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1. INTRODUCTION

Current research and emerging standards in teaching and learning say that students learn best when information is presented in a meaningful context and when the students are involved in things they care about (NRC 1992; NCISE 1989). At the U.S. Department of Energy's (DOE) Pacific Northwest Laboratory (PNL), science education programs have been developed that incorporate these concepts. To help students and teachers understand the process of "doing" science, we provide immersion-based programs in such technical areas as meteorology, marine sciences, wetland ecology, groundwater hydrology, robotics, lasers materials science, biology, and archaeology. This paper focuses on a meteorology program the authors developed in recent years to support this immersion experience approach. We will discuss how we link meteorology with other subject matter, how we show the relevance of meteorology to real-world problems, and how we immerse students and teachers in activities that help them understand how scientists uncover knowledge and solve problems.

2. SCIENCE EDUCATION PROGRAMS AT PNL

The DOE has established a goal to work through its national laboratories to improve mathematics, science, and technology education in our nation's schools. Pacific Northwest Laboratory is actively engaged in this mission at national, regional, and local levels. Pacific Northwest Laboratory's main research center is located in southeastern Washington State at DOE's Hanford Site. The Hanford Site covers 1,450 km^2 (560 mi^2) and was acquired by the federal government in 1943 for the production of materials used in the nation's nuclear weapons program. Pacific Northwest Laboratory's original mission was to provide basic research support for Hanford operations, but over the years, both Hanford's and PNL's missions have changed and expanded. Today, the defense production mission of the Hanford Site is ended, and an environmental restoration mission is in full swing. The approximately 4,500 staff members at PNL are currently conducting research in such diverse areas as environmental sciences (including the atmospheric sciences and oceanography), waste technology, materials sciences, molecular sciences, health physics, robotics, and the social sciences.

With such a high concentration of scientists and engineers, PNL is uniquely positioned to play a major role in assisting educators with developing and improving science education. At PNL, our Science Education Center works with students and teachers from kindergarten through community college. In the area of meteorology, PNL scientists work in three separate programs that target elementary teachers, middle school students and teachers, and high school students.

In the SCIENCE ALIVE program, elementary teachers visit our research centers to attend multi-day programs designed to enhance the teachers' content knowledge and instructional strategies in the environmental sciences. In a 4-day program, teachers are presented with a simulated research problem, undergo training to provide them with the basic tools necessary to address the problem, and work in teams to solve the problem. The problems and training sessions are designed to immerse teachers in the research experience. They must follow the common scientific approach and observe, learn, reason, communicate, and work together to successfully address the problem. After addressing the research problem, the teachers are asked to think about what they have done, discuss their experiences, and to work with our science education staff to develop

strategies for incorporating the SCIENCE ALIVE experience into their classroom program.

The OPTIONS in science program targets regional middle schools with high minority populations. Besides employing teacher workshops that use the same teaching-learning model used in SCIENCE ALIVE, the OPTIONS program sends teams of scientists to schools for special science and technology days. At the schools, students rotate between various classrooms in which scientists have set up equipment for lectures, demonstrations, and hands-on activities about a particular field of science or engineering. Another component of OPTIONS involves scientists and teachers working one-on-one over the course of the school year to develop or enhance curriculum material and bring innovative (but affordable) technology into the classroom.

In the DOE High School Student Honors Research Institute, high school students from each state and foreign countries participate in a 2-week summer program that provides an intensive research experience in the environmental sciences. Students and PNL researchers working together study both the arid environment of southeastern Washington State and the marine environment found on the Olympic Peninsula in the northwestern part of the state.

Goals of these three science education programs are to

- do "live" science
- demonstrate that science knowledge can be used by everyone in their daily lives and is important in a variety of professions, many of which we do not generally think of as requiring science knowledge (e.g., police work, fire fighting, construction)
- show how knowledge from many different, seemingly unrelated fields must often be brought together to solve real-world problems
- show students and teachers that scientists are men and women of all ages, with diverse personalities, who come from all sorts of economic and cultural backgrounds
- increase awareness of science and engineering career paths for young people
- to help students and teachers understand what motivates a scientist
- to update teachers' knowledge of fundamental concepts of science
- to enhance teachers' abilities to use hands-on science in the classroom.

3. THE IMMERSION EXPERIENCE - METEOROLOGY "ALIVE"

To illustrate how we use meteorology in these programs, we will detail the 4-day immersion experience we provide for teachers through the SCIENCE ALIVE and OPTIONS program. To provide a relevant and exciting context for meteorology, we have integrated our training into an emergency response scenario.

3.1 *Day 1 - Morning Session*

At the beginning of our first session together, we tell teachers that they will be subjected to a 2½-day crash course on meteorology, atmospheric dispersion modeling, industrial hygiene, health physics, and related fields. At the completion of this training they will each be assigned roles on an emergency response team. They will then have to use their newly acquired knowledge and skills to perform essential duties and work together during a realistic emergency response exercise. We then tell them that if they each perform well during the exercise, their team should successfully be able to develop an effective and appropriate response to the emergency incident; however, if one or more of them perform poorly, there may be "severe consequences" for team members and innocent bystanders.

If this sort of no-nonsense introduction has not captured everyone's attention, a follow-up announcement is then made requesting that anyone suffering from heart disease, respiratory problems, or claustrophobia identify himself or herself to the instructors at the first class break. There really is not any health threat posed by our carefully monitored program, but the implication that there may be is a very effective tool for increasing the attention level of the teachers. With the class paying rapt attention, they are led through a brainstorming session to discuss the type of skills and information they will need to handle a particular emergency response situation. This session is an introduction to the multi-disciplinary nature of real-world problems and scientific research.

Before the end of this first session, the class is given a schedule for their 4-day program. This schedule is outlined in table 1.

TABLE 1. Sample Schedule for SCIENCE ALIVE Training.

Day 1 -	morning -	initial briefing and statement of problem
	afternoon -	meteorology training at Hanford Meteorology Station
Day 2 -	morning -	lecture and training in atmospheric dispersion modeling
	afternoon -	industrial hygiene and protective equipment training
Day 3 -	morning -	health physics and radiation worker training
	afternoon -	emergency response exercise and initial debriefing
Day 4 -	morning -	discussion of meteorology program experiences
	afternoon -	develop ways to incorporate information and teaching techniques into the classroom

3.2 *Day 1 - Afternoon Session*

In this session, we train teachers in meteorology and weather forecasting. At the Hanford Meteorology Station, we give a brief lecture on the essentials of meteorology and weather forecasting. Then we introduce them to the equipment used to monitor the atmosphere (Glantz and Islam 1988) and the systems used to communicate weather information. Teachers access weather maps and satellite photos, plot their own surface weather maps, access up-to-the-minute regional and local forecasts, release and track a weather balloon to measure the vertical variation in the winds above the station, and use the station's other atmospheric monitoring equipment.

3.3 *Day 2 - Morning Session*

This session begins with a short lecture on atmospheric dispersion and dispersion modeling. The teachers learn about atmospheric transport, the spreading of pollutants through turbulent diffusion, and the behavior of different types of chemical compounds in the atmosphere. After receiving a short briefing on the various types of atmospheric dispersion models and their applications, teachers break into small groups and spend time operating a user-friendly atmospheric dispersion model (Ramsdell et al. 1983).

3.4 *Day 2 - Afternoon Session*

To tie meteorology and atmospheric transport to real world problems, teachers learn about the relationship between these topics and hazardous materials. Teachers receive some basic information about hazardous chemicals, their effects on the human body at various concentration levels, methods for detecting hazardous chemicals, and emergency methods for cleaning up chemical spills. The teachers then receive hands-on instruction on protective clothing, respiratory equipment, and procedures used by emergency response teams to protect themselves from harmful exposures. As part of this training, the class dresses in full protective gear, including self-contained breathing apparatus (for nearly all teachers, this is the first time they have ever worn such equipment, and it really is a stimulating experience). One lucky volunteer dresses in a fully encapsulated suit that totally insulates him or her from the surrounding atmosphere. Other teachers observe firsthand the drawbacks of working in such an environment. Next, a short hazardous waste remediation exercise is conducted in which teams of teachers monitor and remediate a chemical spill.

3.5 *Day 3 - Morning Session*

This session involves training in both health physics and radiation protection. During the previous afternoon's session, teachers learned the hazards of toxic materials; now they are trained in the hazards associated with radioactive materials. They also learn about naturally occurring radiation sources, radiation detection methods, and exposure monitoring. The teachers complete this session by using monitoring equipment to measure the radiation coming from naturally occurring rock formations, glazed pottery, a salt substitute, and other common objects. This information is used to put risks in perspective and give teachers a feel for the concept of relative risk.

3.6 *Day 3 - Afternoon Session*

At this point in the program, we have trained teachers in meteorology and forecasting, dispersion modeling, hazardous chemicals, and radiation. They now have enough information to perform as members of an emergency response team during a simulated accident. While finishing their lunches at the Hanford Meteorology Station, an alarm unexpectedly sounds, and the class is hurriedly mobilized into an emergency response team. The teachers are presented with the following scenario:

> A train hauling tanks of liquid chlorine and other materials has derailed after striking a large truck. The truck was reportedly transporting radioactive material to a disposal site. Initial reports from near the accident scene indicate that one or more chlorine tanks have ruptured or are leaking, several small fires are burning, and that no human activity has been observed near the train or truck wreckage. More information will be forthcoming when emergency response crews approach the accident site.

The class immediately divides into four teams and are given the following missions:

Team 1 - Meteorology

- assess current meteorological conditions (e.g., surface winds, winds aloft, precipitation, temperature, relative humidity)
- forecast future conditions

Team 2 - Environmental Transport Modeling

- model potential airborne transport, pollutant exposure, and deposition
- estimate pollutant concentrations and perform risk assessments

Team 3 - Field Assessment

- select and don appropriate protective equipment
- travel to the accident site, monitor the situation, and provide timely reports to the emergency response center
- perform initial on-site remediation activities

Team 4 - Command and Control

- coordinate activities of the other teams
- disseminate information
- select appropriate protective actions for site workers and the public
- provide information to the public.

As the teacher teams begin performing their job functions, the exercise controllers simulate the input of outside information and control the direction of the exercise. "Real-life" events are simulated as the teams receive contradictory information (i.e., inaccurate field reports mixed in with reasonable information). The teams must also contend with changing environmental and accident conditions, equipment malfunctions, safety rules, and aggressive press personnel hunting for a story.

As well as stimulating the teachers beyond their expectations, the emergency response exercise forces team members to recall and apply what they learned earlier in the workshop—they must observe, think creatively, communicate effectively, and reach team decisions.

Over the course of the exercise it is clearly demonstrated that in the real-world, scientific knowledge is not just needed by scientists in the laboratory, but that policemen, paramedics, journalists, business managers, government officials, and other non-scientists can also make good use of scientific knowledge. The teachers also learn that different fields of science are not totally separate from each other—scientists and decision makers need to meld information from a variety of fields (e.g., meteorology, chemistry, physics, and life sciences) to make appropriate decisions that affect real people.

As things begin to slow down during the scenario, team members rotate to another emergency response team so that they can experience another job.

After the exercise is completed, we debrief teachers about the exercise, and they review what they did right and wrong. The exercise controllers describe the complete exercise scenario and assess the teams' successes and failures.

3.7 *Day 4 - Morning and Afternoon Sessions*

Pacific Northwest Laboratory's education specialists step in at this point and lead the final day's sessions. The day begins with a group discussion about what the team has learned, and how this knowledge can be applied to the problem scenario. The teachers discuss new questions that have arisen during their activities, the concept of uncertainty, and recommendations for further research. Teachers are then asked to take what they have learned and translate it into live science activities for their students. Because the scenario we created is designed for adult learners, teachers have to use their knowledge and skills to adapt what they have learned to fit their students' abilities. The teachers are asked to create a science immersion experience for their students by

- articulating student outcomes
- developing questioning strategies to encourage science inquiry
- identifying or creating appropriate learning activities
- identifying available resources (people, materials, facilities)
- designing instruction to parallel the approach taken by practicing scientists to gain knowledge and solve problems
- creating a science "story" (scenario) to provide meaningful context.

The teachers are then asked to evaluate the plans they have created to see that outcomes, questioning strategies, activities, resources, instructional approach, and the overall scenario work well together.

We ask the teachers to check the realism of their plans by applying a logic test: Is what you plan to do possible? Can you get what you need? If not, modify your plans so you can be successful.

Throughout this planning process, we encourage the teachers to include not only resources and activities discussed during their SCIENCE ALIVE or OPTIONS experience, but other resources available to them. The key is for the teachers to develop the ability to apply this type of approach for teaching meteorology as well as other areas of science and technology.

4. CONCLUSIONS

A number of conclusions can be drawn based on our experience with science education at PNL. First, real-life problems are an effective method of raising participants' interest level. Second, an exciting exercise, in which teachers or students are forced to use their new-found knowledge, helps them retain the lessons they have learned long after the program is over. Third, putting science information in context with real-world problems helps teachers or students learn the importance of the specific subject being taught.

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