seniors focused on local environmental problem solving (Harbor, 2000). This capstone class adapted for training in-service middle school and secondary science teachers by augmenting the inquiry and interdisciplinary science components of the class with activities and discussions on curriculum development and assessment, so that teachers could effectively integrate this approach in to their own curricula and classroom instruction.

There are several reasons why we chose to extend this program to in-service teachers. One of the oft-stated goals of environmental education in the United States is to create an environmentally "literate" population. (Mancl, et al. 1999; Roth, 1991). However, in order to do this, the teachers who have responsibility for educating our children must not only be trained in pedagogy, but must be comfortable with the many interdisciplinary sciences that are associated with environmental problems and issues. Thus, in addition to addressing the educational needs of geoscience majors, it is important for geoscience departments to provide relevant environmental geoscience education for pre- and in-service teachers.

Using local environmental issues as the focus of an investigation (Harbor, 2000) is one good way to include practical experience in an environmental program. This approach can be used both with science majors and with pre- and in-service teachers. Teacher education programs that emphasize the practical experience of performing a real-life environmental investigation (Robottom, 1990), and that include science content knowledge, model sound environmental education approaches that can be used by the teachers in their own classrooms. In this way the in-service teachers who participate are taught not only the science components of environmental geology, but also how to incorporate these components successfully into their own classroom situations.

Two separate programs were funded to improve environmental science skills for in-service teachers (see acknowledgements). The first program was for one year and took place during the1999-2000 academic year at Indiana University/Purdue University at Indianapolis (IUPUI) and the latter, now named ENVISION, is a multi-year program at the main Purdue Campus of West Lafayette, Indiana that began in 1999 and will continue through 2004. Each program evaluated here consisted of a short spring meeting, a 2-3 week summer institute, and follow-up meetings in the fall and spring. The participants met for one weekend in the spring for initial assessment and to start work on field investigations, curricular review and development, and science content. The summer program involved the participants in two to three intensive weeks of science investigation, writing and reporting, and curriculum integration. In follow-up meetings the participants reported back to their peers about the successes and challenges they had experienced in their own classrooms. The participants included science teachers from many parts of the Midwest, including teachers of chemistry, biology, earth science, general science, environmental science, and ecology in middle schools and high schools.

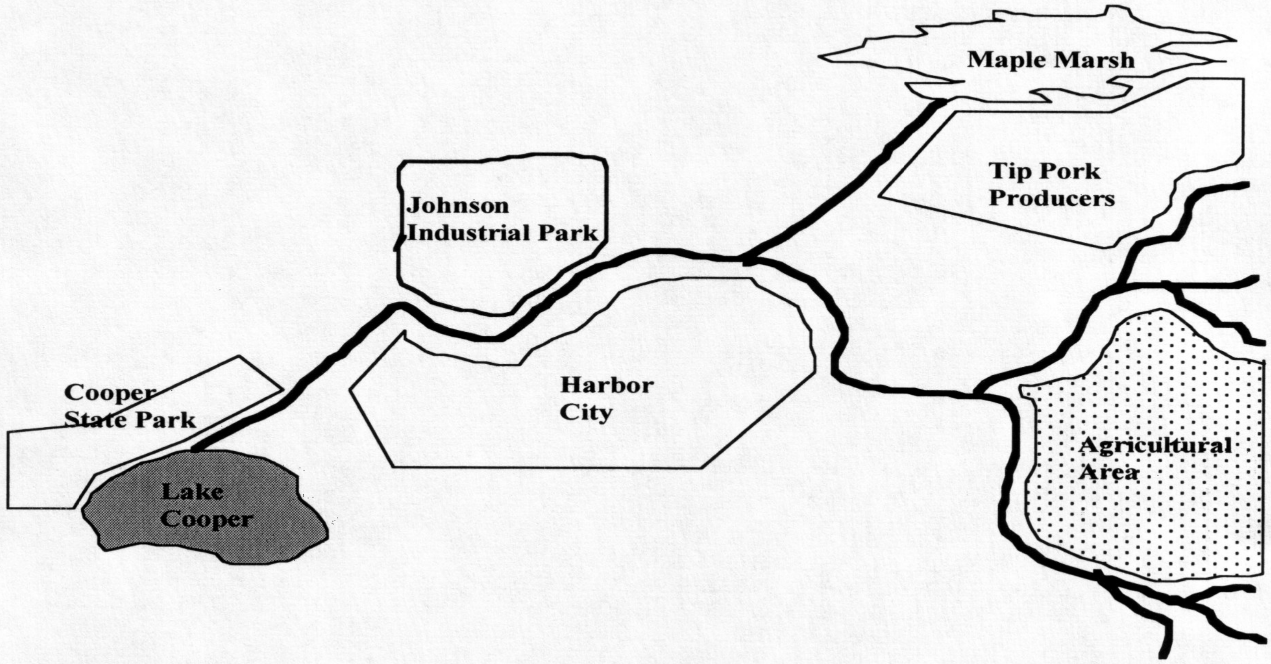
The purpose of this paper is to discuss the assessments used in these two programs for the 1999-2000 year. Detail descriptions of the programs themselves can be found in Shepardson, et al. (in press).

## THE ASSESSMENTS

A critical element of the in-service programs, and the focus of this paper, is assessment. In order to efficiently prepare instruction for the teachers participating in the workshop, it was first necessary to assess their level of understanding of key environmental concepts. Our goals also included assessing how well the teaching methods utilized in this instructional environment were working, and modeling for the teachers how assessment could be integrated into an instructional program. A particular challenge in this program was to devise realistic assessments for the range of activities included in the institute, including improved content knowledge and practical research skills.

We developed assessments aimed at eliciting participants' ideas, understandings, and misconceptions in several areas of environmental geoscience. Several types of assessment were used to determine the teachers' understanding of underlying science, as well as to reveal the thinking processes and problem solving techniques they used. One of the most useful assessment tools was a constructed-response assessment in the form of a stream monitoring scenario (Figure 1).

Constructed-response assessments require students to create a product that demonstrates their




The Indiana Department of Natural Resources and the Indiana Department of Environmental Management are seeking proposals for establishing a monitoring program for the watershed depicted in the above diagram. Your consulting company is preparing a proposal in response to the above request. The request for proposals requires that you indicate the following:

- The four sampling sites (mark locations on the diagram), with a rationale for why those sites were selected.
- Which five parameters you would monitor at each site. The proposal only funds the cost of five. You are to choose five from the following list: nitrate, ammonia, total suspended solids, total phosphorous, dissolved oxygen, pH, water color, PCBs, heavy metals, fish, macro invertebrates (insects/crustaceans), amphibians, and bacteria/fecal coliform. Provide a rationale for the five parameters you selected.

**Figure 1. Stream Monitoring Scenario Assessment Instrument Directions: Complete the scenario to the best of your ability, based on what you currently know.**

understandings (McTighe & Ferrara, 1998). Assessment scenarios are a form of constructed-response in that students respond in writing to the situation described in the scenario. Our scenario required students to propose a plan for monitoring stream quality, based on the data/information provided in the scenario.

## ASSESSMENT SCENARIOS

**What Is an Assessment Scenario? -** In an assessment scenario, the student is given a problem scenario that could occur in a real life situation. The information supplied can be made as simple or complex as the students' ability level permits. The student is asked to perform tasks and make interpretations using the information, and is assessed on the type of processes used in coming up with responses, and on the content of the answers.

The scenario chosen for the class of in-service teachers concerned a stream flowing through a watershed that included several different types of land uses common in the Midwest (Figure 1). The instructional program included a field trip and exercises addressing similar situations and dealing with the same diverse group of potential water contaminants as used in the scenario. In the assessment, the students could propose to measure or test the water for any five of a list of parameters, at four locations along the stream. They were to choose the parameters and the sampling locations, and to explain the reasoning behind their choices. Herman, Aschbacher, and Winters (1992), Hymes, Chafin, and Gonder (1991), Perrone (1991), and Shepardson (2001) have identified criteria for guiding the development of alternative assessment tasks. Our assessment scenario was developed in alignment with these design criteria.

**Assessment Scenarios as Diagnostic and Summative Tools** - This stream monitoring assessment was used for both diagnostic and summative purposes. It was given as a pre-test, allowing its use as a tool for designing instruction (diagnostic, based on students prior knowledge and conceptions), and as a post-test to assess the (summative) impact of the educational program. Inductive analysis (Patton, 1990) was used to identify patterns in the teachers' responses to the stream monitoring scenario. Each assessment was individually reviewed by two of the authors who then discussed their reviews, negotiating codes that reflected specific elements in teacher responses. The assessments were then coded and patterns in codes were clustered to form categories that reflected the teachers' understandings. Thus the codes and categories emerged from the data, rather than from any pre-existing or predetermined codes or categories (deductive analysis) (Patton, 1990).

The pre-test information was used to make decisions about modifying the program curriculum and instructional activities. For example, it was apparent from the pre-test that the students had a poor understanding of the need to collect base-line data for a stream, and to collect information on the same parameters upstream and downstream of a possible source of pollution. These points were reinforced in several ways in the instructional program. If the students had demonstrated a good understanding of these concepts, they could have been less strongly emphasized in the course.

**Why Assessment Scenarios? -** Assessment scenarios reflect the National Research Council's (NRC) emphases in assessment, which include:

> Assessing what is most valued in science
> Assessing rich, well-structured knowledge and understanding
> Assessing scientific understanding and reasoning
> Assessing to learn what students understand (NRC, 1996).

Different types of assessments measure different aspects of what students know and can do (Baxter & Shavelson, 1994; Ruiz-Primo & Shavelson, 1996). Our assessment scenario emphasizes understanding, research design, and reasoning through a situation to solve a problem.

Assessment scenarios elicit students' ideas or understandings and engage students in thinking and applying scientific ideas to problem situations or issues that they can see are realistic. They require students to communicate their ideas, understandings, and thinking. Such scenarios also require students to make decisions about how to complete the task. If students are learning through tackling real world situations, scenarios match or reflect these situations and provide authenticity to the assessment (Schwert, 1999). In cases where the students do not learn through working on real world situations, real world scenarios provide a measure of how well a student can translate knowledge gained in other ways to the solution of real problems. Finally, assessment scenarios elicit a better picture of students' ideas and understandings and provide more reliable evidence of their scientific understandings. Assessment scenarios used in a pre-test and post-test fashion provide a picture of the changes in students' ideas and understandings, that in turn can allow for changes in the instruction that takes place.

## PRE-TEST RESULTS

In both the summer workshops the pre-test scenarios showed that:

- a few of the participants were confused about stream flow directions
- many were unsure what tests to use to determine specific types of contamination, and
- most were confused about how to attain "base-line" data on the stream
- most had a poorly defined concept of "acceptable" levels of contaminants, thinking all contaminants were bad.

By evaluating pre-test scenarios, we were able to target the instruction toward addressing misconceptions and uncertainties. For example, we added emphasis and explanation both in field trips and in-class activities on types and levels of contamination, and strategies for monitoring to obtain base-line data. By comparing pre-test with post-test results, we could determine whether that the instruction we provided was effective.

**Developing Assessment Scenarios -** The main steps in developing an assessment are:

- Identify the purpose for the assessment scenario.
- Identify the key concepts, ideas, and skills to be learned and assessed.
- Obtain data or information from a real situation that reflects the key concepts, ideas, and skills, or create a hypothetical data set that matches a real world situation.
- Write the scenario.
- Check the scenario to ensure that it aligns with the key concepts and instruction.
- Develop the scoring system.
- Field test the scenario and revise where necessary.

An important, but often overlooked aspect of good assessment scenarios is their alignment to instruction and student experiences. A well-written scenario that is poorly aligned with instruction will result in poor student performance and unreliable information about what students know and can do or have learned. Thus, a first step in writing scenarios is identifying the key concepts or ideas students are to learn. For example, in Figure 1, the scenario chosen involved concepts of source identification and monitoring, and specific land uses and contamination problems investigated in the program. The next step is to identify real world situations and data to draw from in writing the scenario. The scenario itself does not have to be a real world situation, but should be based on real world situations or scientific principles. Real situations may also be enhanced with the incorporation of hypothetical details and/or data. We chose a scenario depicting land uses and contamination issues common in Northern Indiana (See Figure 1), yet it is a hypothetical situation.

Good assessment scenarios are complex and based on accurate information or data that are used to answer the question or prompt; they allow students to make decisions by applying their understandings and using information or data. If real data are not available then the data used in the scenario should mirror the real world as well as possible. It is not necessary to write a lengthy scenario. The prompt facilitates the manner in which students complete the task, how they analyze the data or information, and how they respond. More complex scenarios would incorporate different perspectives from which students could complete the task. For example, in our stream monitoring scenario (Figure 1) students complete the task from the perspective of an environmental consulting company. We also ask them to do the testing under constraints of limited assets, like those they would encounter in a real world situation where information must be purchased with limited funds. A different perspective might require students to respond as an employee or biologist of the pork producer who wants to expand his operation. This perspective might result in a different approach to completing the assessment scenario: different monitoring sites and different parameters.

The scenario narrative needs to contain a description of the issues and context, and the data or information the students use in completing the assessment. In addition, individuals or groups with different perspectives could be included in the narrative to increase the complexity of the scenario. Incorporating different stakeholders or perspectives increases the complexity of the assessment, as does an increase in the data or information available for students to use.

The scenario may be written in an open or closed case format (Shepardson, 2001). Open case formats provide students with less structure and more freedom in completing the assessment. This provides students with more opportunities to think about the scenario, providing a more in-depth look at students' understandings (the way they think, rather than the way they respond to the teacher's thinking). Closed case formats provide more structure in terms of how students complete the task, reducing the ways in which they approach solving the problem in the scenario. It also reduces the decision-making processes in which students engage, but provides a clear focus for evaluation. Our stream monitoring scenario (Figure 1) is an open format in that students have to identify the stream monitoring sites and the parameters, as well as provide the rationale for the sites and parameters. They have to make decisions about how to complete the scenario. The scenario could be made more closed by indicating what parameters students are to use, but still allowing them the opportunity to determine the monitoring sites. Indicating the parameters students must use, however, restricts their thinking and provides a narrower view of their understandings. It also reduces the decision-making process; students only have to decide where to monitor.

Testing and revising a scenario is essential. If possible, field test the scenario on a similar student population or have a colleague complete and critique the scenario. Based on the field test results, revise the scenario. In our field testing of this scenario, we eliminated any testing that could not be accomplished by middle or high school students using commonly available equipment and monitoring techniques. A similar scenario could be used for college students that is more complex and contains parameters that are more difficult to measure, like one for major cations and anions, which require the use of an ion chromatograph. A simplified version of the scenario could be employed for younger children, where the sites and parameters to test would be significantly reduced.

**Scenario Components -** The scenario consists of the narrative, prompt, directions for responding, and scoring system. The narrative presents the issue, context, data and information, and the perspective(s) from which students respond to the scenario. The narrative contains all of the information students need to complete the assessment. The prompt states the question or problem students are to address using the information presented in the scenario narrative. The directions for responding indicate the format or product the students are to produce in order to answer the question or solve the problem. For example, students might be asked to respond to the prompt by creating a written response or proposal, a newspaper article, or a slide show. The scoring system describes how student responses will be scored and what criteria will be used to assess student responses. Depending on the purpose of the assessment the criteria may emerge from student responses or be predetermined.

In our use of the stream monitoring scenario we were not looking for pre-determined responses, but were looking for ideas to emerge from teacher responses that would enable us to understand their ideas. In our scenario (Figure 1), the narrative informs students that they will be establishing a stream monitoring program for the watershed depicted in the diagram, and indicates the details to be included in the proposal. It also sets the context: the watershed that contains multiple land use situations. The issue in the scenario is how to monitor the stream. The options include what parameters to sample and where to sample given the land use surrounding the stream. Finally, it presents the perspective, taking the role of a consulting company. The prompt, "Your company is preparing a proposal in response to the above request," indicates that students are to prepare a written proposal for stream monitoring based on the stated guidelines. The directions for responding require a written proposal and the identification of monitoring sites on the watershed diagram.

Our purpose in using this scenario was to determine students' ideas and understandings rather than to score or grade students, however the same scenario could be used as a quantitative or qualitative grading tool. If one were to use it as a grading tool, the criteria for assessing student responses might be based on the following: monitoring parameters selected, the rationale for selecting each parameter, monitoring sites selected, the rationale for selecting each site, the identification of up-stream and down-stream sites, and the identification of a base line site.

**Other Ways of Using the Assessment Scenario -** Although we focused on using the scenario to gain an understanding of the teachers' thought processes, the assessment scenario may be used in other ways. The scenario may be used as an instructional activity where students work through the scenario, with their final product assessed. The scenario may be used in a summative manner to assess student understanding following instruction. Assessment scenarios require more time for students to complete, thus if used in conjunction with traditional assessment questions and items, the number of traditional questions should be reduced. Assessment scenarios may be administered on demand or completed over several days, depending on the product format and the extent of student responses.

**Research Conclusions Based on the Assessment Scenarios -** Changes between the pre-test and the post-test responses of each participant were analyzed, and a detailed presentation and discussion of these results can be found in Shepardson, et al. (in press). In brief, changes occurred in three aspects of the participants' responses: selection of the site for monitoring, parameters to be monitored, and why they chose those parameters and locations. In site selection, there was a 6% increase from pre-test to post-test in the percentage of participants comparing up-stream to down-stream sites. In general, after the training, the participants selected a site upstream and downstream of the same land use designation and compared the water quality using the same parameters. Before the training, fewer of the participants realized the need for establishing a base-line of water quality and instead concentrated their testing on downstream sites to find specific contaminants they felt would be associated with certain land uses. The selection of parameters measured also changed from the pre-test to the post-test with only 59% of the participants choosing to measure the same parameters in several locations in the pre-test and 69% doing so in the post-test.

In the post-test the participants narratives provided not only more reasons for choosing their parameters, but the reasons given were more in-depth, indicating a growth in understanding of stream monitoring concepts. Another notable change in the participants' reasoning was the concept of "acceptable" levels of contaminants. They responded overwhelmingly at the beginning of the program that any contaminants were "bad" for the stream, but at the end of the program their responses shifted to a concept based on overall stream quality. Teacher rationales for selecting macro invertebrates as holistic indicators of stream quality rose from 23% (pre-test) to 90% (post-test), reflecting increasing understanding that macro invertebrates serve as indicators of the synergistic effects of multiple pollutants.

## SUMMARY AND CONCLUSIONS

The scenario assessment developed at Purdue University provided both guidance in refining instructional techniques and a method to evaluate the effectiveness of an instructional program. This assessment was used for two programs to train in-service teachers in environmental geoscience. In each program, the participants were assessed at the initial meeting to determine their understandings of environmental problems related to a hypothetical watershed. These assessments were compared with assessments completed after participating in the workshops to determine how their understandings had changed, but were also used to direct the workshop activities toward addressing participant misconceptions. During the course of the programs we directed instruction to correct misconceptions about stream flow directions, acceptable levels of contamination, and what types of contamination were related to what land uses. Our assessments showed all the participants gained a better understanding of concepts and approaches in stream quality monitoring.

Participants also reported significant changes in their teaching related to the instructional program. Of the participants who completed the program, 94% indicate that they considered the program to be highly beneficial and reported including issues-based inquiry science in their own classrooms. The success of the program is also indicated by the enthusiasm of the participants to share their experiences with others by making presentations at State and National Conferences. Thirty participants made presentations at the 2000 Hoosier Association of Science Teachers, Inc. conference, and 6 made presentations at the 2000 National Geological Society of America conference. We want to stress that the cooperative work between faculty in the Department of Earth and Atmospheric Sciences (School of Science), and the Department of Curriculum and Instruction (School of Education) was essential to the development of assessment tools in this environmental geoscience program. Science and Education faculty provided unique perspectives and skills that enriched the program, and the faculty and staff learned a lot from the collaboration.

The pre-test / post-test format using an authentic assessment instrument, like the watershed scenario, is an excellent way to guide instructional delivery and to rationally assess student learning. We encourage others to consider integrating scenario-based assessments into their teaching both as pre-test diagnostic tools to guide instructional development, and as part of a pre-test, post-test approach to evaluating student learning.

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“The habit of precipitate explanation leads rapidly on to the development of tentative theories. The explanation offered for a given phenomenon is naturally, under the impulse of self-consistency, offered for like phenomena as they present themselves, and there is soon developed a general theory explanatory of a large class of phenomena similar to the original one. This general theory may not be supported by any further considerations than those which were involved in the first hasty inspection.”

T.C. Chamberlin