

***Environmental Detectives: An Environmental Science  
Curriculum for Middle Schools  
Year 2 Evaluation***

**Prepared for the Montshire Museum of Science**

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**Introduction:** During Year 1 of the Environmental Detective project (September 2000-June 2001) project staff from the Montshire Museum began working closely with a group of five middle school teachers from Vermont and New Hampshire. The teachers participated in a series of regular one-day teacher meetings with project staff and scientists from Dartmouth over the course of the school year to begin formulating the general scope and foci of a new environmental science curriculum for middle school students, *Environmental Detectives* (ED). Project staff and field test teachers defined in further detail five core research areas proposed as the sequence of units for the ED curriculum: Chemistry of Living Things (needs of living things); Dose Response; Fate and Transport; Epidemiology; and Remediation. The five participating middle school teachers included two teachers from a school in Hanover, New Hampshire, two teachers from a school in Hartford, Vermont, and one teacher from a school in Lyme, New Hampshire.

Year 2 (July 2001 – June 2002) formally began with a week-long summer teacher institute and week-long lab camp with students held in July 2001. During the week-long Summer 2001 teacher institute, teachers and project staff worked collaboratively at identifying and trying out specific lessons that could be tested with students during the five-morning lab camp held the following week. A decision was made to focus on the first three areas of the curriculum: the chemistry of living things, dose response, and fate and transport. During the lab camp, students had the opportunity to observe in the lab animals and plants collected from a nearby pond, to conduct hands-on experiments investigating aspects of experimental design, needs of living life, dose response and fate and transport, and to embark on a field trip to the nearby copper mines in Strafford, Vermont.

This two-week summer experience served as a classroom lab to further specify the ED curriculum's initial prototype lessons that would be tested during the upcoming school year. The ED curriculum was used during the 2001-02 school year by two middle school science teachers: one teacher in a New Hampshire public middle school, and one teacher in a private K-8 New Hampshire school.

Independent evaluator, Dr. Cynthia Char of Char Associates, followed project activities across Years 1 and 2. Research activities included review of curriculum documents, observations of regular teacher meetings with project staff during Year 1 and Year 2, observations of the teacher institute and student camp held in July 2001, and interviews with, and observations of, field test teachers during their implementation of the ED curriculum during the 2001-02 school year.

Field Test: Phase I. There were two phases of the Year 2 field test effort. In Phase I, one teacher implemented an early pilot version of the ED curriculum at the start of the school year with two sections of his 7<sup>th</sup> grade life science class (16 students total). The teacher conducted ED activities over the course of six weeks, for approximately twenty 45-minute class sessions.

The teacher used the activities to emphasize observation skills, experimental design and dose response, wishing to have the unit help “jump start” his science class at the beginning of the new school year. The teacher used organisms to study the needs of living things, to spark students’ curiosity, and to inspire student questions. Students conducted their own experiments, with organisms such as brine shrimp and crayfish. Students’ research questions focused on needs of life (e.g., *What are the food preferences of crayfish?*; *Do brine shrimp prefer light or dark environments?*; *How do different pH levels affect brine shrimp?* *How do different salt concentrations affect brine shrimp?*). Some investigations targeted more specifically issues of dose response (e.g., how do different salt concentrations affect brine shrimp?”).

From this initial phase of the field test, we learned that the ED lessons generated a high level of student excitement and enthusiasm for learning science, with students interested in observing the animals and in the concept of lethal dose, and pursuing these interests with their own research questions and investigations. Students enjoyed the opportunity to design and carry out their own experiments, which was a classroom practice not typically employed in this science class. The poster presentations proved a good culminating activity for students to demonstrate what they had learned, to feel proud of their accomplishments, and to provide closure to the unit. The curriculum activities also fit well within the teacher’s “needs of living things” unit he normally taught as part of his 7<sup>th</sup> grade year.

Given that the teacher chose to use the ED curriculum materials at the very beginning of the school year, the curriculum materials consisted of a preliminary set of possible lesson plans and resource materials, with the teacher drawing upon his experience from the summer lab camp to craft a series of lessons he wished to carry out with his students. This initial pilot run of the materials revealed that teachers and students need more structure regarding expectations, experiences and curriculum content, and more ample time to run their experiments. It also became apparent that teachers need more than technical and logistical support from project staff, and that it was not realistic to assume that field test teachers would have either the sufficient time or energy to establish a new, more structured and detailed version of the curriculum.

As a result, a project staff member from the Montshire played a more active role in Phase II of field testing, providing leadership in crafting a new version of the curriculum. Furthermore, by co-teaching the unit with the field test teacher, the staff member could learn first-hand the successes and limitations of prototype lessons, and could quickly

make necessary modifications to the current lesson and design of subsequent lessons in the unit.

Field Test: Phase II: The second phase of the field test involved the use of the *Environmental Detectives* curriculum by one field test teacher with three 8<sup>th</sup> grade classrooms. A lead educator from the Montshire project staff worked closely with the teacher, as materials and lessons were developed and refined during winter 2001. The major data collection effort centered on the administration of pre-program and post-program student surveys to all three sections of eighth graders. Classroom observations, and review of final student work, were also conducted by the evaluator.

In his implementation of the ED curriculum, the field test teacher used the materials with all three sections of his eighth grade science class, with class size of 20 students per section (total of 60 students). Class periods were 40 minutes in length, and met daily. The ED curriculum was used for roughly ten weeks, from December 2001 through March 2002, for approximately 40 class sessions.

Description of Curriculum Materials and Classroom Implementation: The set of curriculum materials that were field tested featured a series of 11 science activities and lessons that focused on fate and transport, and dose response. The field test teacher chose to integrate the materials into his Soils unit, which followed an early fall unit on field-ecology and mapping. To provide students with basic information and experiences with some of the underlying scientific concepts, and to offer a transition from the classes' prior field ecology unit to their own research investigations, a set of introductory activities focusing on groundwater were designed and implemented in the classroom. The specific hands-on activities included:

*Where's the Groundwater?*  
*Porosity*  
*Permeability*  
*Soda Bottle Challenge*  
*Aquifer Model Challenge*  
*Availability of water – global/local*  
*Individual water usage*

The centerpiece of the unit was students' own independent investigations of a dose response experiment, in which they defined their own experimental question, and determined which organism and chemical they wished to investigate. Resource binders on eight different environmental case studies were available to help inform and frame students' investigations, and featured the following topics:

*The Side of the Road – Road salt*  
*Mercury in the Environment*  
*Farms – Nutrient Loading*  
*Toxic Waste Disposal*  
*Your Garbage – Solid Waste Disposal*

*Golf courses – Pesticides and Fertilizers*

*Copper Mines*

*Where does your Rain go? Development and storm water run-off*

The case studies were designed to help link core research to local and global cases, and to provide a broader context for scientific concepts and issues, through articles, assignments pertaining to readings and investigations (e.g., background information for investigations, format for investigation design; examples of investigations, web-site information on topics), and an interview component. The case studies were written to accommodate a variety of teaching styles, curriculum integration and time frames, and to be appropriate for group as well as individual work.

For the student investigations, expectations were structured and explicit, with a rubric of required components given to students before the investigation process began. Researchable questions and examples of experimental designs were first modeled by the teacher in a classroom-wide investigation, before students worked in small groups to pursue their own research investigations. Teachers offered continued feedback and guidance to students during their investigation design and research process.

In addition to these student investigations and experiments, there were two classroom visits from local Dartmouth research scientists. In one visit, a biology professor specializing in aquatic ecology discussed experimental design with each small group, and offered helpful feedback to students' ongoing investigations. In another visit, an earth science professor specializing in the hydrology of ground water movement presented some of his research on arsenic as an example of the investigative process, and as a case study situated locally in the students' neighboring state of New Hampshire.

Following their reading of some of the case study materials, students conducted a wide variety of original investigations focusing on dose response, both with plants and animals. Students identified their own research questions to pursue, such as:

*What is the effect of different salt solutions on the germination rate of grass seeds?*  
*How do different concentrations of Round-Up affect the gill movements of goldfish?*  
*How do different concentrations of soap affect the swimming behavior of brine shrimp?*  
*At what concentration of copper sulfate will LD 50 for brine shrimp be reached?*

Findings from their research were written up as research reports, including an abstract, introduction, methods, results (with data tables, photos and graphs), and discussion sections. Students gave an oral presentation of their findings, and presented their work in an open house that was well attended by parents.

Description of Survey Instruments: Pre-program and post-program student surveys were designed to gauge students' initial background knowledge about various aspects of environmental science at the beginning of the ED curriculum use, and level of knowledge after using the ED curriculum. Since the ED curriculum was at its early

stages of development and was being piloted for the time, the surveys were designed to gather information on students' initial awareness and understanding of environmental science, and the degree to which they were able to acquire and apply aspects of this environmental science knowledge in various problem tasks in the survey. The pre-program survey was administered in early December 2001 as the teacher began using the ED curriculum; the post-program survey was administered in mid-March 2002 at the end of the ED curriculum use. The Year 2 field-test also provided a valuable opportunity to pilot these original learning tasks specially designed for the ED curriculum.

Both the pre-program and post-program surveys featured a common set of four different kinds of problems. The first problem type posed a scenario, in which two fictional characters posited different points of view about the harmfulness of chemicals in the environment. Students were asked which person they most agreed with, and to provide explanations that included facts, information, experience and other evidence for their explanations.

The second kind of problem involved a chemical element table to gauge students' awareness of different chemicals in the environment. The table listed eight different chemical elements. For each element, students were to indicate whether they believed the element to be usually harmful to people, or needed for people's healthy bodies, where in the environment it could be found, and whether they believed the chemical to be local environmental problems in Vermont and/or New Hampshire.

The third problem posed an environmental mystery to students. It asked students to explain what they thought might explain the environmental problem featured in the "mystery", and what they thought they would need to do to find out whether their hypothesis was correct.

The fourth problem type was a "question-formulation" task, and asked students to think about any concerns or questions they might have about the harmful effect of things in the environment on people or animals, and to pose these concerns as questions. This problem type was designed to assess students' concerns and awareness about the environment and the general kinds of orientation for question-posing they possessed.

The post-program survey also included a fifth survey item to solicit student feedback for the various activities done in *Environmental Detectives*. Students were presented with a table featuring 11 different ED activities by name and description. They were asked to identify two activities they liked the best and one activity that they liked least, and to provide reasons for their choices. Students were also asked to provide any suggestions they might have for improving the activities and unit.

Survey Sample: The survey sample consisted of three class sections of 8<sup>th</sup> graders. Pre-tests and post-tests were administered to all students in the class. Pre-tests were completed by 58 students, while post-tests were completed by 49 students. The sample of students who completed both pre-test and post-test surveys consisted of 49 students (23 girls; 26 boys. Class 1 (15) Class 2: (15); Class 3: (19)).

## Findings

**Appeal and Engagement of ED Activities:** Students were presented with a list of the 11 different activities and lessons that constituted the ED curriculum unit, and were asked which two activities they liked the most, and reasons for their choice. Students were also asked which one activity they liked the least, and reasons for their choice. As shown in Table 1, the students' favorite activities were their investigations (the unit's centerpiece), and the aquifer model. At the same time, all of the activities had at least a number of students choosing it as their favorite, indicating that each of the 11 activities offered some interest and appeal to students.

**Table 1: Level of Appeal of Individual ED Activities and Lessons**

Activity	% Students Liked Most (n = 49)	% Students Liked Least (n = 49)
Investigations	35% (17)	8% (4)
Aquifer Model	28% (14)	8% (4)
Case Studies	16% (8)	20% (10)
Groundwater	18% (9)	2% (1)
Soda Bottle Challenge	16% (8)	0% (0)
Research Scientist #1	14% (7)	39% (19)
Research Scientist #2	12% (6)	6% (3)
Porosity	12% (6)	0% (0)
Experimental Design/Yeast	12% (6)	4% (2)
Concentrations	8% (4)	2% (1)
Permeability	6% (3)	0% (0)

There was a general consensus on the reasons students offered for liking a given activity. Characteristics that made an activity more appealing (interesting/fun) involved various facets of student work in which students felt active, independent, productive, connected them with other students, people and the real world, and allowed them to present their work to others.

<b>Activity Characteristics that Heightened Student Appeal and Interest</b>
Hands-on
Experimenting, doing research
Allowing you to work independently
Designing your own model
Working in groups
Seeing connections to the real world
Presenting information to others (making posters)
Contacting people as part of research
Having people respond to your research/help you
Working with certain materials (e.g., clay, water, dangerous materials)

Very few activities were indicated as least favorite. These included the case studies and a visit by one of the research scientists. The case studies were primarily criticized for involving too much reading and writing, or having written materials that they found too difficult or boring. The research scientist visit was criticized primarily for the less-than-optimal format required by the school; unfortunately, due to class scheduling and the desire to have more than one classroom benefit from the visit, the research scientist gave a presentation to all three combined sections of classrooms, for more than one class period (more than one hour). Students most typically complained that the lecture was too long, or not interactive enough.

Characteristics that made an activity less appealing (boring/not fun) involved students in an extensive amount of listening, reading and writing (i.e., less active and hands-on), or whether they felt a sense of lack of clarity regarding the information, procedure, or relevance.

<b>Activities Characteristics that Decreased Student Appeal and Interest</b>
Being lectured to
Having lectures too long
Too much reading
Too much writing
Activity/procedure not clear
Hard to understand
Not clear what relevance is; why it makes sense
Not having enough time

Several criticisms in fact indicated students' level of positive engagement and investment in the activity. For example, some activities were not liked because students wanted to have more time, were disappointed that they failed to have positive results in their investigations, or wished to exercise more of their own choice in what readings they read for case studies, or whom they interviewed.

Specific reasons for liking or not liking each of the 11 activities are summarized in Appendix A.

According to students, the ED curriculum offered students a number of engaging hands-on experiments that provided discrete, enjoyable experiences targeting particular scientific concepts. The centerpiece of the unit, the student-designed investigations, were received well by students, who enjoyed coming up with their own research questions, pursuing them through their experiments, and capturing the results and process in a final report and presentation. Students seemed to view the case studies as primarily a separate set of written materials, which were sometimes voluminous or not easy to read. The research scientist visits were appreciated by students particularly for providing some real-world context for on-going environmental research and to provide feedback for the students' ongoing investigations. Based on student responses, the main recommendations for improving materials involves enhancing the clarity of purpose of specific hands-on experiments, attending to the level and amount of reading required in the case studies, and strengthening the connection between the case study materials and

their investigations. Visiting scientists should also be cognizant of the level of technical vocabulary used, minimize exclusive reliance on lecture formats, and allow opportunities for exchange and interactions with students around their on-going investigations.

### **Results from Student Learning Tasks**

Task #1: Point of View Debate: Performance on the pre-tests indicated that the 8<sup>th</sup> grade students began the ED program with some basic level of awareness of the environment. Even in the pre-program survey, students were not naïve enough to think “Almost all chemicals found in our environment are bad for living things”, nor “Anything that is naturally occurring in the environment (comes from nature) is safe for people.” Almost all students more closely sided with the more tempered view of “Most chemicals found in our environment can be both good and bad for living things. It depends.” or the view, “There are many things in our environment that cause health problems for people.” Such student views were also demonstrated in their post-program surveys.

However, a shift was evidenced in the reasons they gave for selecting these points of view. In the pre-program surveys, many students were not able to give reasons for their choice, mainly restating the point of view without providing additional reasoning or evidence (e.g., “I think that Tom is correct because not all chemicals are bad.”) If reasons were provided, most students expressed the notion that “some chemicals are good, while others are bad.” Students seemed to have two interpretations of this idea. Some expressed the notion that there were two categories of chemicals, some inherently good for people, such as oxygen, calcium and iron, and some that were inherently bad for people, such as mercury and arsenic. As one student said, “Some chemicals keep us well and other chemicals make us sick.” Others seemed to focus on the ways people used or treated chemicals is what made them good or bad (“oil helps us run cars, but it’s not good if you pour it on the ground”), or that some chemicals were good for some organisms, and bad for others (“carbon dioxide is both good/bad. Trees need it to convert it to oxygen and it’s harmful to our lungs.”)

Regarding harmful things in the environment, students on their pre-tests were also more likely to cite natural disasters, general effects of pollution, or things in the biological, rather than chemical world (e.g., “Things like earthquakes, volcanoes and big storms all hurt people.”; “Because there are things in our environment that cause health problems, like poison sumac and dirty air.”)

A closer examination of students’ response to one of the scenarios in particular, indicates that many more students in the post-test, as opposed to the pre-test, reflected an acquisition of the notion of dose response. The scenario students were presented with was as follows:



**What Do you Think? Consider this dialogue:**

Tessa: Almost all chemicals found in our environment are bad for living things.

Tom: Most chemicals found in our environment can be both good and bad for living things. It depends.

Whom do you agree with – Tessa or Tom? Explain why you agree with this person. Try to include some facts, information, experiences you've had, or other evidence in your explanation.

Two classes received this scenario as the pre-test task, while one class received this as the post-test task. For the two classes that received this as a pre-test task, 16% of students (6 out of 38 students total; 0/20 students (0%) in one class, and 6/18 in one class (30%)) produced responses that indicated some prior knowledge of a dose response in reasons they agreed with Tom, with several students mentioning specific chemicals in their answers.

*Because some chemicals that we consider poisonous we actually need to survive, but in small amounts.*

*Because there can be a small level of chemicals that can be good, but too much can be harmful.*

*Because organisms need the chemicals but in different levels. Too high could be bad and too low can be bad as well. You need the right level to stay healthy.*

*Because arsenic you need a little bit to survive but too much can hurt you.*

*Example – iron is good in little samples and deadly in big samples.*

In contrast, 50% of the students (7 out of 14) who were presented this scenario as a post-test, indicated the notion of dose response in their answers of why they agreed with Tom. Several students also used the term “toxic” in their explanations, as well as cited results from their experiments as evidence.

*Because lead or copper are well needed chemicals until the dosage becomes toxic for people. My friends and I experimented on copper sulfate and cat grass. The copper was toxic to the grass at 10% and 1% solutions.*

*Because most chemicals are good in small amounts but can become lethal in larger doses. We found that out by putting brine shrimp in small amounts of copper sulfate and they didn't die.*

*Because there are a lot of chemicals that are only toxic when you get a certain amount.*

*Because all chemicals become toxic at a certain level. So it depends on how much of the chemical is in the environment.*

*Mainly because some chemicals are needed for a healthy body. However, they can be harmful when too much of a chemical is taken in.*

Three students drew upon experiences from *Environmental Detectives*, but produced responses that reflected that they still held onto the notion of “some chemicals are harmful, and some are not,” or “some chemicals can be put to good purposes,” or were focused on specific pieces of evidence they felt seemed to refute particular claims as to the harmful or non-harmful effects of particular chemicals.

*Tom, because some things in our experiments we just use water and food coloring. But in other things we use solution where we even have to wear gloves and goggles.*

*Tom, because when Carl Renshaw came from Dartmouth College to talk about arsenic, he said that it is in our water. It is very bad but you don't see me dying. Also, a lot of chemicals are used for healing patients, using medicine.*

*Tom, because it depends on the chemical. Some facts that I know that because when we were using Round-up it says that it won't harm animals when you put it on the ground. It's wrong because it harmed the goldfish we used.*

The second scenario was much more subtle in its connection to dose response, but also revealed a slight increase in students' responses from pre-test to post-test.

**What Do you Think? Consider this dialogue:**

Mike: There are many things in our environment that cause health problems for people.

Megan: Any thing that is naturally occurring in our environment (comes from nature) is safe for people.

Whom do you agree with – Mike or Megan? Explain why you agree with this person. Try to include some facts, information, experiences you've had, or other evidence in your explanation.

For the one class that had this scenario on the pre-test, only 5% of the students (1/18) indicated some passing reference to dose (“I partially agree with Megan because everything in the environment is good for you in doses and amounts.”)

In contrast, for the two classes that had this scenario on the post-test, 19% of the students (6/32 total; 2/15 (13%) in one class and 4/17 (23%) students in another) used the notion of dose response in why they agreed with Mike.

*Because anything can be harmful to you if you have enough of it.*

*Because everything is toxic at a certain level.*

*Because everything can be harmful. It just matters about the dose.*

*There are things in the environment that are dangerous. Arsenic, for example, is really bad in NH, and if the dose is big enough it can kill you.*

Several students, however, continued to still rely on examples from the biological world, such as bacteria from plants, and mushrooms and other plants. As one student said, “Everything is toxic to people, if there is enough of it. For example, there are several kinds of mushrooms and other kinds of plants that can be very harmful to people.”

There was also an increase in students’ mention of specific chemicals, and in particular places that these chemicals were found. In the class who had this scenario as the pre-test, only one student (5%) made reference to a specific chemical:

*I agree with Mike for there are chemicals and products that come from nature that can harm us such as mercury and certain molds are natural but can cause harm.*

In contrast, 19% (6/32; 4/15 (27%) in one class and 2/16 (12%) in one class) of students in the post-test made reference to specific chemicals in their answers of why they agreed with Mike. Students made particular reference to copper and arsenic, two chemicals focused on in the units.

*Because there are things in this environment that are natural but are bad for you. Copper is found in the environment but is harmful.*

*Because if you live near a copper mine and the copper gets in your well, you can get sick.*

*Because arsenic is naturally occurring and that is dangerous. So is copper, mercury and other chemicals.*

*Because in New Hampshire there’s lots of problems with arsenic in the water. Arsenic comes from the ground.*

*There are many naturally occurring things in the environment that harm people, such as mushrooms, lead, and nitrogen.*

In summary, students’ responses to this “point of view” task indicated a clear increase in their post-program surveys by incorporating the notion of dose response in their rationale, and reference to specific chemicals in the environment. A number of students also drew

upon particular experiences they had with their own investigations or contact with visiting scientists that had been part of the Environmental Detectives curriculum.

Task #2: Chemical Table. In general, students’ pre-program survey responses displayed that most students possessed a basic level of awareness about the degree to which specific chemicals and elements were harmful or healthy for their bodies. More specifically, students seemed generally aware that elements such as calcium, oxygen and iron were needed for healthy bodies, while elements such as lead, mercury and arsenic were harmful. This general awareness remained largely unchanged, when comparing students’ pre-program and post-program survey responses. This is not surprising, given that an emphasis on the range of chemical elements was not a primary focus in the ED curriculum.

Students’ baseline knowledge of where these elements were found in the environment, as reflected in the pre-test, generally pointed to man-made objects or food (e.g., lead is found in pencils, old paint and pipes; mercury in thermometers; calcium in milk, iron in cereal or vitamins). In the post-test, more students tended to indicate that chemicals were found in the ground, air or water.

Further increases in students’ knowledge of chemicals in the environment is also indicated in the analysis of one specific chemical, arsenic, in this survey item. Arsenic was specifically covered in the ED curriculum, both through a presentation of a visiting Dartmouth professor whose research focused on the study of arsenic in well water in New Hampshire, and through an article available in one of the case studies. (Students, however, did not choose this article as one they elected to read.) As shown in Table 2, students’ post-test responses indicated an increase of their understanding that arsenic is found in water, and in their awareness that it is a local environmental problem in Vermont and New Hampshire. The language used by a small group of students also became more specific, with terms describing ground including “in rocks and soil” and “in veins of rocks”, and terms describing water including “ground water”, “well water” and “wells”.

**Table 2: Students’ Ideas of Where Arsenic is found in the Environment**

<b>Source</b>	<b>Pre-test (n = 58) % viewing as source</b>	<b>Post-test (n = 48)</b>
Ground	19%	19%
Water	7%	19%
Air	3%	0%
Other	10%	13%
Thinks is Local Environmental Problem	33%	44%

The terms included in “other” remain quite varied and general (e.g., in bodies, poisons, chemicals, cigarettes, minerals, liquid, in the USA, everywhere.), as did the low incidence of students thinking that arsenic is found in the air.

Task #3: Environmental Mystery: In the post-test, students were presented with the following environmental mystery:

Scenario: Audrey's lawn borders a golf course. She has noticed that for the first time in 20 years, there is no sound of spring peepers coming from the pond located in the golf course. While walking her dog, Rocko, near the pond, she observed the following:

1. The pond's water had dropped to half its usual volume.
2. There was a thick green scum of algae growing on the surface.
3. A man dressed up in a moonsuit-like covering was packing empty Round-up (a commonly used herbicide) into the back of a truck.

Design an investigation that would begin to study the reasons for the disappearance of the spring peepers.

Thirty four students chose to respond to this mystery. (13 students chose to respond to a second environmental mystery about brine shrimp.) Analysis of their responses indicated that 20% (7) of the students indicated clear references to concentrations, doses and levels of toxicity; several students even referred to doing LD (lethal dose) 50 experiments.

23% (8) of the students included actions referring to testing of the pond water for the presence of Round-up. Responses by several students also indicated the notion of the pond's broader ecosystem.

*I would test the level of Round up in the water. If there were any dead frogs I would test the level in them too. Then I would ask the superintendent of the golf course what the concentration of round-up he was using in. I would collect some of the algae and bring it to a lab and have it tested for what its components were. If there was a large amount of Round up in the water I would tell the town about it and have the course shut down.*

Several students also included references to the importance of testing soil samples, and the possibility of run-off or that round-up was absorbed through the ground.

*I would get a sample of the water, bring it to a lab and get it tested. I would also get some soil tested. If I found Round-up in the water I'd tell the golf course manager what is happening.*

*I think the reason why Audrey doesn't see or hear spring peepers is because they are putting chemicals (toxic) on the golf course and it is running into the pond*

*I would figure out and ask where the RU is going. I think all the RU from the golf course absorbed through the ground and went into the pond. Once it got into the water the spring peeper ate it and killed all of them.*

In addition to analyzing students' responses for the presence or absence of the concept of dose response, or the need for testing of the water, students' responses to this environmental mystery were also examined for the extent to which a focused multi-step or multi-faceted investigative process was described. Students' responses were coded as falling into one of four categories of response:

*Level 1:* Able to cite relevant observations from the scenario, but bases conclusions and performs actions in a non-investigative manner.

*Level 2:* Describes actions pertaining to the testing of pond water, and/or doing an experiment.

*Level 3:* Describes two actions or steps in a single investigative process, or a coordinated set of investigative actions, with some minimal flow and logic.

*Level 4:* Describes three or more actions or elements relating to a single experimental design, with a moderate flow and logic.

Of note, over 2/3's of the students offered responded that included the need for some type of scientific investigation, either in the form of water testing, or an experiment (68%; total of Levels 2-4). Students were relatively equally distributed across the four categories, with 26% being in each of Levels 1 and 2, while 21% were in each of Levels 3 and 4.

At the most basic level, 26% (9) of the students offered a variety of conclusions of what they thought was the cause of the disappearance of the spring peepers, given the clues in the scenarios. Some students were able to offer some educated guesses about they thought might be causing the peepers' disappearance, but largely described discrete clues they noted or actions that they would take.

*I think the peepers were killed or were stunned and moved to a new healthy environment because of the Round up. I would contact the person or owner of the golf course and tell him that the pond on the golf course are affected by the Round up killing/harming the peppers and what ever else could be in there living.*

*There probably wasn't enough water for the spring peepers to live in.*

*The round-up most likely killed them.*

*Round-up may have gotten into water.*

*Spring peepers probably need to have fairly clean water.*

*Spring peepers may not like that kind of algae.*

*That certain kind of algae may kill the spring peepers.*

*If the water is half-way down then that could have caused the frogs to migrate, or maybe their prey died from the Round-up, you can tell their prey died somehow because the top of the lake is covered in algae. So my guess would be that their*

*prey died from Round-up and they died of three reasons. 1) Lack of food. 2) the frogs were killed by the Round-up, 3) They ate contaminated prey or maybe they just migrated, who can tell?*

*I believe the reason why the spring peepers are not there in the pond is because the water is too low and the RU is running into the pond which is poisoning their food and water and possibly kill their food. I'm not sure why the water's low, but it might from lack of rain. If you want the peeper back simply stop using RU. Clean the pond and put some more water depending on its size*

Offering a somewhat more scientific response, 26% (9) of the students indicated that they would test the pond water and/or conduct an experiment.

*I would test Round up in water to see if it started killing the fish or peepers. I would also see if it grew the algae on top... I would see if it caused other problems. Because if the dose of the Round up is too much it will be really harmful.*

*Interview the owner of the golf course. You could test Roundup on goldfish then test their gill movement per second.*

*I would make an investigation on the round-up they were putting on the golf course.*

*#1 – I would go to the owner of the golf course and ask why they were using the Round up.*

*#2 – I would take a sample of the water and have it tested to see if it's safe.*

*#3 – I would put spring peepers in the water to see what would happen to them.*

The third level of response involved students describing more than one step in a single investigative process, or a coordinated set of investigative actions, with some minimal flow and logic. 21% (7) of students responded in this fashion.

*Make a RU solution and see how much affects the spring peepers. Then find out how much the golf course uses and depending on those things you can determine whether that is what killed the spring peepers.*

*The first thing Audrey should do is contact the golf course manager what kind of chemicals they use on the course. Then she should take some of the pond water and put it in a tank. First she should attempt to find how much RU is in the water. Then she should try putting small fish in the tank to see if the water it toxic.*

*The first thing I would do is take a sample of the pond water and see what the acidity level is. Then I would buy some RU and mix it in with faucet water and check the acidity level of that. Then I would take a sample of the algae and talk to a science teacher about it. After all my observations I would talk to the manager about the RU and show him the pond.*

The fourth level of response indicated a multi-step investigation, consisting of three or more actions or elements relating to a single experimental design, with a moderate flow and logic. 21% (7) students responded with this most detailed level of response. Students' responses were in varying degrees of specificity.

*Get a peeper, take about 2 bucketful of the RU from the pond. Put the peeper in 1 bucketful of RU; watch your results; write down your result. Take the other bucket of RU and test it; to see what it is.*

- 1. A hypothesis on what you think is happening (hmm, I wonder?)*
- 2. Research data on RU and harmful effects.*
- 3. Test hypothesis, test toxicity of water, and algae.*
- 4. Make theory*
- 5. Take the problem to the board of environmental hazards (if there is one.)*

*I would begin with making different solutions of Roundup and testing them on the frogs and the behavior of the frogs after the Round-up was mixed with their water. To see if the frogs' breathing changed at all with the Round up. And if the frogs died I would know that they're spreading too much Round-up on the golf course.*

*Step 1: Get a sample of the water and the algae.*

*Step 2: Then I would find out how much Round up is in the water.*

*Step 3: After finding out how much Round up is in the water, I would make my own solution but with that same amount of Round Up.*

*Step 4: I would put peepers in the water. I would study how it affects them. If they die, then it's the Round on the golf course that's killing them, and the course needs to make better steps to spraying pesticides without killing animals.*

- 1. First you need to find the needs of a living frog.*
- 2. Then conduct a LD 50 experiment by buying RU and frogs.*
- 3. Make different solutions of RU, like 1, .1,.01, and so on.*
- 4. Have a control of frogs. Frogs in a healthy environment. If they die, the experiment is useless, study the frogs. Find out what a healthy frog looks like.*
- 5. Put the frogs in the solution.*
- 6. Study the frogs.*
- 7. Find out what solution they die out.*

*I would test the RU to see if it was toxic to goldfish instead of using frogs. I would put goldfish in many different solution of RU and see if the water level drops, if a green algae developed, and if the round up killed the goldfish. I would use a 1%, .01%, .001% and 10% solution of RU. I would do the experiment numerous times to make sure I wasn't getting some weird results. I would use a data sheet that looked something like this*



*Solution/Number dead*

*.001%*

*.01%*

*1%*

*10%*

*That is roughly what it would look like.*

In summary, 68% of the students were able to respond to the environmental mystery task by indicating either briefly, or in some level of detail, the ways in which they would conduct tests on the pond water, and/or conduct a lab-based experiment focusing on the effects of Round Up on frogs or another organism such as gold fish.

Task 4: Students' Posing of Environmental Questions: The most open-ended task of the surveys was one in which students were asked to think about any concerns or questions that they might have about the harmful effect of things in the environment on people or other living things, and to pose these concerns as questions they would like to have answered. This problem type was designed to assess students' concerns and awareness about the environment and the general kinds of orientation for question-posing they possessed.

The questions students posed on the pre-tests typically featured topics of pollution, diseases (e.g., West Nile virus), or global warming, the ozone layer, or disasters such as oil spills. A small number of students posed questions regarding the harming of wild animals such as deer, and questions about trees, presumably reflecting the current unit they were doing on field ecology just prior to their *Environmental Detective* unit. The handful of students who posed questions featuring chemicals touched upon the testing, handling and effects of harmful chemicals.

*Who discovered all those chemicals?*

*If a chemical disease is airborne, do birds die first?*

*If harmful chemicals were found in the environment, what would be done about it?*

*What can you do if you know there is too much of a certain chemical in your area/house?*

*Why don't we just make certain chemicals illegal to use?*

In contrast, a greater numbers of students posed questions on their post-test surveys which included reference to chemical effects in the environment (16%), mention of specific chemicals (e.g., arsenic, copper, mercury, chlorine, ammonia, lead, nitrogen) (32%), as well as cited specific commonly used "chemical treatments" such as road salts and "round up".

**Table 3: Students' Awareness of Chemicals as Environmental Concerns, as reflected by Questions Students Posed**

<b>Terms Mentioned</b>	<b>% of students on Pre-test</b>	<b>% of students on Post-test</b>
"Chemicals"	10% (5)	16% (8)
Specific chemicals by name (e.g., arsenic, copper, mercury)	6% (3)	32% (16)
"Road salt" or "Round-Up"	0%	16% (8)
Local environmental locations	0%	10% (5)
Reference to amount of a certain chemical	0%	10% (5)

(n = 49 for matched sample of pre-tests and post-tests)

A small number of students (10%) now posed questions referring to specific locations in their local environment:

- What percent of Vermont's water polluted?*
- How can we prevent water near the Elizabeth Cooper Mine from becoming polluted?*
- What would happen if there was a spill of arsenic in the White River?*
- Would someone use DDT in Vermont?*
- What is really wrong about fish in the Connecticut River?*

A similar proportion of students (10%) also produced questions on their post-tests that reflected a notion of dose response, and queries pertaining to the effects of an amount of a certain chemical:

- Do we need a certain amount of carbon in our bodies to live?*
- How much arsenic is good for us?*
- How much chlorine would be considered toxic?*
- Will too much mercury in the rivers effect humans if they went swimming?*
- How much fish out of the Connecticut River would hurt us [if we ate them]?*

As shown in Table 4, the contrast between the questions students posed before and after their use of the Environmental Detectives curriculum could be quite striking, indicating the impact of the curriculum on students' awareness and interest in chemicals in the environment.

**Table 4: Changes in how Individual Students Posed Environmental Questions, before and after Environment Detectives**

Individual Students' Pre-test Responses	Same Students' Post-test Responses
<i>How can we prevent diseases such as West Nile Virus from infecting animals?</i>	<i>How can we prevent water near the Elizabeth Cooper Mine from becoming polluted? Are there safe chemicals that can be used on golf courses to protect aquatic life?</i>
<i>What is so wrong about global warming?</i>	<i>Is road salt hurting plants living near the road? Can all local rivers or streams be checked to see if they are clean?</i>
<i>What makes the leaves turn different colors?</i>	<i>What are the long term effects of mercury on humans?</i>
<i>Lead poisoning from shotgun cartridges.</i>	<i>If our bodies need arsenic, how come it's deadly to us? Could lead in our drinking water kill us?</i>
<i>What happens if there is an oil spill?</i>	<i>How lethal is mercury to animals/humans? Why is nitrogen bad?</i>
<i>I am concerned about water getting polluted.</i>	<i>How do chemicals that are not native to this area become introduced to this area? How much arsenic is good for us?</i>
<i>If harmful chemicals were found in the environment what would be done about it?</i>	<i>How does mercury get into the environment? Do we need a certain amount of carbon in our bodies to live?</i>
<i>Who discovered all those chemicals?</i>	<i>What exactly is ammonia? How harmful is arsenic?</i>

### Summary of Students' Performance on Learning Tasks

In summary, students' baseline responses on the pre-program surveys suggested that many students began the *Environmental Detectives* unit with an orientation focusing primarily on the biological world (e.g., plants and animal), and in which environmental problems were mainly thought of in terms of pollution, natural disasters, and issues such as global warming. Most students possessed a basic level of awareness about the degree to which certain chemicals and elements were generally considered harmful (e.g., lead, mercury, arsenic) or healthy (e.g., calcium, oxygen, iron) for their bodies. Sources of chemicals were commonly traced to "man-made" or common objects (e.g., lead being in pencils, paint or pipes, mercury in thermometers, calcium found in milk.)

Students' responses on their post-program surveys following their use of *Environmental Detectives*, indicated an emergence of students' notion of dose response and increased awareness of specific chemicals in the environment. This was observed in students' rationale of why they held a certain point of view about an environmental problem, their process of solving an "environmental mystery," and in the kinds of specific questions and concerns they had about the environment. Students also indicated an increased awareness of chemicals and elements residing in natural sources (e.g., in the ground, air and water), and in their own local environment. Furthermore, following their use of the ED curriculum, students began demonstrating a level of ability of solving environmental mysteries using experiments and investigations they could conduct (e.g., testing of pond water, or experimental lab tests of the effects of chemicals on living organisms), with

increasing definition of the various steps and components of an experimental design and procedure.

The various findings from these learning tasks, coupled with students' interest and engagement in the variety of activities and investigations available through the *Environmental Detectives* curriculum, indicates the positive impact of *the Environmental Detective's* curriculum on students' awareness and interest in chemicals in the environment.

### **Update: Activities for Current Year 3 Evaluation**

Evaluation activities are currently underway in Year 3. A total of five science teachers, new participants to the *Environmental Detectives* project this year, are involved in the current field testing of the new version of ED curriculum units. The teachers are trying out the ED curriculum in four different schools in Hartford, Thetford and Sharon, Vermont, and in Orford, New Hampshire

All five teachers were present during the 2002 Summer Institute, and are actively engaged in trying out the ED curriculum during the current 2002-03 school year. Evaluation activities include observation of the 2002 Summer Institute and regular teacher-project staff meetings, classroom observations of teachers using *Environmental Detectives*, pre-program and post-program student questionnaires, examination of student work, and interviews with field test teachers, project staff, and Dartmouth faculty. The major foci of this year's research will include: 1) an examination of the ways in which the ED curriculum is incorporated into different teachers' current science curriculum and classroom practices; 2) teachers' perspectives on the distinct educational value, and challenges, of the ED curriculum, and 3) the particular contributions of the Dartmouth College component, linking teachers and students with scientists, faculty, and scientific research at the College.

## Appendix A; Students' Reactions to Individual Environmental Detective Activities

Name of Activity	# of Students	Reasons liked or disliked
<b>Aquifer Model</b>		
Students Liked Most	14	Got to build things/models. Able to design it & see if it would work. Not all planned out for us. Context – see where water from parking lot would go; build our own wells Liked when we made the diagram
Students Liked Least	4	It didn't make much sense, wasn't clear; pretty boring. Didn't really see why we did it. I didn't really make any sense to do that. The one we made didn't work and I didn't really understand it. It was hard to understand...because of all the different steps it takes to make one.
<b>Investigations</b>		
Students Liked Most	17	I really like the investigations & the researching, because we got to discuss our experiment and conduct it our own. Working with others/in a group Interesting finding out things I had never known before. Knowledge I gained out of it. When I'm trying to find the info for the poster, I learn it. Then when other people in my group and I talk about it, it makes even more sense. We got to work with daphnia & talk to scientists from Dartmouth. I like to do diagrams & doing poster presentations. Making the poster was really cool. Had to find information & we got to tell people what we found.
Students Liked Least	4	It was hard to divide the work evenly between all of the people in the groups. And have it more relaxed with more time. Our experiment failed to have any positive results :☹ It was hard and it took a long time.
<b>Case Studies</b>		
Students Liked Most	8	Fun learning about the different stuff & reading the articles. Gave me a chance to learn more about oil spills & also ask a professional (in that situation) some questions that I had. Got to try different things to see what was toxic. Articles were interesting. Got to see what really is a problem locally. Got to learn more about that one subject & answer some questions.
Students Liked Least	10	Too much writing. Too much reading. I liked the interview but I would have liked to maybe find the articles instead of having them given to me. Hard and boring w/ all the research we had to do. Too much writing, research & answering questions. You didn't have a choice if you wanted to interview someone.
<b>Groundwater</b>		
Students Liked Most	9	I like working w/ my hands & using water tables. Fun testing with it. Got to build stuff & play around. Got to figure out things for ourselves & find the different parts Got to set it up in the diagram, and actually see it. Got to see how the water moved through the ground. Got to learn about how a well like mine at home works, and many

		different ways to see how it does work. Was fun. Clearness in how to conduct this experiment & the outcome of this experiment.
Students Liked Least	1	Could not understand how to do the activity.
<b>Soda Bottle Challenge</b>		
Students Liked Most	8	We had fun designing the experiment. Made me think about how I was going to do something. Kind of related to real life stuff. Fun trying to stop water flow out of the bottle. It was fun using the clay and other things to get the water to flow out a certain hole in the bottle. Interesting to see what the water would do.
Students Liked Least	0	
<b>Porosity</b>		
Students Liked Most	6	I liked making the models. Got to make our own design. Fun using the clay. Fun to see the differences. Something I can use in the real world for knowledge. And it was cool how you have to have the right soil type to have such things like a well, foundation & septic tank. And how we got into things like mound systems & how they work. I could understand how to do the activity.
Students Liked Least	0	
<b>Experimental design/Yeast experiments</b>		
Students Liked Most	6	Really easy & fun (& quick). Didn't last too long. We got to use many different things & it wasn't all planned out for us. It was hands-on. It was independent work. We got to define it ourselves and see what worked and what didn't. It's fun to watch things reproduce rapidly and/or overflow.
Students Liked Least	2	Didn't find it interesting. Hard to clean up after, and we didn't have enough time to conduct our experiments.
<b>Concentrations</b>		
Students Liked Most	4	We worked with harmful things & I like kind of dangerous things. Was more interesting hands-on activities. Making the solutions was really cool. I liked seeing how the substance changed when it was diluted.
Students Liked Least	1	Boring, sometimes confusing.
<b>Permeability</b>		
Students Liked Most	3	Got to work with our friends & w/ clay and see how water moves through the ground and filters itself. It was easy and fun and interesting on how some water systems work today.
Students Liked Least	0	
<b>Research Scientist #1</b>		
Students Liked Most	7	Better understanding of things he is researching & what we researched. Learned a lot of things such as how many new chemicals they invent every day. Talked to us about arsenic and how the earth formed.

		<p>Was interesting, learned a lot.  The stuff he told us about how VT &amp; NH used to be millions of years ago was really cool.  He was very resourceful &amp; gave a lot more history in VT and NH.</p>
Students Liked Least	19	<p>Too long &amp; boring.  Not involve us in his discussion.  Just sat and listened to him. Didn't do any hands-on activity with him.  Was too in-depth for us. I didn't understand what he was trying to get at.  He used a lot of really hard words that confused me.  ...But fun to learn Jesse's is in an ancient volcano.  ...But facts were interesting  ....But I liked him and thought he was cool.  ...But had good information  ...But it was kinda cool that he could work on it for the rest of his life and never solve the problem.</p>
<b>Research Scientist #2</b>		
Students Liked Most	6	<p>Fun to talk with about our experiment  Very interesting to listen to because she knew a lot about what we were doing.  It's nice to see what other people have to say about our stuff.  Explained how we could make the smaller solution.  She helped me out during my project and she was nice.  She had some interesting things to say that helped us.</p>
Students Liked Least	3	<p>They talked too much and used too big words, and made it sound boring.  I didn't get involved in it – like all the explaining about methods &amp; procedures.</p>