SCIENCE, SOCIETY, AND AMERICA'S NUCLEAR WASTE: A RESOURCE CURRICULUM

Ginger P. King, Director
Education and Information Division
Office of Civilian Radioactive Waste Management
U.S. Department of Energy
Washington, D.C.

Timothy L. Hill
Senior Program Manager
Science Applications International Corporation
Washington, D.C.

ABSTRACT

It is crucial that today's students understand what nuclear waste is and how it can be disposed of safely. The generation now in school will play a major part in managing this waste in the years ahead. In response to teacher and student request, the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management has produced "Science, Society, and America's Nuclear Waste," a four-unit secondary resource curriculum. The product of six years of research and development, the curriculum provides information about scientific and societal issues related to the management of spent nuclear fuel from nuclear powerplants and high-level radioactive waste from U.S. defense activities. This paper discusses this curriculum, its design, format, validation, and use.

INTRODUCTION

The Nuclear Waste Policy Act of 1982 and Amendments require DOE's Office of Civilian Radioactive Waste Management to develop and operate a waste management system that will provide safe storage, transportation, and permanent disposal of spent nuclear fuel and high-level radioactive waste. Developing the system is a long-term task. Under current plans, the earliest a permanent geologic disposal site -- the major component of the system -- will be ready to receive spent nuclear fuel and high-level radioactive waste for disposal is the year 2010. Much work will need to be done and many decisions will need to be made before the system is complete and fully operating.

Making decisions about complex issues is difficult; in fact, often the more information that is available and the more people that are involved in the decision process, the harder it is to make decisions. However, it is also true that decisions based on more knowledge and with more participation are that much more sound and readily accepted and implemented. Developing the system involves very complex technical and societal issues and problem-solving, and the law requires participation by States, Indian Tribes, and the public in this process. Responsible participation and making societal decisions about how to manage and dispose of nuclear waste requires some understanding of both the science involved and of how decisions about nuclear waste management may or may not affect people and the environment.

Because of the long-term nature of the task and its technical importance to society, it is crucial that today's students understand what nuclear waste is and how it can be disposed of safely. While an older generation is currently planning for the disposal of nuclear waste, the generation now in school will play a major role in managing the waste and disposing of it. Today's students will be in positions of responsibility when the plans become reality and the waste management system and facilities are operating.

In response to years of teacher and student requests, and to help prepare today's students to be responsible citizens of tomorrow, the U.S. Department of Energy's Office of Civilian Radioactive Waste Management (DOE/OCRWM) has produced a secondary resource curriculum entitled, "Science, Society and America's Nuclear Waste." This 4-unit, 30-lesson curriculum is the product of 6 years of development and teacher/student testing and provides information about scientific and societal issues related to the management of spent nuclear fuel from nuclear powerplants and high-level radioactive waste from U.S. defense activities. The curriculum is available to teachers free of charge and is provided only to teachers who specifically request it.

The intent of "Science, Society, and America's Nuclear Waste" is to provide teachers with supplementary materials that are relevant for science and/or social studies classes and will help students prepare for informed, active participation in the democratic process as they go through life. More and more, decisions in our technologically sophisticated world require interface among science, technology, and society. This resource curriculum is designed by using science, technology, and society criteria as the guiding principle.

DESCRIPTION OF CURRICULUM

The curriculum contains materials for both students and teachers. Student materials include readings, review exercises and activities, a glossary and index for each unit, and an index for the entire four units. The Student Readers are each approximately 50-60 pages long and entitled: Unit 1 - Nuclear Waste; Unit 2 - Ionizing Radiation; Unit 3 - The Nuclear Waste Policy Act; and Unit 4 - The Waste Management System (see Fig. 1).

Teacher materials include a Teacher's Guide for each of the four units and supplemental teaching aids. Each Teacher's Guide contains the corresponding Student Reader material and about 250 pages covering classroom activities, readings, and transparency masters; background notes; suggested daily lesson plans and procedures; sample discussion questions and answers; suggestions for enrichment activities; and a metric conversion table. Additional materials available to teachers free of charge from the Civilian Radioactive Waste Management Information Center in Washington, D.C.

Science, Society, and America's Nuclear Waste

UNIT 1
NUCLEAR WASTE

- Unit 1 Introduction
- Reading Lessons
  - Energy and Electricity Review
  - Nuclear Waste: What Is It? Where Is It?
  - Unit Summary
- Glossary
- Index
- Bibliography

UNIT 2
IONIZING RADIATION

- Unit 2 Introduction
- Reading Lessons
  - Ionizing Radiation: Sources and Exposures
  - Unit Summary
- Enrichment Reading Lessons
  - Atoms and Isotopes Review
  - Biological Effects of Ionizing Radiation
  - Radioactivity Review
- Glossary
- Index
- Bibliography

UNIT 3
THE NUCLEAR WASTE POLICY ACT

- Unit 3 Introduction
- Reading Lessons
  - The Nuclear Waste Policy Act: An Overview
  - Probability: The Language of Risk Assessment
  - Unit Summary
- Glossary
- Index
- Bibliography

UNIT 4
THE WASTE MANAGEMENT SYSTEM

- Unit 4 Introduction
- Reading Lessons
  - What Measures Ensure Safe Transportation of High-Level Nuclear Waste?
  - What Will A Geologic Repository Look Like?
  - The Role Of The Monitored Retrievable Storage Facility

  Unit Summary
- Enrichment Reading Lessons
  - Rock Characteristics Important in Repository Siting
  - Ion Exchange and Zeolites
  - Topographic Map Skills
- Glossary
- Index
- Bibliography

Fig. 1. Table of contents-student edition.

(1-800-225-NWPA, or in Washington, D.C., 488-5513) include: videotapes on a variety of topics related to nuclear waste management; an IBM computer software program on risk; selected readings on international waste management; and exhibits that are available for loan to schools.

The curriculum, supporting classroom activities, and teaching materials present a brief discussion of energy and electricity generation, including that produced at nuclear powerplants; information on sources, amounts, location, and characteristics of radioactive waste, including spent nuclear fuel and high-level radioactive waste; sources, types, and effects of radiation; the U.S. policy for managing and disposing of spent nuclear fuel and high-level radioactive waste, and what other countries are doing; and the components of the nuclear waste management system. The resource curriculum is modular and flexible. It can be used in its entirety or selectively depending on student background, ability, and interest, as well as time constraints, curriculum requirements, and other guidelines.

Unit 1, "Nuclear Waste," introduces students to energy and electricity generation, including nuclear electricity generation. It discusses the relevance of the topic of nuclear waste to students' everyday lives and activities. The unit provides an examination of the different types of nuclear waste; the geographic distribution of spent fuel in the United States; and the sources, characteristics, and locations of nuclear waste, including low-level, transuranic, and high-level waste. For students who have already studied the various forms of energy and electricity generation, this unit may be used as a brief review.

Unit 2, "Ionizing Radiation," provides information relevant to radioactivity and radiation, its natural and man-made sources, and concerns about exposures. The basics of atomic structure, isotope identification, and the biological effects of ionizing radiation are also discussed. The concept that ionizing radiation is a part of nature and our natural environment and can result from human activity is introduced. Radioactive decay and half-life is discussed in depth to help students

develop an appreciation for the necessity of planning carefully for disposal of these wastes.

Unit 3, "The Nuclear Waste Policy Act," identifies the key elements of the U.S. nuclear waste dilemma and introduces the Nuclear Waste Policy Act and the role of the public in the development of a high-level waste management system. Through participation in "hands-on" activities in the classroom, Unit 3 is intended to help students begin to develop insight into the difficult task we face in the development of the nuclear waste management system and the complexity of the task of siting, transporting, and disposing of high-level nuclear waste. Risks specifically associated with radioactivity and nuclear waste are explored. In addition to examining key elements of the Nation's nuclear waste management program, mandated by the Nuclear Waste Policy Act of 1982 and amendments, the unit examines questions of equity, burdens, and benefits related to nuclear waste disposal; the roles of the Federal Government, States, and Indian Tribes; and finally the role that individuals can play in the development of the nuclear waste management system.

Unit 4, "The Waste Management System," describes the major components of the waste management system and the difficult and time-consuming task of developing the system. It discusses various aspects involved in ensuring safe transport of spent nuclear fuel and high-level waste, from the design and testing of shipping casks to the evaluation of rail and truck routes. Unit 4 also discusses potential designs for the structure and functions of a geologic repository for permanent disposal of the wastes and geohydrologic, geochemical, and environmental characteristics or properties that are important in repository siting and performance.

CURRICULUM DESIGN

The curriculum is designed for grades 8-12 and is suitable for environmental science; social studies; and science, technology, and society classes. It is modular and flexible and can be used in its entirety or selectively. The teacher may spend as little time as one 40- or 50-minute class or, if used in its entirety, the curriculum could cover from 9 weeks to 1 semester. The materials for a particular class or course will depend on student background, ability, and interest, as well as time constraints, curriculum requirements, and other guidelines. Suggested courses appropriate for science, social studies, or a science/social studies team-teaching approach are outlined in the Teacher's Guide. In addition, a matrix is included that provides general guidance concerning level of difficulty and curriculum applicability.

INSTRUCTIONAL FORMAT

The instructional format adopted for use in the development of the curriculum is based upon the standard design model used in university teacher training programs throughout the country. Important elements of the instructional format include: options for follow-up for either the classroom or for further research by students, self-evaluation by the teacher to assess the success of the lesson and reaction to particular aspects of the lesson, and lesson plans. The standard daily lesson plan format used is that format taught by colleges of education across the country and required by many States and school districts for teacher evaluation purposes. Figure 2 shows the standard format used in "Science, Society, and America's Nuclear Waste."

The standard format includes statements of:

- Purpose
- Concept
- Duration of lesson
- Behavioral objectives
- Skills used/required/acquired
- Vocabulary
- Necessary materials
- Suggested procedures
- Teacher evaluation of learner performance
- Related activities/readings
- Enrichment activities

Fig. 2. Standard Format of Lesson Plans

CURRICULUM VALIDATION

During the early stages of curriculum development, certified teachers from Science Applications International Corporation conducted a pilot test for DOE to validate the curriculum design and determine its suitability for the secondary level target audience. A six-week pilot test of the materials took place in a ninth-grade Geography class during the fall of 1989 at Jefferson Junior High School in Oak Ridge, Tennessee. After incorporating changes as a result of the pilot test, during the 1990-1991 school year, the curriculum was field-tested through team-teaching by science and social studies teachers at secondary schools in Mobile, Alabama; Ponce de Leon, Florida; Atlanta, Georgia; Smyrna, Georgia; Baton Rouge, Louisiana; McComb, Mississippi; Winnsboro, South Carolina; and Woodlands, Texas.

The curriculum has been reviewed by selected staff, faculty, and/or workshop participants from Louisiana State University Center for Energy Studies; the University of Nevada, Reno and Las Vegas; the University of Tennessee; Pennsylvania State University; Hope College; the University of South Florida School of Medicine; the New York State Department of Education Science, Technology, and Society Education Project; the Nevada Science Project; the National Council for the Social Studies Science and Society Committee; and the First International Workshop on Education in the Field of Radioactive Waste Management--at the Crossroads of Science, Society, and the Environment, which was co-sponsored by the multinational Organization for Economic Cooperation and Development/Nuclear Energy Agency, U.S. DOE's Office of Civilian Radioactive Waste Management, and the Swiss National Cooperative for the Storage of Radioactive Waste (NAGRA).

INTRODUCING *TEACHERS* TO THE *CURRICULUM*

On July 31, 1992, DOE held a nationwide teachers workshop broadcast live from the University of Tennessee to introduce teachers to the curriculum. The workshop was downlinked in all 50 States at 196 locations and attended by approximately 2500 teachers. Copies of the four-volume, seven-pound teacher guides were provided at the various sites for those teachers who pre-registered for the workshop.

The broadcast featured panels of teachers who field-tested the curriculum for DOE through the Louisiana State University and the Science Applications International Corporation; taped student classroom activities and interviews with experts in a variety of scientific fields; a tour of a nuclear

powerplant; and a tour of the Yucca Mountain Site in Nevada that DOE is studying, as directed by Federal law (the Nuclear Waste Policy Amendments Act of 1987), to determine whether or not it is suitable for development of a deep, geologic repository for disposal of spent fuel and high-level waste.

To make the workshop interactive and to address teacher questions about the curriculum, during the last 30 minutes of the 4-hour broadcast a live panel consisting of a scientist, a policy specialist, and a curriculum expert was provided for workshop participants from around the country to call in toll-free on the air.

Evaluations received from workshop participants indicated that the curriculum is much needed, the workshop was very useful, and that future workshops were desired. As a result, a second nationwide satellite teachers workshop is scheduled for April 24, 1993. This workshop will be a 2-hour program and follow-up to the July 1992 workshop. It will add to and expand on the scientific and societal topics discussed in 1992. In response to the evaluations received from the 1992 workshop, the April 1993 program will look at current events and issues as they affect the high-level radioactive waste management program, what other countries are doing, and other nuclear-waste- related topics, such as reprocessing, that other countries do.

WHO IS USING THE CURRICULUM?

As stated earlier, the curriculum is distributed ONLY to teachers who specifically request it, and we maintain a database of all those who do request it so that we may provide supplements or updates to them. As of January 31, 1993 -- just 6 months after the curriculum became available for school use -- our database indicated that teachers had requested more than 7,000 sets of Teacher Guides and almost 60,000 sets of Student Readers. Requests have been from middle- and secondary school teachers in all 50 States. In addition, requests for the curriculum have been received from more than 2 dozen countries and is being used in 115 colleges and universities around the country either in the Colleges of Education or as a resource in other classes.

NEXT STEPS

In response to workshop evaluations and teacher requests, we are currently completing a lesson on reprocessing and are working on additional video material for classroom use. As events concerning nuclear waste management change or progress, we plan to produce supplements to the curriculum and subsequent satellite workshops. We are working with utility education and information center managers to provide our curriculum for teacher workshops and we are reviewing the curriculum for further adaptation for college and university level use as well as community college use.

SUMMARY

Our resource curriculum, "Science, Society, and America's Nuclear Waste," was developed and tested by teachers for teachers, has been well-received by teachers, and is clearly helping to fill a very large gap where educational resource material has been lacking. We plan to continue to review, revise, update, and evaluate our curriculum to ensure that it is current, factual, and useful.