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AUTHOR Dede, Christopher
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ABSTRACT

This paper summarizes the model used for science/society programs at the University of Houston. The model is examined with respect to the following perspectives: the best disciplinary locus for science-related social issues; optimum teaching style, instructional background, and grade level; appropriate instructional objectives; ethical problems; the conceptualization and definition of scientific literacy; needed directions and research investigations for science education to realize this concept; and the relationship of scientific literacy to planning for alternative futures. (Author/HLH)

EXAMINING A MODEL FOR TEACHING SCIENTIFIC LITERACY THROUGH INTERDISCIPLINARY COURSES FOCUSED ON SCIENCE-RELATED SOCIAL ISSUES

Christopher Dede
University of Houston at Clear Lake
Houston, Texas

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I. Introduction

The conception of using the future as an organizing framework for teaching science has emerged during the last five years as an important new direction in science education. Dr. Paul DeHart Hurd pioneered in this area, suggesting this idea in the 1930's, even before the field of futures research was developed. [1] More recently, this author has published several works [2,3,4,5] which apply the principles of futures research to pre-college science teaching. At the 1975 NARST meeting, Dr. George T. O'Hearn presented a paper on "Science Literary and Alternative Futures." [6]

This paper will describe a theoretical model for science education based on futures research. Interrelated multidisciplinary science/society courses are used as the vehicle for conveying scientific literacy to students. The model programs designed from this model are flexible, so that different types of scientific literacy appropriate to different roles within society can be developed within a single overall framework.

As this model is applied at the University of Houston at Clear Lake, the concepts and processes appropriate to each type of scientific literacy over the next thirty years are continuously defined and examined by working groups of scientists, educators, social scientists, and futures researchers. These concepts and processes are conveyed through utilizing likely future science-related social issues as the basis for course goals and experiences. The concept of guided self-selection within a range of integrated, University-wide multidisciplinary courses is central to the model, as this allows upper-level students with significant work-related experience to choose learning experiences most suited to their abilities and interests. However, the fundamental philosophy and structure of the model are such that this University-based approach to scientific literacy is also generalizable to different types of student needs, including pre-college instructional settings.

This paper will include:

i) a summary of the philosophic and theoretical framework of the model

ii) a discussion of the implementation of this model at an upper-level university (the application of these conceptual constructs to a concrete, on-going set of programs facilitates identifying areas in which these constructs are most useful and locating gaps in the theoretical perspective).

iii) the results emerging from the model appropriate to the theoretical perspectives delineated in the 1975 NARST "scientific literacy" symposium (on questions of the conceptualization and definition of scientific literacy, needed directions and research investigations for science education to realize this concept, and the relationship of scientific literacy to planning for alternative futures).

iv) the results emerging in this model appropriate to the theoretical perspectives delineated in the 1975 NARST "science-related social issues" panel (on questions of the best disciplinary locus for science-related social issues; optimum teaching style; instructional objectives; and ethical problems).

v) a discussion of the generalizability of exploratory research on this model to other instructional settings.

II. THEORETICAL MODEL

The Pragmatic Philosophy of Futures Research

The set of assumptions on which this model is based are derived from the field of knowledge known as "futures research." The study of the future stems from a pragmatic approach oriented towards the delineation of alternatives. Willard Jacobson emphasizes the value of this type of approach for scientific literacy in his article "Approaches to Science Education Research":

> While the mechanistic, reductionist philosophies of science have been of great utility in the physical sciences, in dealing with social situations where complicated human beings both as individuals and groups occupy the center stage and where the whole is almost always greater than the sum of its parts, the philosophy of pragmatism with its emphasis on the analysis of possible consequences provides a promising base.

This type of model offers a theoretical scope which can encompass both the disciplinary concepts and processes of science and the intricacies of societal interaction with technologies derived from these disciplines. A single model can thus suffice for integrating "science for scientists" with "science for citizens". The disciplinary knowledge provides a framework for considering science as an input-output system, which in turn facilitates the systematic consideration of scientific interactions with society.

Briefly stated, the assumptions from futures research that underlie this model are:

1) an array of alternative futures, both desirable and undesirable, are open to mankind at any point in time.
2) The major likely futures in this array are foreseeable and can be grouped into a finite number of clusters, each cluster containing a large number of relatively similar scenarios.

3) Decisions made in the present will predictably determine which cluster becomes the major societal direction in the future.[7]

4) Science is a major conscious long-term change force in our society, for science (via technology) creates new future clusters open to us.

5) Education (broadly defined) is a major conscious long-term change force in our society, for education ultimately determines which future clusters we will choose.

Coupled with these assumptions is a value, also central to futures research, that "high morality depends on accurate prophecy" (John Platt).[8] Thus, the goal of science education within this theoretical framework becomes to convey knowledge, skills, and attitudes which allow students to choose -- given the probable interactions of science and society -- what future they want. This approach conveys "scientific literacy" in its truest sense, and satisfies the four criteria discussed by O'Hearn: understanding the nature of science, basic scientific knowledge, scientific processes, and social/cultural implications of science.

One metaphor for this model is that of a "tree" with "branches," each branch a cluster of alternative futures. One branch, for example, might be the "post-industrial" society envisioned by Daniel Bell.[9] or Herman Kahn.[10] Another branch might be the "zero-growth" society promoted by Dennis Meadows.[11] As we stand on the "trunk" of the present, we walk through time towards these future branches, each step requiring decisions which eliminate potential futures and thus remove branches from the tree. A scientific or technological breakthrough may add a few new branches but inevitably, by the time we reach the future, only one branch -- now the present -- will be left. Whether this branch resembles Bell's scenario, Meadow's scenario, or some other scenario totally different depends largely on the scientific and educational decisions we make between now and then.

Applying this Philosophy to Scientific Literacy

One way to illustrate the application of this philosophy to scientific literacy is to utilize Joseph Schwab's conception of the four bases of science education: the needs of the learner, the structure of the scientific disciplines, the needs of society, and the needs of the teacher.[12] Within the model described in this paper, the following framework emerges.

A. Needs of the Learner

The four major roles for which science educators prepare learners are scientist, citizen, educator, and decision-maker (e.g., politician). Ideally, rather than designing separate sets of courses for each role, a common pool of courses can be utilized from which model programs for each role are selected, based on the learner's previous experience and the type of scientific literacy needed for that role. A sample course pool and model programs generated by this particular model are given later in this paper.

B. The Structure of the Discipline

Each scientific discipline, when viewed through an input-output model, has certain types of resources needed for scientists to perform experiments and certain types of technologies likely to emerge from theoretical work during the next generation of scientists. Therefore, by utilizing analytic tools derived largely from economic and technological forecasting and assessment, a framework of input and output interaction with society can be derived for each particular discipline-based course. For example, a course on genetic engineering taught within this model would consider:

Needs from Society	Effects on Society
-cost-benefit analysis of money applied to research	-implications of different biological manipulation technologies for society
-amount and type of trained manpower needed	
-biological resources needed	

C. Needs of Society

The specific societal needs that science education must address vary, depending on the particular cluster of futures one is discussing. However, the following questions are important issues in all clusters.

1) Who controls the applications of science?

2) What is the ethical role of the scientist?
   citizen?
   educator?
   decision-maker?

3) How can science be used to direct us toward one particular type of future?

These sorts of questions serve as general themes for all courses within the science/society pool and provide a common theme throughout the students' model program. Examples of the ways these issues are addressed in different types of courses are given later in this paper.

D. Needs of the Teacher

Within the usual constraints of 20-30 students per class and 45 hours contact (university level courses), the teacher must communicate the following types of knowledge in courses dealing with science and society.

Science Courses: Scientific Concepts
Scientific Processes
Scientific Attitudes

Professional Courses: Professional Skills
Professional Knowledge Base
Professional Ethics

Human Science or
Public Affairs Courses: Methodological Framework
Fundamental Data Base
Major Schools of Thought

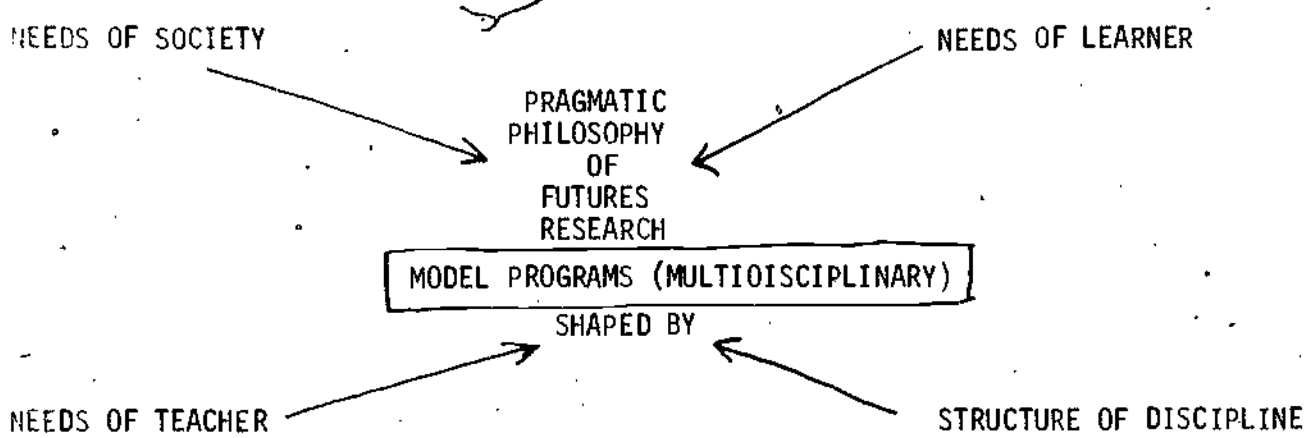
Humanities Courses: Artistic Work
Critical Analysis Skills
Major Schools of Opinion

The diversity of these needs has acted as a force to fragment teachers into offering departmentally controlled discipline-based courses. These courses, while useful for specialists, do not convey the full sweep of science within society. Even in universities in which courses focused on science related social issues are offered, these courses are frequently labeled as "special" and "interdisciplinary" and divorced from the more traditional science courses, thereby removing them from the central focus of scientific literacy. Using the pragmatic philosophy described earlier, however, the teacher can satisfy the needs of his particular area -- whatever it may be -- and still legitimately introduce material directed towards a view of the whole science/society interaction (as will be illustrated by example later in the paper.)

Thus, each course within the model produces, out of its own disciplinary constructs, an understanding of the larger interactions of science and society. Some sample illustrations of this type of analysis are provided later in this paper.

The Overall Model

The following chart illustrates overall interactions within this theoretical model.



Using this type of approach, scientific literacy appropriate to each individual students' goals can be developed through an integrated set of interdisciplinary courses encompassing science, professional studies, public affairs, human sciences, and humanities.

A detailed rationale for this theoretical perspective, a comprehensive description of this model, and an assessment of the implications for science education if this approach is adopted are given at length in a previous work by this author.[2]

III. IMPLEMENTATION OF THE MODEL AT AN UPPER-LEVEL UNIVERSITY

Institutional Context

The University of Houston at Clear Lake City (UH/CLC) is a new campus (opened 1974) within the state supported system of the University of Houston. UH/CLC admits upper-level (junior, senior) and graduate students only, with seven community colleges in the surrounding region serving as one source of students. The campus is located midway between Houston and Galveston, one-half miles from from the NASA Lyndon B. Johnson Space Center. Fifty-five percent of the present student body are graduate students; one-third of the students come directly from community colleges, the other two-thirds have a median age of thirty-two and bring in an average of five transcripts. The present student population of the University is 3,000; this is expected to grow to 15,000 by 1990.

The fundamental charge of the University from the legislature is to extend the educational opportunities of students who have completed two or more years of college, to provide non-traditional curricula in response to the needs of contemporary society, and to meet the continuuing and often specialized educational needs of the unique population of the Bay Area-Gulf Coast region of Texas. The University has responded to this charge by developing non-traditional multidisciplinary degree programs and by emphasizing cross-disciplinary teaching. As such, given the scientifically oriented community along the Gulf Coast (with its space, petrochemical, and medical facilities), the University provides an ideal context for developing an innovative science literacy program defined in terms of social issues.

The institutional structure of the University is shown in Table I.

School of Sciences Technologies	School of Professional Studies	School of Sciences and Humanities
Program in Science for Society	Programs in Business and Industry	Programs in Human Sciences
Programs in Industrial Technologies	Programs in Professional Education	Programs in Humanities
	Programs in Public Affairs	

Within this structure, the Programs shown in Table 2 are, at present, participating in the implementation of the model.

School of Human Sciences and Humanities	School of Professional Studies	School of Sciences Technologies
Program in Literature	Program in Environmental Management	Program in Biological Science
Program in Behavioral Sciences	Program in Pre-School and Elementary Education	Program in Physical Sciences
Program in Man and His Past	Program in Middle through High School Education	Program in Allied Health Sciences
Program in Studies of the Future	Program in College Education	
Program in Economics	Program in Educational Management	
Program in Health, Leisure and Sports	Program in Government Planning and the Political Process	

Table 2

Model Programs

Table 3 illustrates a representative subject of the courses integrated within the model and containing knowledge designed towards scientific literacy.

Illustrative Courses

BIOLOGY: Life Science for Teachers (one year, eight hour course)

CHEMISTRY: Chemistry for Teachers (one year, eight hour course)

ECONOMICS: Contemporary Socioeconomic Perspectives

EDUCATION: Educational/Societal Futures

ELEMENTARY EDUCATION: Math and Science Methods in the Elementary School

ENVIRONMENT: Ecology and Public Policy

GEOLOGY: Earth Science for Teachers (one year, eight hour course)

GOVERNMENT: Science, Technology, and Public Policy

HISTORY: American Technological Style
Science and Religion in Historical Perspective

LITERATURE: Literature and Film: Science Fiction

PHYSICS: Physics for Teachers (one year, eight hour course)

PSYCHOLOGY: Drugs and Behavior
The Future of Behavior

SECONDARY EDUCATION: Secondary Curriculum and Methodology (Science)

SOCIOLOGY: Understanding Technology
Science and Human Values
Moral Issues on the Future of Science

TABLE 3

Table 4 illustrates sample model programs developed under the model using this pool of courses.

BIOLOGICAL SCIENTIST

BIOLOGY: Life Science for Teachers

ENVIRONMENT: Ecology and Public Policy

PSYCHOLOGY: The Future of Behavior

SOCIOLOGY: Bioethics

DECISION-MAKER

ECONOMICS: Contemporary Socioeconomic Perspectives

GOVERNMENT: Science, Technology, and Public Policy

HISTORY: American Technological Style

SOCIOLOGY: Understanding Technology

EDUCATOR -- PHYSICAL SCIENCES

CHEMISTRY: Chemistry for Teachers

EDUCATION: Educational/Societal Futures
Science Methods (Elementary or Secondary)

HISTORY: Science and Religion in Historical Perspective

LITERATURE: Literature and Film: Science Fiction

PHYSICS: Physics for Teachers

PSYCHOLOGY: Drugs and Behavior

SOCIOLOGY: Moral Issues in the Future of Science

CITIZEN

ECONOMICS: Contemporary Socioeconomic Perspectives

LITERATURE: Literature and Film: Science Fiction

PSYCHOLOGY: Drugs and Behavior

SOCIOLOGY: Science and Human Values

TABLE 4

Of course, these model programs can be varied to a considerable extent, depending on the background and experience of the student. The course pool is in fact larger than shown (and constantly growing), so the courses and programs listed should be regarded as illustrations rather than a complete list.

Within the next year, several new degree-granting programs will be inaugurated within the University. Table 5 shows those programs which will actively participate in the model at their inception.

SCIENCES AND TECHNOLOGIES	PROFESSIONAL STUDIES	HUMAN SCIENCES AND HUMANITIES
Program in Administration of Health Services	Program in Development & Utilization of Human Resources	Program in Law and the Citizen
Program in Information Systems and Retrieval	Program in Education - Related Sciences	Program in Visual Art
	Program in Industrial Leadership Planning	
	Program in Transportation Studies	
	Program in Urban and Suburban Studies	

TABLE 5

ILLUSTRATIVE COURSES

A brief review of three courses (a discipline-based science course, a professionally-based course, and a human-science course on science-related social issues) will illustrate concrete application of the theoretical principles described in Section II.

GEOLOGY 4031, 4032, 4011, 4012 is a one year, eight hour course with laboratory called "Earth Science for Teachers." The course is mixed graduate and undergraduate; the disciplines covered in one year are geology, astronomy, meteorology, and oceanography. Unlike "science for teachers" courses at most universities (which tend to be justifiably despised as watered-down versions of courses for science majors), "Earth Science for Teachers" is as intellectually rigorous as any other course in the geology curriculum. The course focuses on material suitable for students at the pre-college level, and thus omits some disciplinary areas suitable only for college level students. This, in turn, allows room to consider earth science-related social issues within the larger context of literacy within the earth sciences.

The "structure of the discipline" input-output model applied to "Earth Science for Teachers" yields:

<u>Needs from Society</u>: 1) cost-benefit analyses of money applied to research in:

energy
natural resources development
space science
climactic control
oceans as a food source
etc.

2) what is the ethical role of the scientist (in each of of the respective disciplines)? of the present decision-making bodies governing these technologies? of the teacher? of the citizen?

3) how can each of these sciences be used to direct us towards one particular type of future?

Approximately twenty percent of the course time is spent on science-related social issues. In general, these issues are not isolated from other course material, but are taught in conjunction with the disciplinary constructs needed to understand that particular issue. The overall goal of the course is to give educators (broadly defined) earth science literacy through teaching the disciplinary concepts, tools, and skills needed to comprehend the earth sciences, while simultaneously placing this knowledge in the context of its likely effects on the future of society.

ELEMENTARY 3361 (a six credit, one semester course for undergraduates) and ELEMENTARY 5032 (its three credit graduate counterpart) are professional courses for education majors which focus on "Science and Math Methods in the Elementary School." The science portion of the pre-service course for undergraduates is oriented primarily towards acquainting the students with the different post-Sputnik curricula developed by NSF and modeling the use of inquiry techniques to teach science. The science portion of the in-service graduate course is more complex and utilizes case-studies brought in by students from their own classrooms to analyze how best to teach science.

In both courses, emphasis is placed on the fact that only a small percentage of elementary school students go on to become scientists or engineers. Therefore, the primary purposes of elementary school science are to keep children excited about exploring natural phenomena; aware of tools, concepts, and attitudes that can help them in their explorations; and cognizant of the major ways in which science and society interact. The first two goals are easily covered in any good methods course. The "science/society literacy for citizens" goals is emphasized to the students in these courses in the following ways:

1) overviews of the history of scientific development with emphasis on debates about the definition of "progress."

2) descriptions of the different sorts of socially-related work scientists do, emphasizing non-racist and non-sexist approaches to determining potential scientific ability.
3) depictions of the different types of technologies that will probably exist when current elementary students are full-fledged citizens, stressing the kinds of ethical decisions these technologies may require on the part of society.
4) discussions of major schools of thought on the role science should play in shaping the future of society, emphasizing examples that can be used to illustrate these concepts to elementary school students.

Approximately fifteen present of course time is spent on science-related social issues. As in the "Earth Science for Teachers" course, these issues are not isolated from the other activities in these courses, but are taught in the context of inquiry exercises or discussion lessons often used in the elementary school. Since "teachers teach as they were taught," the goal of these courses is to provide a model for communicating science literacy to the child: concepts, processes, attitudes, and science/society understandings.

SOCIOLOGY 4931 is a mixed graduate and undergraduate course on "Moral Issues in the Future of Science." The student composition of this course tends to be extremely diverse, with majors in futures research, in behavioral sciences, in science, and in education being most frequently represented. The course procedes through a developmental sequence as follows.

-issues in prediction of the major likely socioeconomic structures for the United States within the next generation

-forecasts of the major technological innovations likely to take place within the next generation, given a particular societal framework

-assessment of the major societal consequences of a given technology

-catagorization of the major alternative ethical stances that may be taken with regard to a given issue

-conceptualization of the ways conflicting ethical positions are resolved, both within an individual and among individuals in a group setting

-development of a personal meta-perspective from which to view the individual and societal consequences of alternative ethical stances on the issues created by future scientific developments

-definition, given this meta-perspective, of the ethical responsibilities of the scientist, the politician, the educator, and the citizen.

A set of case studies of likely future technology-based ethical problems is used as a vehicle to convey the knowledge and skills needed to do the above. All of the course is directed towards science/society literacy; about fifteen percent of the course focuses on disciplinary concepts within science so that students can understand the technical issues involved in these ethical questions.

These three courses provide a limited illustration of applications of the model in Section II to University-level science education for scientific literacy. Of course, other courses taught in science, in professional studies, or in human sciences use differing instructional approaches, so these three courses are representative in only a limited area.

SUPRA-UNIVERSITY APPLICATIONS

Thus far, the primary implementation of this model at UH/CLC has been within the University. Long-term, the model will serve as a basis for a consortium—

of science-based institutions (aerospace, petrochemical, electronic, and medical) and educational institutions (public school districts, community colleges, and universities) to engage in community-based education for scientific literacy. While implementation on this scale lies some years ahead, UH/CLC is beginning to take steps towards building such a consortium. For example, within the next year, an Institute for Educational Applications of Space Research will be inaugurated at UH/CLC, and incorporated with the network created under this model.

IV. RESULTS EMERGING FROM THE MODEL RELATED TO THE NARST 1975 "SCIENTIFIC LITERACY" SYMPOSIUM

To some extent, applications of this model to teaching scientific literacy have been discussed throughout. A few statements can be made to summarize the results emerging from this model:

- given that education has as one of its goals the communication of skills sufficient to enable a citizen to make intelligent decisions about science for the next forty-odd years of his life, the relationship of scientific literacy to planning for alternative futures is central.
- scientific literacy can best be taught in a multi-disciplinary framework involving a variety of courses from different disciplines, each of which incorporates appropriate material towards an understanding of the overall scientific literacy gestalt.
- the conceptualization and definition of scientific literacy should include an analysis of the likely future skills needed by the consumer of scientific literacy, given the role that this person expects to play in society. Futures research can then be used as a vehicle for teaching these skills, especially those related to science/society issues.
- needed directions and research investigations for science education to realize the concept of scientific literacy center, at this point, on empirical investigation of the strengths and weaknesses of models for scientific literacy. Some of the research questions emerging from implementation of the model described in this paper are discussed in Section VI.

V. RESULTS EMERGING FROM THE MODEL RELATED TO THE NARST 1975 "SCIENCE RELATED SOCIAL ISSUES" PANEL

The incorporation of material on science-related social issues into all manner of courses has been discussed throughout this paper. Implications derived for this type of teaching from this model can be summarized as follows:

- -no single best disciplinary locus for teaching science-related social issues exists. Rather, these issues should be incorporated into many different courses in a variety of disciplines, using a futures research perspective to determine which material is appropriate for which course.
- -optimum teaching style, instructional background, and grade level at which science-related social issues should be taught varies greatly, depending primarily on which disciplinary locus is being utilized as a vehicle for conveying those particular issues. Some suggestions on teaching style and instructional background are contained in the "needs of the teacher" section of this paper. Preliminary research on the experiences of pre-college teachers associated with this University indicates that science-related social issues can be taught with intellectual respectability at any grade level, if couched in the proper manner.
- -appropriate instructional objectives for teaching science-related social issues can be derived directly from the pragmatic philosophy of futures research, as demonstrated earlier in this paper.
- -ethical problems in teaching science-related social issues do not exist within this particular model. By using alternative futures as the vehicle for considering these issues, a variety of ethical perspectives can be given equal attention by the instructor.

VI. GENERALIZABILITY OF EXPLORATORY RESEARCH ON THIS MODEL TO OTHER INSTRUCTIONAL SETTINGS

Generalizability

In many ways, UH/CLC is an ideal university-level setting for a trial implementation of this type of model; the institution is without traditions; non-departmental; rapidly growing; oriented towards futures research; committed to excellent, cross-disciplinary teaching; and located in an area rich in science-based institutions. To the extent that other institutions (University level or below) differ from these qualities, implementation of this model is likely to be more difficult.

However, once implemented, this model is likely to be equally successful in any institution. Nothing in the theoretical design of the model limits its applications to settings such as UH/CLC; on the contrary, the model is deliberately constructed so that courses within the model fall under disciplinary headings, the "real-world" needs of the teacher within any given discipline are considered, and students are educated to fill a wide variety of roles. Further, implementation of any model for the term itself presupposes a necessarily cross-disciplinary approach that is at the heart of most difficulties of implementation.

Ultimately, UH/CLC hopes to produce materials which will help other types of institutions -- at all educational levels -- to implement a model such as this on a trial basis. These materials would include:

--self-instructional packages in futures research

--sample curriculum packages

--strategies for teacher-training

--suggestions on institutional frameworks which can be used to minimize problems of implementation.

Research Questions

Some of the questions for further research emerging from implementation of this model are:

-what is the most efficient way of coordinating the considerable cross-disciplinary exchange of information needed for this model to function?

-what is the simplest way to convey the basic principles of futures research needed to work within this model?

-how small a pool of courses is sufficient to produce a sufficiently rich set of model programs for a university-level student population and how much overlap of material from course to course is ideal for teaching scientific literacy?

-how realistic is the assumption that education can prepare citizens scientifically literate for the next forty years, given the present direction of our technocratic civilization?

While the challenges are great in conceptualizing and implementing this type of model for scientific literacy, the needs of our society for the skills that this model conveys are greater still.

FOOTNOTES

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