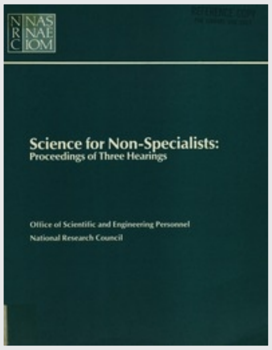

Science for Non-Specialists: Proceedings of Three Hearings: Undergraduate Science Education, Improving College Science Education, Understanding the Science Knowledge Needs of the Non-Science Professions

DETAILS

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AUTHORS

Committee on the Federal Role in College Science Education of Non-specialists; Office of Scientific and Engineering Personnel; National Research Council

SCIENCE FOR NON-SPECIALISTS: PROCEEDINGS OF THREE HEARINGS

Undergraduate Science Education

Improving College Science Education

Understanding the Science Knowledge Needs of the Non-Science Professions

Proceedings of Hearings Conducted by the Committee for a Study of the Federal Role in College Science Education of Non-Specialists

Office of Scientific and Engineering Personnel
National Research Council

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Office of Scientific and Engineering Personnel
2101 Constitution Avenue, N.W.
Washington, DC 20418

PREFACE

The Committee for a Study of the Federal Role in College Science Education of Non-Specialists was given a three-fold charge by its parent Commission on Human Resources (now the Office of Scientific and Engineering Personnel) of the National Research Council: (1) to determine how science is being presented to undergraduate students who are not studying to become scientists; (2) to recommend improvements that may be needed in what is generally perceived to be a neglected branch of undergraduate education; and (3) to determine if there is a role for the federal government in assisting colleges and universities to meet their responsibilities to provide this important subgroup of their students with an appropriate science education.

As part of the committee's data collection efforts and assessment of the problem, three meetings were held to elicit information from other individuals concerned about science education:

- November 14-15, 1980: An invitational hearing in Bloomington, Indiana, allowing students, faculty, and alumni from Indiana University to describe their impressions of the current status of undergraduate science education for non-specialists.

- December 16, 1980: An invitational conference in Washington, D.C., on past and present efforts to improve undergraduate education of non-specialists in science and technology.

- March 20, 1981: An invitational conference in Washington, D.C., with 17 representatives from various nonscience professions--law, journalism, business, theology, public service--to understand what they need to know about science and technology.

This informal volume contains the edited proceedings of those meetings.

It is intended as a supplement to the committee's principal report--Science for Non-Specialists: The College Years, National Academy Press, 1982--as a way of providing additional details and of indicating the process that the committee followed. The proceedings have been prepared from transcriptions of taped discussions at the meetings. It was not possible to submit the text of remarks to speakers for review before issuance of this document, but it is believed that the present account faithfully reports those remarks. To aid the reader, a summary of each meeting is also given.

The reader will find here a description of problems--and solutions--as well as an evaluation of what has been tried in the past. The words of students, teachers, practitioners in the professions, and others who have attempted to improve the education of non-specialists in science speak directly and from personal experience to the issues the committee had to deal with. It is hoped that reading these will impart fresh understanding and new insights into these problems.

The committee has benefited from the support and advice of many people and organizations. Financial support was provided for both the original study and publication of the proceedings by the National Science Foundation. The interest and encouragement of Alphonse Buccino of the NSF Office of Scientific and Engineering Personnel and Education are gratefully acknowledged. Within the National Research Council, Harrison Shull, formerly chairman of the Commission on Human Resources; William C. Kelly, executive director of the Office of Scientific and Engineering Personnel (OSEP); and William K. Estes, OSEP's senior consultant, have offered valuable suggestions. The committee would also like to acknowledge the able efforts of its study director, Pamela Ebert-Flattau; Gregory Crosby, research associate; and Linda Dix, who served as editor of the report and of these proceedings.

We also wish to thank the many individuals--teachers, students, administrators, members of the professions, and others--who took part in the committee's meetings, conferences, and workshops and provided much valuable information. Names of the participants are given following the summary of each meeting.

To all of these persons, the committee expresses its warmest thanks.

Richard Gray
Chairman

COMMITTEE FOR A STUDY OF THE FEDERAL ROLE IN THE COLLEGE SCIENCE EDUCATION OF NON-SPECIALISTS

Richard G. Gray, Chairman, Dean, School of Journalism, Indiana University (Journalism)

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David E. Wiley, Dean, School of Education, Northwestern University (Education and statistics)

Study Director

Pamela Ebert-Flattau, Office of Scientific and Engineering Personnel, National Research Council

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UNDERGRADUATE EDUCATION

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Indiana University, Bloomington, Indiana
November 14-15, 1980

Summary

The Committee conducted a regional hearing on November 14-15, 1980, at Indiana University to enable both students and faculty to express their views of college science education for non-specialists. In addition, a representative of the Indiana Higher Education Commission made some introductory remarks on this topic.

Robert Scott of the Indiana Commission said that because one's understanding of science affects almost everything one does, science must be understood for more than its own sake, and courses designed particularly for non-majors are needed--"laboratory as well as demonstration courses, philosophy and history of science courses, and philosophy and ethics courses concerning science." In addition, the science base in technical education must be broadened along these lines to eliminate the "tunnel vision and shortness of attention span" that students in many such programs have developed toward science. Secondly, incentives are needed for the development of new courses. He said both institutions and the federal government should provide these incentives, citing activities of the National Academy of Sciences and the former college commissions for the sciences as desirable efforts that "may have to take place every decade to focus new attention on a particular problem." A third major point of Dr. Scott's presentation was that the general public and the scientific community are mutually dependent: "We [non-scientists] are at their mercy in our ignorance, but they must know that they are at our mercy when we are ignorant."

Sixteen students at Indiana University--who the Committee believes are fairly representative of not only I.U.'s student body but students across the country--spoke to the Committee about their high school and college experiences in science. Although most of them had had at least four years of high school mathematics andscience, half of them felt this background was weak, not preparing them for college science courses, which were more difficult than they had expected. A major concern about college science courses lay with the university's counseling system. Students often avoid advisors, relying instead on course descriptions and discussions with the course instructors for information before enrolling.

Indiana University has attempted to offer science courses for both science majors and non-specialists, leading to conflicting opinions of their worth. Classes with mixed enrollments--non-majors and science majors--seem to be ineffective for the former because of their highly competitive nature. Students also cited the following difficulties: (1) emphasis on memorization rather than learning by application; (2) large classes; and (3) impersonal grading of multiple-choice tests by computers. Some regarded such a combined class in chemistry as a "weed-out" course offering no "satisfaction of learning because . . . [the students] are trying to get the grade." The college physics class, on the other hand, was seen merely as a "regurgitation of . . . the high school course," which had stressed problem-solving.

On the other end of the spectrum are science and mathematics courses offered specifically for non-science majors. The one science course eliciting a favorable response by non-specialists was biology, presented to show its application to everyday life and enabling students to use "better judgment about scientific issues." For the most part, however, these courses were not seen as serious courses. They were considered too general and lacking in laboratory experiences and opportunities to learn scientific procedures. One solution offered was a range of courses ranked by difficulty--not just a choice between an easy course such as "Physics for Poets" and a difficult physics course for pre-meds.

Many education students commended the Indiana Model. This is a program in which elementary education majors take a teaching-methods course along with each science and mathematics course. Among the results of that program are experience in applying what students learn to what they will teach grade-school children and laboratory experiments that eliminate a fear of science while stimulating a continuing interest in science. However, two non-science majors said that these courses become too broad when all non-specialists are grouped together in courses such as biology and chemistry. They recommended courses for specific groups of non-specialists--e.g., biology for recreation majors --so that the information presented would be applicable to their individual majors.

Student recommendations to the committee took several main directions. First was to stress the importance of science in one's daily life. Repeated over and over again was the fact that science courses should provide one with analytical tools needed to pursue many careers and to examine something logicallly. Growing from this realization was the recommendation for non-majors to have more required science courses, particularly ones with hands-on experiences in the laboratory. The third recommendation was for a better quality of courses in each of the science fields and for less emphasis on "coverage" or increasing the quantity of science courses.

Members of the Indiana University faculty and two of the school's graduates attending this hearing addressed their remarks to the ways that a background in science can aid a person in his or her career and recommendations of science requirements for non-specialists. Science was considered important in all disciplines represented except history. For instance, two professors of law both said that courses in quantitative analysis, statistics, computer science, and logic would help an attorney handle the "more technological issues . . . being litigated." Similarly, educators could profit from gaining "science process skills" (inference, observation, manipulation, and experimentation) in order "to find data, to recognize good sources of data, to analyze it, and to synthesize it." Both of these ideas were repeated by members of the mathematics and physics faculties. Finally, the representative of the journalism school stressed the necessity of a strong science background for communications students: "[J]ournalists are in a unique position to influence public attention or public appreciation of science as a cultural and economic force in our society." Only the two graduates of Indiana University, both history majors, said that their science education was seldom used in their careers. However, one did note that her science background enabled her to understand news articles about scientific issues.

Having discussed science's importance, the faculty cited various courses that college students should take. These suggestions ranged from a maximum of one mathematics course and four courses in the natural and physical sciences to a minimum of two semesters of physical science, analytical geometry, and statistics. A law professor recommended laboratory courses in chemistry, biology, zoology, and medicine as well as a course in economics for pre-law students. The emphasis throughout was on courses beneficial to students after their college graduation. In mathematics these were called "usable mathematics courses" and included probability, statistics, calculus, and linear programming. In science the suggestions included the following: (1) offer science courses having an interdisciplinary approach; (2) revamp all of science schooling, beginning in the elementary school; (3) make science requirements standard in all schools; (4) increase minimum requirements for high school graduation; and (5) rely more on the laboratory or inquiry approach in science classes.

* * * * *

Participants

<u>Speaker</u>
Robert Scott, Associate Commissioner, Indiana Commission for Higher Education

<u>Faculty, Indiana University</u>
Michael Carrico, School of Law
Judith Franz, Department of Physics
Donal Kerr, Department of Mathematics
Julia Lamber, School of Law
Edwin Lambeth, School of Journalism
Alfred Ruesink, Department of Biology
Alex Tanford, School of Law
Donald Winslow, School of Education

Alumni, Indiana University
Barbara DeWitz (History)
John DeWitz (History)

Students, Indiana University
Catherine Bonser (Economics/mathematics
Jennifer Crittenden (Linguistics)
Jan Eveleth (Astrophysics)
Cathy Friedman (Speech pathology)
Kitty Grogan (Elementary education)
Julie Jontz (Audiology)
Karen Kovacik (English/Spanish)
Judith Lawrence (Sociology)
James McConnell (Telecommunications)
Stuart Muir (Comparative literature)
Ann Neugebauer (Speech communication)
Patricia Postel (Recreation)
Teresa Richards (Elementary education)
Debbie Rissing (English)
Jill Sandler (Elementary education)
Holly Stocking (Communications)
Douglas Strommen (Economics)
Jason Young (Political science/psychology)

* * * * *

Introduction

Dr. Gray introduced the panel members and the Committee's study director before introducing Dr. Robert Scott, director of academic affairs for the Indiana Commission for Higher Education.

DR. SCOTT: I would like to let you know something about my academic background and interests. Before joining the Commission, for 13 years I was at Cornell University as an Associate Dean in Arts and Sciences and professor of anthropology. During that time, I taught and advised students and served on a number of curriculum committees that engaged in topics about science. Thus, I have done some thinking both about the nature of science and about science in the curriculum. Now I chair the Advisory Council at Bucknell University.

The Commission for Higher Education is a statutory body created by the General Assembly to advise it and the governor on matters concerning post-high school education. In Indiana, about 25 percent of the general tax fund is dedicated to higher education; and for this next biennium, that will be over a billion dollars. We are the group responsible for advising on that budget, for approving any new academic degree programs, and for reviewing existing programs. In recent months in Indiana, the Commission has supported several proposals for new degree programs, in part because we felt that new programs would contribute to the scientific and technological literacy of undergraduates at the institutions offering them.

An understanding of scientific principles and an appreciation of science are necessary for making all sorts of decisions, whether they are business decisions, personal judgments, or political choices. I find it hard to understand how people with no understanding of science will actually come to rational decisions and choices on moral and ethical issues that concern science or technology. During this past decade, the public has shown great apprehension about science and technology, but we must correct that condition if we are going to have the kinds of advances in health and energy productivity and environmental management that we aspire to. We cannot have one without the other. Science must be understood for its own sake and for other reasons. The study of science, whether one is a science major or not, contributes to the improvement of one's critical thinking powers; this is a major theme in the recent report of the Commission on the Humanities, and it seems to me that science has a great deal to contribute to that.

According to the Carnegie Council on Policy Studies, more than half of all college students plan to take a year or more of physical or biological science. Now, while that percentage may seem impressive, the statement raises several questions: What kind of course do these students take and, of course, what about the other half? Clearly, we are concerned about them, too. Most of the 50-plus students take a year of science to complete a distribution requirement which, at most institutions, is a course designed as the first one for students who will become science majors. But the needs of the non-science majors for knowledge and understanding about science differ in many ways from the needs of those who are engaged in an apprentice or pre-major course of study. Thus, it is to the development of courses for those who are not apprentices that I urge attention and support.

It seems to me that the specialty areas within science, as well as in other fields, have fairly well developed curricula for those who would enter the profession; much more attention has been paid to those students than to those who, while not science majors, must still be knowledgeable about science. And these courses should not be those at the 100 level, an introductory course in biology for future poets, but in fact courses at the 200 to 400 levels in science and technology for non-majors. They should be laboratory as well as demonstration courses, philosophy and history of science courses, and philosophy and ethics courses concerning science. They should be available for both majors and non-majors alike because certainly what would be valid for the non-major ought to be equally valid for those who would major in science. In my experience with institutions in other states as well as here, there are far too few of those courses; and one must imagine and consider why there are so few and what the incentives are for the establishment of some courses that are missing. Are they representative of institutional philosophies, administrative philosophies, or external forces?

The curriculum is an expression of an institution's purpose. The curriculum is created in fulfillment of an institution's mission, and its design is the result of both internal and external forces that can serve as incentives to include certain subjects and to exclude others. What we need now are some new incentives for faculty-designed courses for non-majors in science to help overcome, in a more general way, the math and science anxiety that we read about but that we see far too few courses actually developed to serve. We cannot leave such instruction to the whims of television producers, although it seems to me they are doing a creditable job, given their mission, of providing such. However good their occasional products, though, it seems to me that these are obligations of the university faculty.

In thinking about incentives for the development of curriculum, for the development of higher education in this country, we should also look beyond the institutions to the federal government, which has played a major role in providing them. One can start with the Northwest Ordinance, which provided land for the development of schools in hopes of dispersing population, and also consider later acts that provided script for land instead of land itself. There was a whole movement toward scientific agriculture, a federal incentive which developed the Land Grant College Movement.

It is now time for incentives for a new era, and science and technology are areas that deserve support--not just at the university level but also in the elementary and secondary schools, not just for full-time students but for returning students and continuing education students and for the in-service training of those engaged in other activities and professions.

Indiana has a somewhat unique budgeting system that considers four components. One is inflation: price changes are taken into account to develop one part of the budget. Also, enrollment changes are taken into account. But there are two other parts of the budget which are not standard: (1) program change, that is, the introduction of new programs or the stopping of programs; and (2) quality, maintenance, and improvement--an area of the budget in which the state acts as a private foundation to which institutions submit proposals. For this biennium, institutions submitted 98 different proposals worth almost $65 million for various projects. Some of them had to do with the use of technology for learning. Three of the IU system proposals had to do with reducing the number of part-time students and reducing class size at three of their campuses. Purdue University had a major proposal for improvement of instruction, new resources, and new faculty in geosciences.

Institutions typically submit proposals for projects that satisfy institution habits instead of thinking more broadly about what would be in the best service for the state. The Commission will be recommending to the General Assembly that funds be set aside for projects more in line with broader state interests. For example, the major proposal from IU, for medical insurance and improvement to the medical insurance policy, would have absolutely no benefit to instruction, student services, or the enhancement of learning. The Commission will depart from its past procedures and try to get at the very point you are making.

Another consideration is that of the 29 public-institution campuses in Indiana, only four have undergraduates whose average age is 21. All the others have an average undergraduate age of 26 and 27. This is not a unique state in that regard, but we often think of college students as those 17 or 18 to 22; however, there are others who deserve our attention. An opportunity exists for leadership, for scientists and for those who support science to rethink their responsibilities about the teaching of science to all of us.

Most of us are at the mercy of scientists because of our ignorance about science, but there is another side to that coin. Scientists must know that they are at our mercy when we are ignorant: public policy is developed and supported by the populace; and if the populace is ignorant about science, that does not bode well for future support for science. We are at their mercy in our ignorance, but they must know that they are at our mercy when we are ignorant. Ultimately, that educational purpose is another reason for thinking creatively and for scientists and supporters of science to become leaders in the development of new curricula.

Question: Some estimates are that 50 percent of the students take a year of science. Does this mean that 50 percent of the students are in institutions having no distribution requirements in science?

Response: That is right. There are 3,000 institutions of post-high school education in our country, and a great many of them emphasize either technical areas the first two years or have completely loose curricula without any direction of the students. Besides students who take a science course either as a prerequisite for a professional degree or as a distribution requirement, not very many are left to register for a science course entirely voluntarily, with neither of those purposes in mind. At Cornell, both the biology and the chemistry departments developed a popular course for sophomore non-majors. But all freshmen had to go through the basic, introductory organic and inorganic chemistry with the pre-meds and the science majors; and because there are not too many non-scientists who want that competition, the structure effectively eliminated for everyone the opportunity to take what was a very good sophomore-level course because the department would not create a new introductory-level course.

Question: You said there were opportunities for leadership. Could you give us some examples of those opportunities?

Response: The National Academy of Sciences has an opportunity for a leadership role--after it collects information from various parts of the country and chooses which ideas have merit and which experiences seem to have been valuable to students--to make recommendations (either to other funding agencies, to institutions, or to professional societies) that certain models of curricula for non-scientists seem to have merit. Citing examples of good experiences and calling attention to problems are other functions of leadership. Activities such as the college commissions of the '60s may have to take place every decade to focus new attention on a particular problem. Certainly, the problems and the environment change. The environment for curriculum change in the '60s was of an entirely different order than it is now.

Question: Earlier Dr. Weathersby described the vocational technical system in Indiana. He felt that even if we offered federal incentives to broaden this technical education program into more of a "liberal arts in general education" program, perhaps the state legislature would be upset, since these particular programs are feeding technicians into job areas. Do you have either a practical observation or a philosophical one about whether we can assist technical education in broadening the science base?

Response: I definitely think it is necessary. It seems to me there are at least two approaches. One--directly engaging those technical institutions--causes difficulty because that is not their mission. In this state, most of those technical institutions are quite near either an IU campus or a Purdue campus; and in several cases, there is good cooperation in terms of offering courses at the collegiate campus for employees at the technical center, either at the campus or at the institution. That is one way to attempt to broaden the science base without either changing the mission of the university or the technical institution or running into difficulty with the General Assembly.

A great many of the students enrolled at our technical colleges are there for short periods of time to get training for a job. Often, they are already working in a plant or in some shop and need the extra training in order to advance, creating a kind of tunnel vision and a shortness of attention span. What concerns me about the curriculum there is that, in essence, it is a dead-end one that raises no aspirations. However, there are opportunities for different kinds of programming that bring people back for advanced training. We are encouraging links between those technical centers and the university campuses so that there can be some transfer.

The technical campus in central Indiana has 1,700 students, appallingly few people for a major industrial part of the state; but the area vocational school run by the school system has almost 1,200 so that the traditional technical setting may be the wrong place to look for this kind of education. Perhaps the secondary school system, recognizing its falling enrollment, will improve its vocational-technical offering to appeal to adults in a way that the technical college, which tends to get the 17- to 19-year-olds who didn't do very well in school, does not. The area vocational school's adult population is those who have been working for a while. That, rather than the technical institution, may be a more appropriate setting to try out what you are suggesting.

Student Comments

Sociology

MS. LAWRENCE: I did not declare my major until after my sophomore year. When I first came to IU, because I intended to go into medical technology, I was in the basic classes, beginning with Principles of Chemistry. Within the class itself, we talked about things--like the ozone layer--that affect everyday life. It helped me understand more clearly what I read in the newspaper. It was very competitive; and after that class, I realized I didn't want to always have my nose to a microscope. If it had been different, I might be interested in medical technology and not sociology at this point. But it was one of those classes that required students to have good study habits and to be able to talk to the teachers, and the first semester is such a really hard adjustment period. If I had had it later, maybe even one semester later, I might have continued in science. I think about taking the second semester of chemistry, just as a challenge to see if I can really do it. I often wonder if I would have gone on with that if it had come at a later period in my college education.

Then I took a biology class designed for non-majors, and I really liked it. We studied plants, animals, and civilization. We examined history, agriculture, and the domestication of animals. The course never got really complex, but it helped students figure out the value of different types of food and different ways in which man depends on animals and plants.

I have always liked math, although a lot of people enter sociology because they don't like numbers. They just want to make statements on relationships. My statistics class and my calculus class were challenges. By going into sociology, I found out that it is important for the average person to be able to understand what a statistic is and to be able to read graphs because many everyday activities are presented to us that way; and if a person doesn't understand the basic ways to read a graph, it is just all going over his head.

The weak points in my education in science and math were not taking as many classes as I probably should have. I have taken only those science and math classes that either fulfill a requirement to graduate or pertain to my major. The real weak point is that non-science majors aren't required to take many science and math courses; and because these courses are perceived as being the more difficult ones, most non-science majors don't take them.

Question: Does the chemistry department have a course for students not interested in chemistry in a professional way?

Response: Yes, they have the one I took, which was basically for pre-med and consisted of one whole year of non-organic chemistry followed by one whole year of organic chemistry. Then they have one for nursing majors that is more concentrated in two semesters. There is also a 100 class for non-majors interested in chemistry but unwilling to get down to the finer points.

Question: Did you feel that the chemistry course really prepared people to be chemists? Do you think the course designers knew what you would need for medical technology and so on?

Response: It seemed like a weed-out course because a lot of people come down here thinking, "I am going to be a pre-med" and "I am going to med school." But they get hit with the fact that the courses are a lot more complicated and in very detailed form.

Question: What was your high school science and math experience like, and how much did you take?

Response: Until my senior year, I was in an accelerated math program for those who showed advanced skills. I had a really good background with geometry, analytic geometry, and algebra. Then, I kind of wanted to take it easy. With science I went beyond the basics, taking two semesters of chemistry; but I didn't take accelerated physics because at that point, I didn't know what I wanted to do. All I worried about was getting good grades; and sometimes I didn't take the harder classes because I didn't want to get bad grades. But now, I advise my brother and his friends to take the harder classes in order to get a good background and not to worry about grades because if you are not challenged, you are not going to get much out of the class.

In each successive grade, the classes got smaller and smaller. I was in Geometry X in tenth grade, although I really did not decide to be there. Our teachers from junior high school picked students they thought should be there, and from then on, the students decided what they wanted. When I was going into algebra, I wanted to take the easy program. But that algebra class wasn't challenging, and I changed my courses back to the X, where I learned a lot more. I knew a lot of people in the easier programs, but they were not as involved in them, taking those courses because they had to. On the other hand, in the accelerated ones, people were really involved and interested or they probably would not have been there. However, when I reached my senior year, I was just not willing to put in the extra effort.

Question: Are your parents scientists or academic people?

Response: Neither one of my parents went to college; but my dad is an industrial engineer, and my mom is a secretary at the same corporation. However, from an early age, I really liked math; because it came easily to me, my parents have encouraged me to pursue a career in it. Now I am thinking about continuing beyond a B.S., and having a supportive family helps a lot.

Outdoor Recreation

MS. POSTEL: The science department offers courses for biology majors, chemistry majors, physics majors, and non-science majors. For intance, they put English majors, recreation majors, and telecom majors in one class and expect them to sort out totally different goals and objectives, to find out the little things applicable to their major. That is really difficult because everyone is at a different point. The English majors do not want the same thing out of an introductory biology class that I want as a recreation major, and it is impossible for the instructor to give that.

My major requires a minimum of 15 hours of science, but about 30 hours should be required. However, the courses should be less general and broad and more applicable to any major. I have taken nine hours of geology, including environment conservation and introductory geography; introductory physics and physics of energy; and biology. However, I can only find little bits and pieces of information that I can use in my field because it is all broad.

The science department should offer courses that recreation majors could take, such as interpretive courses in specific science fields. I don't care if I know the Latin names of all the flowers and all the phylums, but I would like to be able to show a child how the components of growth and decay and maturation affect our environment. That is what I am looking for, but that is not what I am finding, although the recreation professors are qualified to teach those types of science things. They teach techniques and methods, but we get none of them. For instance, Dr. Barbara Schaluka taught to rec students a horticulture class about the different flowers--not just their Latin names but their impact on nature: how fragile they were, what would happen if they were gone, how that would affect the food chains. But that class is no longer offered. In a few of my classes, the professors are not attuned to the recreational or the environmental awareness needs that should be emphasized.

Question: Wouldn't anatomy and physiology courses be useful to a recreation major?

Response: I would say they would be more useful for a phys. ed. major than for my major.

Question: I can see how some things that you study can be applied immediately. Isn't there much that you might learn--for instance, in physics--that you wouldn't foresee any use for at the time but that might be useful five years later?

Response: There is great exposure to things undoubtedly helpful in any field, but there is a difference between the exposure and the knowledge and application. Information is of no use to me if all I can do is store it.

Question: In any of these introductory classes, do the professors talk about the goals and objectives of the class, or how the course might prove useful to you?

Response: I think many times that is what they have in mind, but they don't say, "This is what I would like to see you learn from this unit." They more or less present information, which students are supposed to absorb and give back on an exam; then, that is the end of it. There is no carry-through, even in my department. It is not progressive. For example, second-year biology is not based on the introductory biology course. Too much is left for students to connect in order to see the relevance and the implications.

In some courses, there isn't any relevance to my major. Many times instructors just consider a student as a non-science major, not a recreation major. They don't consider that their class could be applicable to each major. I would rather have a more specified curriculum instead of a variety of these science courses. I wish departments would say, "You really should take this course, and this course, and so on."

Elementary Education

MS. SANDLER: I'm in the second group of students that explores basic science fields and then concentrates on biology, physics, astronomy, and geology. Simultaneous with other planned classes, we take three separate science methods courses that prepare us to teach those classes. First, I took a methods class and a biology course, followed by a methods course and a physics course, and I'm taking my last methods right now on geology and astronomy. In my methods class, I teach what I learn in my science class. We find out what we are doing right and doing wrong and structure the methods accordingly. I really like the idea of these classes.

Members of the science departments teach them, but the courses are geared for education majors. A lot of people feel these classes are for students who can't pass the other ones; but when my friends see what I have to do in these classes, they understand that many of my classes are rougher than theirs. They are designed to be applicable to my teaching, which I think is better; but even if I did not have professional plans to go into teaching, they would still be good. The methods course is what mainly ties everything together; and if you were not going into teaching, you would not be taking that. But the first methods course I took introduced me to the sciences and showed me techniques to deal with science. I didn't know what imprints were; I didn't know what anything was before these courses. But I think a non-education major, somebody who was taking it to learn facts, could learn a lot. Also, we are learning basics as well as a few higher levels so that we will be adequately prepared in the classroom.

When I first came to IU and found out I had to take 18 hours of science, I nearly had a heart attack! In high school, I did the bare minimum to graduate; I didn't plan on coming to college. I think I had the two required credits of biology and then I had two credits of math. I should not have passed biology, but my teacher passed me so I could graduate. So I had no background at all to come to college and take all these classes. I thought I was going to flunk out automatically because these science classes are geared toward education majors and require us to do experiments that we will later use in the elementary schools.

Question: Were they teaching you facts, mostly demonstrations with kids, or history?

Response: The basic science skills and the physics concentrate on doing. We did all the labs, and there were lectures, but little factual history of science. Biology dealt mostly with facts. You didn't have to know the biology itself too much. But in astronomy and geology, you did have to know the names of important people in those fields. What we did tied into programs such as elementary science service for the American Association for Advancement of Science Curriculum. For instance, we learned how to weigh and measure and so on in the first course in order to use that knowledge throughout the courses, especially in physics.

Question: You like science because you can see what you are being taught in these courses; it is applicable to what you are going to have to do. Now the students that you have in elementary school are not necessarily all going to want to be teachers, so how are you going to make that kind of impact on them? How are you going to show them that science is applicable, that it is meaningful to their lives?

Response: The basic thing is to teach something by making a game of it. If you make it fun, students will do anything you want; and even if they don't want to, they are going to learn about it--just by accident. For instance, I taught a lesson today similar to a lesson taught last week; and someone said, "Oh, are we going to do this again?" I said, "No, we are going to do something different but with the same material." And we had a good time with it. We played games and did different things with it; and afterwards, the students asked, "Oh, do we have to go already? Are we done? Can't we do more?" So if the kids really have a good time, they will learn. You always have to make it a game to get any learning done. You can't have kids keeping their nose in a book all the time and reading about things. They have to be doing things. So why make it hard when you can make it fun and finish it?

Comment: Our particular problem is inducing college-level students to enroll in science courses beyond what is required of them; and at that level, it is not so practical to make learning a game. It usually turns out to be some fairly hard work. I wonder if what you say carries over or whether, after people reach that stage, they are willing to do hard work that is not a game.

Response: I can be honest. If I did not have to take science as part of my four-year program, I would not have. I was very scared. However, most of my friends weren't because they had had it before. Most really liked it.

Question: What kind of scare was it? Was it the amount of work you thought it might be or that you thought that you might not be able to understand it at all?

Response: It is not what I <u>thought</u>. I <u>knew</u> I was not going to be able to understand it! These classes [designed for education majors] really freaked me out in that they helped me to understand science. I couldn't believe it because all through high school, I had never understood anything in science. In my other science courses, teachers would present the material; and if we understood it, fine. If we didn't, we flunked. Here they are presenting science so we can really, really understand what is going on. The physics teacher, for example, just took any incident and explained it with things that we had seen so we could understand a lot better. The teaching methods here are just more effective. And students in these classes have a good time and understand what is going on better than in some classes, particularly some of the education ones. I think they go on to more science classes.

Comment: There may be another factor. I find that I never understand things until I have given them simple explanations. It may well be that you understand because you, in turn, had to make the explanations to kids in your class.

Response: That is a lot of it because you must be able to explain something easily to a kid. You can't be using big, complicated terms. And that is how our teachers are approaching us. They are using language we can understand whereas in courses outside the education department, instructors use big words.

Question: But has your vocabulary grown?

Response: Yes.

Comment: Somehow I avoided science, got somebody else to do it, or dropped it.

Response: I am [practice] teaching in a first-grade classroom right now, and the teacher has told me she is not teaching science. She has taught two science lessons all year and says that is all she was taught, and that is what I would have been like.

MS. RICHARDS: The first course in the 1500 series was a good, general course that touched on everything I had had in high school but presented things that I would teach to elementary kids. However, the professor went into greater detail than was expected in an introductory course. She acted like we had had a lot of biology before, making the course really hard.

I had physics and learned a lot. My professor applied it in the sense of how we would explain it to kids. The other courses in this 1500 series are general science, astronomy and geology. All but astronomy and geology are 16-week courses, and all five are four-hour courses. And I really enjoy them because we have lab experiments together with methods classes and then go into the schools and teach what we are learning.

Comment: Because it is being brought down to a level where all of that fear evaporates; all the theoretical kind of bookish stuff goes.

Response: In the methods courses, we are doing essentially what the kids would be doing. That takes away some of the fear of the science. We also did some units called "Small Things" and "Growing Seeds" that were fun.

Question: Is it true that there is no mathematics in this sequence of courses?

Response: Math is handled in elementary education by the T courses. T101 presents the basics. Then we have geometry, statistics, and probability, as well as the methods class that goes with all three.

<u>Question</u>: In any of the science courses, have you found out what math is good for?

<u>Response</u>: In astronomy and physics, we use math.

<u>MS. GROGAN</u>: I'm given science classes to build my own classes around, and the methods courses are odd, but I just really love the program.

I had no problem with the biology class. I enjoyed the professor, and both the fundamentals and the additional information that she presented gave a little bit more than you have to know to present to the students. The methods courses enable you to bring the material down to the grade-school level.

The mathematics program was a waste of my time. I cannot believe I was paying money to sit in a classroom in order to learn how to add and subtract. I just could not believe I received two points on my final exam for punching the 4 plus 1 equals 5. Also, statistics was a joke. I gained nothing from those two courses. In both of them, the associate instructors were from the math department, and we talked nothing about elementary school. They were such a waste.

<u>MS. RICHARDS</u>: I felt it was very much a waste of time, too, because it was so easy. The methods class was a little different. That is why I am saying I wish I had taken a methods class with T101, 102, and 103. It might have applied more to what I would teach. The math that I am taking right now, E343, teaches that. We are learning how we would use different concepts to communicate but nothing about mathematical theories themselves.

<u>Question</u>: We have had three persons here very excited, obviously, about the science courses in education. How would you improve the math instruction? What suggestions could you make so that you would be as enthusiastic about math as you are about science?

<u>MS. RICHARDS</u>: The math for elementary education majors was very basic, adding and subtraction and multiplication and division. We were shown how to do something that we should have already known.

<u>Comment</u>: The kind of enthusiasm evoked by this science sequence suggests that other parts of the university might be able to learn something from it. Sequential courses might also be applicable to people in other areas such as English or history.

<u>MS. GROGAN</u>: I don't think we should all have the same courses.

<u>Comment</u>: A recreation major said that she was turned off by science because the courses are not designed for her. One of the reasons you seemed to be turned on by it is that the courses are especially designed so that education majors can apply the material immediately.

<u>MS. GROGAN</u>: Yes, but non-elementary ed. majors benefit much from that. They would learn the basics from the lectures, but the course is mainly

designed to enable us to teach the subject. For example, I am taking astronomy now; and this morning, Teresa and I taught our little first-graders about the moon, telling them what we had just learned in class. Our astronomy professor asks us how we would present material to a kid. He explains it to us that way. However, he is from the science department and seems to fear teaching education students, knowing that we have to go out there and teach. He seems afraid that he doesn't know how to present it as it should be presented to the kids.

I think the faculty think we are stupid. They seem to think, "Oh, you are all elementary majors? Okay. And we have to teach you at the lowest level." I have gotten that feeling from the professors across the board.

Question: Do you have to fulfill general university requirements, or are your requirements in the school of education?

Comment: The school sets the requirements. But students in elementary education are required to take more science than liberal arts. You should take four science courses if you are in liberal arts--the political science major, the telecom major, and so forth. Recreation is a separate school, but those students take more hours of science than the typical liberal arts, or non-science, major.

MS. GROGAN: I think we should.

Question: Who provides the funds for non-science majors to take courses in astronomy?

Comment: The School of Education must be paying to have people come over from the science departments. There is a department of science education with a regular faculty. There is probably an exchange at the dean's level on salary. They probably only teach one course a year in the School of Education.

What is interesting is that there has been such enthusiasm about science from all three of you.

MS. GROGAN: This kind of science program is very important to me because my own preparation is weak. Also, I believe in hands-on experiments.

Question: Is there a corresponding course for secondary education majors who plan to teach science?

MS. RICHARDS: No, I don't think so. Those students just take whatever education courses are required along with the science courses taken by non-education majors.

Comment: I think we should see if people who are science/education majors at the secondary school level are as enthusiastic as they are at the elementary.

Question: When physics, let's say, is taught in the context of your particular future needs, in terms of teaching the children, you are very enthusiastic about it. Has that stimulated your interest in science on topics that are not applicable to teaching kids?

MS. GROGAN: Yes. Now even when I see an article on an aspect of science that I would not be teaching to the school kids, I read it!

Political Science, Psychology

MR. YOUNG: The relationship between science and political science depends on what area of political science you go into. Because I am interested in such things as environmental policies, biology would be very helpful for understanding certain political policies. It would apply less to other aspects of political science, such as constitutional law. For example, how a lake can be affected by chemicals would greatly affect whether bills should be passed against certain industries' dumping their pollution into the rivers and whether it is realistic to expect industry to be able to clean up a certain pollutant. I would not take a course for non-majors, though, simply because I have been told by students and advisors it is so general. However, a general course might cover more area and touch on something that might help in the future, but I think doing actual biological experiments might show me first-hand what is involved rather than just reading about it. But if it is obvious that you need a certain knowledge in order to take another course, then you take the courses sequentially.

Psychology would also be useful, and I have been told to have a lab in either biology or chemistry. I have had astronomy and calculus and will be taking statistics and a lab course.

Question: Have these courses improved your knowledge and understanding of the problems of the environment?

Response: Astronomy was just a facts course, not very analytical. The math courses have been helpful for analyzing ideas, helping students to recognize how X affects Y, rather than bombarding them with facts. This will be useful if I go into a graduate psychology program and focus on research. I hope to pursue social psychology, analyzing public behavior. I haven't really decided yet how much science I will include with the political science, and I may go to law school eventually. In my science and math courses, I want to get a fairly heavy dose of statistics and such things.

Speech Pathology

MS. FRIEDMAN: I have a strong background in psychology, as part of the requirements in the department, but my math is limited. As an undergraduate, I took only finite math taught by the math department and statistics through the psychology department. Anatomy and physiology of speech covered exactly what it says; it was kind of an extension after having anatomy. The supplement to that was speech acoustics, an extension of physics. However, I had not had physics and didn't find it really necessary.

Question: Which courses did you get the most out of--the general courses such as biology and anatomy--or the courses taught within the speech department, specifically for speech students?

Response: Biology gave good general knowledge, and I would say that it was necessary. However, my anatomy and physiology of speech class in the department was very detailed, very explicit, and very pertinent to what we do. Anatomy was most definitely a necessary prerequisite to the speech class; without that prior background, understanding the details would be very difficult. The quality of teaching was better in my speech class, where the professor has degrees in speech and hearing science, which is basically mechanisms of speech and breathing and respiration. However, the labs were more extensive in anatomy. Within the department, we had only a few labs, maybe four, throughout the semester.

Question: Is a bachelor's degree in speech a terminal degree, or do you need a master's to become a practitioner?

Response: You do need a master's degree to be your own clinician and to be completely certified. With a bachelor's degree, you still can teach, but you are an aide to another clinician and not certified by the American Speech and Hearing Association until after your first clinical fellowship year, after you have your master's.

Question: Did you follow the science prerequisites set down by the speech department, or did you select some science courses?

Response: The speech department gives you a choice as far as the sciences. I did not have chemistry in college, only in high school.

Question: What were the science and math requirements in your high school?

Response: We had biology, chemistry, physiology, and math. The three years of science did not include physics, although it was offered. I had four years of math: general math, trig, algebra, and geometry. But I guess in all honesty I would have to say math has not come easy for me, and I still would have to work at it. I feel very comfortable with science, but the thought of taking a chemistry class in college maybe would have frightened me a little bit, but not enough to deter me if I'd really wanted it. This good attitude about science resulted from the good high school teaching in that area.

Question: How did you get interested in your field? When did you start that interest?

Response: When I was younger, I had envisioned myself in teaching, rather than in business, and had planned to teach retarded children. Also, within our high school was a nursery school class that I taught. That good experience gave me exposure to it. And I had done volunteer work with children, so that when I came to college, I thought my general area would be special ed. But when I took an introductory class in speech and hearing, I made the decision to go into speech.

Question: As a result of all this science work, are you interested just in the applications to the field in which you are going to be working? Or do you have broader curiosities as a result of courses? I mean, are you interested in space exploration, the universe, or medical problems?

Response: My interests would lean toward the medical field, to anatomy. I do have a big interest in that; and at this point, if I had to choose a second field, I would choose nursing rather than pursue an educational field.

Question: Would courses taught in the speech school be more vocational in orientation and less liberal? Or less substantive?

Response: I would have to agree; but at the same time, they would be more applicable, more narrow, more directed. They were not necessarily less rigorous or less liberal in their orientation in terms of broadening our horizons, making us curious about the world around us.

Biology had a broader perspective to the whole class and to what it was teaching; classes in the speech department are so much more specific.

Question: As a citizen, which would have benefited you? We live in a world of science; and our government spends millions of dollars on science, defense, and things related to science. In order to vote intelligently and become a leader in the League of Women Voters, for instance, what would be your chief benefit?

Response: The general sciences--biology and anatomy--versus my speech. There is such a general applicability of a course like anatomy and biology that is basic to your understanding of the world around you.

Question: What about math? Have you used any of your statistics or finite math in life yet? Or was it just a course that you fulfilled?

Response: In graduate school now, we have taken a class in graduate research, and I have used statistics, enabling me to make value judgments and critical judgments about research studies. Having taken both of those classes, I can now read journal articles and understand the charts. I'd have been lost without it.

Question: If a course were offered just in broad, general science with no focus on any single profession, would you want to take it?

Response: If it was early enough in my undergraduate career, and if I had the time, it would be. But, in all practicality, you have to think about what is really going to apply to you and help you at the end.

MS. JONTZ: Cathy and I have shared a lot of similar classes because the distinction between audiology and speech pathology isn't made until the graduate level. Audiology is hearing assessment with different types of measures, analyzing people and how they hear, evaluating their sensitivity. It involves their Q and E, and we do a lot of fitting with hearing aids and all kinds of evaluation. We do much in rehabilitation. In audiology, speech pathologists are qualified to do oral rehabilitation; and in most cases, because the audiologist ends up doing most of the diagnostic work, the speech pathologist gets the majority of the oral rehabilitation.

As an undergraduate, I had speech anatomy, physiology, physics, calculus, and statistics. I haven't had biology. But the labs in anatomy were exceptional; now they even use cadavers. They were conducted by second- or third-year medical students who went in depth and spent a lot of individual time with the students.

I disagree with Cathy just a little bit so far as what she said about the applicability of anatomy. Both anatomy and physiology could be improved a lot because the instructors never showed how this applied to the research going on today. To me, they just presented it, and you just had certain parts to learn. Some people complain that as it is now, it does not apply enough to their field. But if they were encouraged to take it, in the long run it would be beneficial. It should be offered in high school because the major difference I see between a lot of people's performance in college stems from their different science preparation in high school.

Question: Do you think a course combining anatomy and physiology might be the best thing for everybody to take?

Response: Yes, I really do. Maybe it would not have to be quite so specific or could be divided into very small segments. You just can't retain all that for the next class.

Question: Can I just ask what you had in high school?

Response: Chemistry, biology and four years of math (geometry, and special college preparatory math classes). I plan to take two psychology classes with labs and pathology, neuro-anatomy, and etiological psychology because I want to do research after I get my degree in audiology.

Question: At what point did you take physics--the beginning of college?

Response: In my freshman year; and I really would like to have a better grasp of the principles of physics because to me it is such a radical change from my usual way of thinking. The way physics students just visualize things was hard for me. For instance, the teacher would lecture about something that seemed very concrete, but when he would give us test problems, we had no indication that any problem was applicable in the situation.

Comment: At Michigan, we have a course that is taken as a prerequisite by all pre-meds, pre-dents, pre-everything; it is a straight physics course that is not created toward applications of any kind, but everybody takes it.

Response: I would have liked to have had a better experience in physics. I always thought this was going to be the hardest science course for me because I had not had it in high school. My high school physics teacher was very subjective in his grading. He would fall asleep when he was lecturing. In college physics, the instructor would dwell for five lectures on one basic point such as something dropping into the water, but he could never make the transition so we could see how it applied. A lot of music majors, speech and hearing majors, and other people just take acoustical physics because they think it will be an easier physics class.

Comment: I still don't associate it with what I have known as pre-professional physics. In our school they have just one big course with 800 or 1,000 students in several sections, for two lectures and a laboratory every week. This is a standard course that every pre-professional student takes.

Response: That is the problem. People feel they are learning more in anatomy than will be practical for them in speech and hearing; and they say, "I don't really need this stuff. I don't really need to learn about all the tissues and things," not realizing that anatomy makes speech easier. Advanced physics would have given me a lot more information than I would ever probably need, but it would have been beneficial for me. Instead, I had a watered-down course.

Question: Do you think that if the speech department required advanced physics, that would be better preparation?

Response: A lot of people are discouraged from speech and hearing just because they have to take anatomy. Similarly, adding physics on top of anatomy would discourage a lot more people.

Question: Do you know if, in two-year colleges, you can get an associate degree in speech and hearing and be a technician more than a clinician?

Response: There is something like that in audiology, but I am not really familiar with it. Maybe they go to a four-year school.

Question: Did you have similar feelings about the science courses required for speech?

Response: There is a completely different orientation to the way the courses are offered to you. My instructor demanded that we talk. All the tests were oriented towards applying what we learned to a practical situation. That was a lot more beneficial because the little details that he left out I would probably not have remembered anyway. Instead, I had to know how this was going to relate. So in that sense, it was more applicable for me.

Question: All right, now I will put the same question to you as I put to Cathy. How does this science background help you as a citizen, a D.C. lobbyist, or just someone interested in the quality of the environment?

Response: I think it would be helpful. The problem here is the one that says "specialized" for no reason, and you almost need a happy medium betweeen the two because you want not only a certain degree of knowledge about other things but also some kind of applicability for what you know.

Question: Would you classify yourself as a non-scientist?

Response: I don't know. I feel closely related to a medical interaction in audiology and certain areas of speech; there are aspects of speech pathology that are really directly related to the medical field. I am not sure that there is a classification of non-science for us.

Question: Do you think you have an understanding of the methods of science--the way scientists think, the way scientists approach problems and evaluate validity and viability? Do you think you think in scientific terms, scientific modes?

Response: I would say that. I am more directed toward scientific thinking in a lot of my classes where the material is based on research articles.

Comment: There is sort of an in-between area. When I was with another study in the behavioral sciences area, we treated the communications sciences as a behavioral science with clinical dimensions. You see, there is a difference between scientific thinking and clinical thinking that borrows from the natural sciences. Allied health professions need natural sciences, but all of the training predisposes toward clinical thinking. They are non-scientists; they are clinicians. They are more therapeutic in that area, and there is a difference.

Students are under such great pressure to just take the requirements and get out of school. What would you think about spending five years in an undergraduate program instead in order to take more courses?

Or one option would be to lessen the requirements in the areas that you have to take. If you had a more relaxed approach to getting a bachelor's degree, would you be interested and therefore inclined to take science or humanities?

Response: I think I would have leaned more towards the medical field or have taken a few recreation-type classes.

MS. FRIEDMAN: I would have taken more classes in anatomy, in statistics, and in the arts and humanities. You only need to take four classes, and I don't know enough about music or literature.

Question: How would you evaluate your science courses and other courses you have had in the social sciences in terms of their quality of teaching and just how much you learned to satisfy your curiosity?

Response: I feel much more positive about the science areas than I do about some of the other general undergraduate requirements. I learned more in the sciences courses. I had very good teachers in both classes, and in general, because of the people I had, the classes were very much equal. The main difference was the exceptional lab work in my science classes. I feel I learned more in the sciences, but this is because of my high school experience; I was able to go to a higher-level science class when I came down here.

Communications

MR. McCONNELL: I would be a perfect target for a disappearing experiment. I stay away from physical sciences and mathematics because I am intimidated by the degree of difficulty and time.

I would like to devote attention towards my math, but it takes a lot of time to set up a pill detector or splice tape and get a project. Chemistry and courses like that take a lot of time, too, and I have seen people stay up all night in preparation for exams for them. However, there is always an alternative; for instance, I took geology as an easy way out because we are required to take two courses in math or physical sciences and I wanted to spend most of my time on what I wanted to do for the rest of my life.

Question: Since you are a telecommunications major, wouldn't knowing quite a bit about physics be helpful? What kind of technically-oriented courses would you take?

Response: Musical acoustics, such as the School of Music's science course in electronics. I am taking that as an elective because it doesn't fulfill my arts and sciences distribution requirement. But I would avoid electronics in the physics department and biology. This course probably has more to do with creativity, with creating something on tape that can stand alone. Also, the course description was more inviting, making the course sound interesting enough for me to see the professor about it. The description explained that this course goes into basic electronics and how to apply it to telecommunications.
Comment: We have a similar situation with two electronics courses, one in physics and one in music. Even physics majors take the one in music, claiming that the music teacher has great equipment and knows what a tape recorder is, while the guy in physics hardly knows what a transistor is.

Response: That's exactly it. I just recently found out that the music department was offering these audio courses in electronics and music without the use of musical instruments, basically. Knowing that is a big help to me.

Question: We are asking you a lot of specific questions, but I wonder if there would not have to be some study of the basic, underlying physical principles of the transmission of sounds? I am thinking of modern ways of generating musical sounds electronically, synthesizing all kinds of fantastic things. Is that something that you would need physics for? Or can you get that technique without actually having to study basic physics?

Response: Usually, the professor is knowledgeable enough. You are considering two different fields. For instance, to work on a sound board, you don't have to be an engineer; you just have to know what you are doing and to watch the VU meter. If the VU meter breaks down, you call in an engineer who knows how to fix it. I'm a user of science, not a creator of science.

Comment: This discussion can be generalized in lots of other fields.

Question: How did you become interested in sound production?

Response: It is just one of those things I have always wanted to do, and I don't know why. I've always had interest: How did they film that? How did they get that technique in "Star Wars"?

Question: Do you read popular magazines?

Response: I read Broadcasting Magazine, which reports new equipment such as digital record players.

Question: Do you feel that the university setting puts you down because you are doing things that are not traditionally academic?

Response: No, they have not given me much input about that, partially because we have one counselor for 800 majors.

Comment: That is not in journalism, but rather in telecommunications. We teach broadcast news and courses here in a separate department.

Response: I have to find out about courses for myself; for example, I had a 10-minute time slot yesterday to decide what is going to happen the rest of my life. When I told my counselor that I wanted to talk again, she said, "Okay, the next free time I have is January." That makes me unable to find out about the major courses.

Comment: Telecommunications majors are the second largest group in the college--after biological sciences, which combines three or four different departments.

Question: How do you feel about the equipment that the university provides?

Response: Very, very good except the WFIU telecommunications department has to pay to use equipment such as the special four-track sound board. Also, I am not allowed to use the equipment unless I either am in a class at the time or have a project. It is useless to be in the studio around 5:00. You can be in the middle of a taping and have to leave because someone else needs the overtime.

Question: Now, we have heard about your interest in physical sciences. Would the biological sciences help you in your work at all?

Response: They probably would, but I don't find the time to give the effort for really hard courses where people walk in knowing all the terms. I did take Psychology 101, which is classified as a biological science. I had to go to three experiments. It's a way around. The description of one of the courses I am taking next semester, advanced audio production, says, "Do not take any other courses which demand much time." That is one reason that I go to lab now. Some courses don't demand much time; you sit in a lecture and take three tests for a credit.

Question: Did you ever learn any science from television, either instructional or otherwise?

Response: An introductory course, R204, which all majors have to take, deals with the scientific background in telecommunications, but I did not enjoy that at all. I had no television programs that were edifying and educational. Most of the courses I take are applied; you just go out with a camera and learn good techniques on producing.

Question: What science and math did you take in high school?

Response: I took chemistry, the required two years of basic biology, and four years of math.

MS. NEUGEBAUER: As a speech communications major, I have one class in psychology, P-101, that counts towards the biology requirement. I have had the introductory biology class for majors. I have had 10 hours of calculus at the 200 level and the introductory computer science class for majors. And I have had a couple of classes in abstract logic taught by the philosophy department but similar to the courses taught by the math department.

The biggest thing that these classes did for me was to give me analytical tools, not necessarily factual data. My math background throughout high school and college, taking a theorem and trying to prove it, helped me a lot in speech and argumentation. I find it much easier to pick out what is wrong in arguments.

Other areas of speech communication often use natural sciences as a paradigm to help explain what is going on. I know a big school of thought right now in the social sciences (business, speech communication, political science) is the so-called "systems theory" school. It is big in speech communication, especially when you are studying group interaction and organization communication. I know they use it to study the organization of Congress. The whole paradigm was taken from biology, saying organizations are like organisms. Although I had no factual data from biology that specifically helped me to understand this theory, having biology classes gave me a better appreciation of what the systems school is like.

The only part of the natural sciences that would relate specifically to speech communication would be psychology classes dealing with attitude formation, motivation, and other social science aspects.

Question: You took a lot of calculus. Is that necessary for a speech communication major?

Response: No. I just took that because my father, a math professor at Purdue, suggested it, and I do like calculus.

Question: What do you expect to be doing 10 years from now in speech communication?

Response: Our department basically has three areas. One is the study of rhetoric, giving and criticizing speeches; "interpersonal and group communication" covers interactions and group decision-making; and "organization communication" deals with how managers communicate downwards and how employees communicate upwards. I am planning to study classical rhetoric in graduate school. Ten years from now I will be doing research to earn tenure and possibly coaching a debate team.

Comment: Your interest in science and mathematics comes not from things that necessarily happen at school, but family impetus really got you started down that path.

Response: I took biology because I am an avid bird watcher, and I enjoy the Christmas bird counts. I picked that up from some of my friends.

Question: I heard that you could pick a budding scientist by going to bird watching clubs. Numerous examples are given of Nobel prizewinners and people like Jim Watson who grew interested in science as bird watchers. Were many of your childhood friends bird watchers?

Response: No, just one friend got me started. Not many people I know are into it. They tend to think people who watch birds are queer.

Comment: I know a person who was a bird watcher when he was young, and he turned out to be a very successful art sleuth. He can determine if a picture is a fake because through bird watching he learned to recognize all the little nuances of color and detail at once, and he applied that to art.

MS. STOCKING: I am a graduate student in communications and come from a background that is very similar to that of a lot of these non-specialists. I took the easy way out, as a couple of people here did in terms of science, taking an easy physical geography course as my science course. I did not take any math in college because it was not required. I had taken chemistry in high school, and I liked it. I had taken algebra and geometry in high school and liked them. But for whatever reason, when I got to college, I was not interested in pursuing science or math.

Working as a reporter, I found that from time to time I had to cover stories with science implications; I usually handled them well because the rubric in journalism school was if you are a good reporter, you can cover anything. It doesn't matter what your background is. I became contributing editor for a social science publication, Human Behavior, and wrote a lot about the social sciences. But I did not really adopt or develop my current interest in public communication of science until I began to do research in graduate school here at Indiana University.

I have looked at some studies of science writers, their training, and their recommendations for training future science writers. The most recent, a 1975 survey of 132 science writers by Sharon Dunwoody, asked science writers to describe their own personal training and to make recommendations for training future science writers. Most of the people had been either journalism or English majors having at least introductory courses in basic sciences, most commonly chemistry, physics, and biology. These courses also were what they recommended future science writers to take.

Very high on their recommendations--higher than practically anything else--is experience in the laboratory. And I had experience in the laboratory, particularly in psychology, which is a very experiment-oriented course here. Even more important than the content is the approach to science, learning how to think in terms of control groups, experimental groups, probability, reliability, validity--a lot of concepts that I knew nothing about when I was a contributing editor for Human Behavior. I started doing social psychology experiments. I started to learn to think like an experimental psychologist.

I was fascinated because my thinking had been uncontrolled before and I hadn't realized it. I had not realized that when I was operating as a journalist, I was missing so much and accepting as cause and effect things that weren't causally related at all. Then, I learned that I am more interested in synthesizing other people's research and making it understandable than I am in producing research.

And I have some fairly strong thoughts about science education for journalists. I have educated myself primarily. I regret that I have not had many courses in the sciences, even as a graduate student, and will try to make up for that as soon as I finish my doctorate through things like Council for the Advancement of Science Writing Internships, which provides money to take hard science courses. But I think that the sociology of science is very important so that science communicators can understand that science is not as "objective" as many scientists would like to believe and as much of the public believes. We have here a very strong sociology, history, and philosophy of science program. I think that is very important, more than the content, in fact. As a journalist or as a scientist, you often have to hop from one specialty to another; you need a scientist's trained mind. You have to investigate various interests and specialties outside your own and to use analytical skills. People writing and communicating about the sciences really need to develop that larger framework and way of understanding and approaching problems.

I have been watching the Sagan program. I don't like the profiles of him looking into the sky, but it has been really fun for me to watch that program. I buy science books. I ask specialists if this is an accurate reflection of what is going on, since Carl Sagan often translates something incorrectly because he is outside his own area, too.

Question: What could have been done earlier to have helped you have a more valuable experience at Northwestern? You started out liking science in high school. Then you got to a period in which you avoided it.

Response: I was desperately afraid of science, and part of it had to do with the work involved.

Question: This university requires undergraduate journalism majors to take at least four science courses--two biological science courses and two physical science courses. Do you think there could be some special science courses that would be more meaningful to journalism majors?

Response: I don't know. I do know that my introduction to statistics came through programs in education at the University of Southern California and here. I have also compared what I know from statistics and psychology with what people have learned in the education schools, and I have a much more positive attitude towards statistics, a more practical and theoretical course than many people in psychology think. I came away with a positive attitude, unafraid, and learned to do the work.

I have a personal interest in teaching more about social sciences to people who want to become science communicators. Examining a number of studies, I have found that science writers have very little interest in the social sciences, partly because of their relative lack of training in that area and partly because of public consensus that the social sciences really are not sciences. That is sad because a lot of times when people highly competent in their fields cover the social sciences, they don't do a good job. And they don't know how to evaluate the social sciences, which are muddier than the harder sciences in many ways: values affect methods, and response is often sloppy.

Another thing occurred to me about training. A scientist at the Institute for Public Information asked science communicators around the country what they believed accounted for the current explosion of interest in science among the mass media. A producer of ABC's new program, "Quest," indicated that people are interested in science right now because the world is so uncertain, iffy and changing that people need a sense of certainty and believe that science provides definitive answers. I thought to myself, "Oh, no!" This is a popular misconception on the part of a lot of people, including working journalists, that science provides definitive answers. That just reinforced my feelings that we ought to be teaching people more about the process of science, that science is dynamic, that what is true today is not true tomorrow.

Question: In general, is it true that journalism majors can never really predict whether they might have to write about science? Would it follow that they ought to have lab courses because they might be worthwhile?

Response: It would be really interesting to show students in journalism education programs that they have a 100 percent probability of covering a science story and that a science story these days is no longer just the basic findings of science. It would be practically impossible to avoid science if you are a general assignment reporter. As a matter of fact, a number of content analyses of science news provide data indirectly. The objective of one study was to look at science news articles according to who wrote the story, a regular science writer or a general assignment reporter.

Language, Literature

MS. CRITTENDEN: As a linguistics major, I think that science for non-majors is real easy. I have had one general math course, survey of calculus, non-majors biology, and a course on the environment. There is a great dichotomy between the courses and their use or demand. I find that very unpleasant because they are dominated by people very interested in grades, not in the science as a subject. Therefore, most students either take really hard courses that have these people in them, or lukewarm courses that are just jokes.

Question: What is an example of one of those easy courses?

Response: They are courses that are made in such a way that only the best half of your test scores are always counted, and there are all sorts of other options. I don't see any way that a student could leave that course without having at least a "B."

Comment: Some 40 or 50 percent of the students in that course get a "C." It would be tough to get an "A." It is not that easy!

Comment: There is a distribution of intelligence; and it is very hard for bright people to realize what happens in such a class. A lot of people cannot go one step further as far as intelligence.

Comment: One thing that bothers me about this group is that everybody is saying, "I would take courses voluntarily or I would like to take new courses." We are obviously a minority because most people are either taking them because they have to, to get into the pre-professional, or because they don't want them in the first place. We are not reflecting reality here.

Response: What I took in high school is not a really fair criteria. My father, a physicist who teaches here, has always been a strong believer in taking science courses. So I took a lot of science, the full four-year track. You could take it in different years; and in that way it was a little bit silly for me to take the math course, but I did take the one-semester survey course at I.U. The alternative was a really hard course which met five hours a week. That left a big choice at the two extremes.

Question: What is linguistics about? Coming out of psychology, I know about psycholinguistics, but is there any application of science to straightforward linguistics as a subject?

Response: No, there is none at all. In fact, linguistics right now is dominated by Noam Chomsky, a science-directed figure at M.I.T. One linguistic theory is that your mind deals with language in a way similar to a computer, in terms of the system or structure. If that is true, then there are laws that dominate that system, and you can figure out how those laws interact. It is similar to a given universe in which you are trying to figure out the laws of physics.

What is frustrating is to be in a course where you throw out half of the material and say, "It is not applicable at all. Don't worry about it." When I am in class, I feel like I should be learning something. It hurts to just throw away material like that.

It seems that if you were setting up a university, you would automatically have courses; and yet, it gets more and more complicated so that now you are talking about "voluntary requirements."

Question: But supposing Indiana had first-year core courses, would you be?

Response: Oh, yes.

Comment: Also, you are dealing with the difference between a school with 300 incoming students and another with 8,000.

Comment: You have to take some basic courses. I enjoy the freedom of taking any course I want at the university, particularly a course in economics. If I can get an economics degree without mathematics except for various statistics courses, I'll be glad. But I need a choice. Math should be required either to become a mathematician or to become a business major. There is no in-between.

Comment: That is why distributional packages might be a good solution. There could be some kind of cooperation on the departmental level to design freshman-level courses and packages; and each package would contain a math course, a physics course, a chemistry course, a biology course, and maybe even a psychology course. They can have different emphases--for example, a humanities emphasis, or a scientific emphasis, or a pre-med emphasis.

Response: So the emphasis would be there on top of a core package. And you would have the same group of students opt for the whole package probably.

Comment: If you don't have the voluntary option, the same students always see each other, get to know each other, and throw ideas back and forth.

Response: There could be essentially two distributions, one based on pre-packaged courses and the other on additional courses in different areas.

Comment: When I had to take those core courses, I knew nothing about several areas--economics and philosophy of science, for example (we had Mickey Mouse high school). If you can expose people to areas in which they may not have had any exposure before, they might find that they have interest where they didn't even realize they did.

Response: Yes, that is the reason that the department should have a distribution requirement that says, "You have to take three humanities." Students can take Uralic and Altaic Studies, a history course, and a philosophy course and still not be exposed to literature. I am not necessarily for forcing people to take those; but when you had 24 courses that necessarily covered all of those things, you were exposed to all of them. For example, I never would have taken a music course except that I had that requirement, but I enjoyed it.

Question: What is the advising system here like?

Response: In economics, the advice was always, "Take the courses you want to take." I have never had a signature.

Comment: I am pretty sure that to go through registration, the graduate students and people who want to continue in school must have their cards signed.

Response: I just pick up my card and walk through registration. They don't even know what classes I am taking. I just ask, "What are your requirements on whatever?"

As a freshman, I talked to an advisor who labeled me as an undergraduate; and I decided I was going to do so much all at once, and the advisors agreed to it. Until you declare a major, you have a general advisor; and once you declare a major, usually after your freshman year, you transfer over to a department.

Question: Can you delay until you are clearly into something?

Response: You can delay as long as you like, until the junior year. But when you graduate you have to have a department major; and in order to do that, you have to have an advisor. Usually, you keep track of what your requirements are and your motivations, the numbers of hours, the course titles, and your grades.

Question: Are you just a maverick, or is this common?

Response: I actually went through this whole year without an advisor.

Question: What about additional advising?

Response: I went to freshman pre-registration this summer so maybe I had extra help. Most people come in here either knowing exactly what they want to do (their parents have already planned it all out) or else they don't care and must depend on the student advisors, who mean well and try so hard but are up against a wall. They spend at least half an hour with each student (and more like an hour with each one) the first day they get here, and they do really make a strong effort. On the surface, that doesn't have many results. I can't say how it affects the students. There are no honest-to-God faculty members as advisors but, rather, students who work for the university and not for the department.

Question: Not for the departments? And so, in a sense, they are professional advisors and not professional teachers in that sense?

Response: Oh, some of the advisors also have holdings in that department. They are just not advising incoming students.

Comment: I have had an interesting experience with advisors. My department actually has a list of required courses, and you have to get the signature of your advisor. Majoring in astrophysics means there are only certain courses that you take to get your degree. It is not like I am telling an advisor, "Well, I would like to take this and that." My advisor doesn't play a real strong role.

I also have advisors in the physics department, the math department, and the philosophy department; but a lot of times they were not very helpful. Because they don't know enough about either the other departments or opportunities in their own departments, I can't understand why these people are advisors. I have gone to the physics department and the philosophy department, asking about opportunities in several areas, and these people just don't seem to be able to handle the questions. I don't know whether I am asking the wrong ones or whether they are incompetently trained as advisors. There might be a problem at the undergraduate level in terms of what information the advisor has to know.

Comment: A student can go to a bookstore and buy a book that says, "This course is really better. This course is great."

Response: Yes, only I would be very suspicious as to how accurate the information was. I don't look at those as being very accurate. But the main problem is that we don't know whether our advisors are secretaries or whether they are professional people talking about courses. Advising 800 students is a very hard job. If you are asked about a course, you have to know a lot about the material, which is not something they seem to know. I tend to go to the professors, which is usually what the advisors will recommend. They will say, "Ask the professor who is teaching the course." I do that every year, too, for general information, such as taking a summer physics program, since many are offered to undergraduate students. I go to the advisor first; and if he seems unable to give me any direction, I look at what is posted on the bulletin board.

Comment: At my university a few years ago, we decided that in addition to minimum distribution credits, we would try to enforce a lot of things through good advising; it has been somewhat successful, but not as much as we thought it would be.

Comment: When I visited advisors in the economics department, we would just talk about anything; but the math department rotated advisors, and students could just take whatever they wanted, since the advisors didn't care what students did.

Response: I think what he is saying is that very few departments have a trained advisor. I know that in comparative literature, every change is too often; yet once one person becomes a good advisor, he is replaced.

Comment: In a sense, from this committee's point of view, the most important advisors are those that operate in the first year or two of college.

Response: Again, from what I have experienced this summer, you will have quite a chore convincing people. The freshmen come in with so much freedom, knowing exactly what they want to take or to avoid; and there is nothing you can do to stop them.

Response: Yes, but the advisors that deal with students in the first two years are important. They should have general information, although the reason I am in linguistics is only that my professor is the undergraduate advisor. Maybe operating within the departments, extremely poor advisors change students' whole feeling about a course.

Comment: Freshman and sophomore advisors, in order to buy time from the departments, get paid an addition to their regular salary. There is a little bit of leverage about courses. It has worked, not as well as we had hoped it would but much better than any other system.

Response: Funding. You can always get a department money.

Comment: Sure. A foundation grant.

Question: Are you also cutting your expenses?

Response: Yes, and some industry support helps.

MS. KOVACIK: I am a senior majoring in Engish and Spanish. At Butler University in Indianapolis, I took a four-credit biology course, psychology, and a rigorous elementary trigonometry course. Here I have had statistics and anthropology. I plan to take physics next semester.

The method of science courses is very similar to that used in English classes. I have a personal interest in genetics, and I might eventually get another degree in biology. I am interested in both science and literature so that it was hard for me to choose a major, to exclude science and favor literature.

Question: What has been your favorite course? You said you liked biology.

Response: Yes, I enjoy the bio-anthropology course because we do work in genetics and evolution, but the introductory biology course was probably my favorite science course. We did some anatomy and some eco-science, but it was not specialized in a particular area. We only worked about four or five times in the laboratory, and the professor did everything because Butler is a pretty small school. I didn't have any graduate students as teachers.

Question: What science and math did you take in high school that disposed you so favorably towards it?

Response: I took a good chemistry course in high school, but the biology program was not quite as good. Because I never had physics, I plan to take it next semester, but I don't know whether I will take what they often call the non-calculus course or the one that the engineers take. A couple of engineering students have told me that the one with calculus is actually easier.

Question: Do you have any suggestions as to how things could be improved?

Response: There could be more exciting course descriptions.

Question: We are interested in non-classroom methods of science education. Do you watch science programs on television?

Response: I really don't have access to television; but from the library, I have checked out things like the Bronowski series; and Professor Woodcock, who teaches a course for scientists to learn good writing skills at the university, has a good tape about the interface of science and literature.

If I do graduate work, I might take some history and philosophy of science courses because they sound enticing, discussing C. P. Snow and some of the misconceptions about science being some sort of absolute. However, when I first graduate, I want to work with the Peace

Corps. That is why I'll probably need some sort of practical science. Also, I have taken so much literature that I welcome these other courses in which I can solve problems in a different way than I would by reading Shakespeare.

MS. RISSING: My interest in science commenced as a curiosity. I was split, balanced right between English and the sciences in high school, as I did equally well in both and was equally interested in both. So I took the easy way out, majoring in English, but I could never entirely squelch my interest in the sciences. I just sort of kept nibbling away at a science course here and a science course there until I finally decided that I could not waiver any longer but should throw myself completely into the English lit, where I had most of my credits.

Because I was worrying about graduation, last year I took all English courses. However, I was in an exchange program in Canterbury then, and I realized that English is not going to feed me. I decided to capitalize on my interest in the sciences and am looking now into the possibility of careers in science such as science writing. I am taking chemistry, but it is slightly more specific than the general foundation I need. I think I am going to use almost everything that I am learning in biology, but then, I have a lot more interest in biology because I can relate to it a lot better than to the chemistry, which is more quantitative and remote.

It is rather difficult for me sometimes to change my thinking from the more creative analysis of English lit to the more logical, step-by-step thinking that is required in science courses. However, I like to know that I can look at something in a logical manner, a scientific manner, and that I am able to deduce problems in a more solid way. Yet, some of this may result from studying in England, where the learning system is much less structured.

MR. MUIR: I'm majoring in comparative literature, but because I'm from Oak Ridge, Tennessee, and my father is a physicist, I grew up with a very strong science background. I don't think you would find a public school anywhere else in the country with such a strong science curriculum as the one in Oak Ridge, and I was in the science track the whole way through. In high school, I took two biology courses, physics, chemistry, and four years of math; that was the way I was geared. All my friends went into science, too; and even as late as my sophomore year in college, I thought I was going to be a physics major.

But then, I found that I really wanted to study literature. I haven't renounced the sciences; in fact, the sciences have had a great impact in three ways on the way I study literature. The first one is the knowledge of the history of science. For instance, I can't understand naturalism in the late 19th century without understanding Darwin's theory of evolution. I can't understand the Renaissance idea of what man's place in the universe is without understanding the Ptolemaic theory and the Copernican theory. I can't understand 20th century literature without knowing Freud, and more specifically, authors who are scientists themselves. In my graduate class in French, I am the only person who understands the professor's allusions to the uncertainty principle or Einstein's theory of relativity. In addition to that historical perspective, the second application of study in the sciences is use of very analytical and systematic method. You form hypotheses to prove or disprove. Laboratory experience has influenced the ways I approach literature and do research. And finally, in my daily life, I can enjoy watching programs like Nova or reading Scientific American; a lot of people can't do that without this major.

Question: Is there some revulsion towards science?

Response: Most people, if they take a science course, take it to fulfill a requirement. The attitude toward these distribution requirements is to get them out of the way and get into your major; it is not something you are supposed to learn. These are artificial separations of making one course a distribution requirement and another a requirement for your major and not seeing that they are going to be tied together or have some practical benefit.

Question: The distribution requirements cause a very large number of students not to be exposed to much science. But how do you feel about the idea of distribution courses?

Response: They are good, but the approach to them is bad. I am not saying that people shouldn't be forced to take those things. For example, when I attended Maharishi International University in Fairfield, Iowa, all freshmen were required to take 24 core courses, structured to represent different areas--the sciences, the arts, the social sciences--and to have paradigms for students to follow through them. This structure helps students learn. For instance, you take a very simple principle, such as coexistence of opposites, and apply it to science as well as to literature. Students see the same things in both courses, receiving a common ground for learning. Another concept is that of unity to duality to multiplicity. You see both in physics and in language learning. For instance, kids first speak one word, then they speak a two-word sentence, and then from there they speak infinite-length sentences.

But even more important than that, this structure eliminates these artificial separations between two fields. Although the sciences and the arts aren't the same, students see that the human endeavors are the same, whether in science or in the humanities. You see this level of similarities. I found the integrated, general education to be very helpful.

Question: Is this somewhat like the Occidental plan, whereby students educate each other, all doing the same thing at the same time, a classic example of a community of scholars working together?

Response: That does have an effect.

Comment: The problem is that universities get caught up in themselves;

and the professors don't receive pay-offs for those kinds of courses but have to build reputations in their own disciplines. However, there seem to be many benefits to that kind of a course.

Response: Another problem is choosing the basic themes or paradigms to use; and I am sure a lot of people would disagree on that. Yet common experience is enough to tie courses together. As an undergraduate, I had several large survey courses for which everybody signed up. They were divided into mini-courses taught by very good professors from both the language department and from chemistry. When the materials were all exposed together, good things happened.

Comment: Another problem is that departments get in the way of such comparative ventures being developed; and the better run the university, the more that is apt to happen. But that is an interesting concept.

Response: I see what you are saying, but I also think that the paradigms made the program successful because they showed similarities between the disciplines. At Macalester College (before I attended Maharishi International University), I took a freshman seminar called "Paradigms of Consciousness" taught by professors from political science, philosophy, and psychology; but students seldom developed any "paradigms of consciousness." However, at Maharishi, the entire student population of 1,700 practiced transcendental meditation. That is the source of their paradigms. But that may not apply to everybody's needs, although that practice is used at other schools, too.

Question: The Commission on the Humanities released a report this year, arguing among other things that there has been a decline in interest in the humanities as an elective in colleges; and they are very worried about that and that science as a whole has really benefited from federal support while the humanities have not. The Commission argues that the study of humanities like literature can add to people's thinking and their abilities to operate in life. What have you added to your knowledge base or your outlook on life from the study of literature, not science?

Comment: I went to Cal Tech, which had distribution requirements but in reverse: science and engineering were emphasized while distribution requirements forced students to take some literature and history.

Comment: At M.I.T. they do absolutely that, and that added a good deal to my options, just by being forced to take ancient history and English.

Comment: But your question was "Did it equip you with a way of looking at the world or with the methods of research or of approaching knowledge?" I have sat in on frequent meetings here in which certain faculty members refused to let certain courses be counted in the distribution requirements because they don't have the distinct methodology. In fact, the psychology course now counts only for the natural sciences because of the methodology. So we now have departments that are split into two areas, the part dealing with the humanities and the part in the social sciences, although the methodology used in literature and the methodology of science are both systematic.

Response: There will always be subjective elements, more value judgments, in both; but they are stronger in the humanities, where intuition and impressionism are relied on more as students are encouraged to establish their own feelings about the text and what they are studying. In essence, I like it because, although I approach the material scientifically, at the end I evaluate the text in terms of how it affects me inside.

Comment: The Commission on the Humanities hopes to work more closely with the sciences in the future; but they feel, especially in areas like philosophy, that scientists should understand that judgments don't arise as a method from science, but rather from the humanities. It is at that point that the interface is made.

Question: You were saying that you gained great insights into literature because of your science background. And are you saying the reverse of that now?

Response: No, I am not. I am saying that that is how I analyze it. I enjoy literature because of the aesthetic experience I get from it. My knowledge of science enhances that enjoyment.

Question: How much science have you had in college?

Response: I had biology at the University of Tennessee while I was still in high school. At Macalester, I had sociology and psychology. And at Maharishi, I took chemistry, physics, biology, and astronomy. They were all in the first two years of college.

Question: Do you think that liberal arts students in general should have more science courses in college than they take now?

Response: More is a quantitative thing. I would put the emphasis on the qualitative. Students only need one really good science course; ten that don't help the humanities person are useless. When the two girls were discussing one physics class that was not very good, I was thinking that if that one physics class had been better, if they could have gotten something out of that one, it would have helped them a whole lot. They did not need to take more classes; they just needed to have one good one.

Astrophysics

MS. EVELETH: Basically, society is technologically oriented; to a great extent in everyday life, we are surrounded by that. It is important that people--whether they are in sciences, in humanities, or in social studies--have an understanding of their daily life and how the sciences affect them. It is important, also, for scientists to make sure that they are getting the support they need from the society. College students should be getting quality science programs, not necessarily four years of calculus or three years of physics or something but the basic, general kind of quality courses in each one of the science fields--or at least biology, physics, and especially math. Too many humanities students are scared of numbers, but basic mathematical reasoning is very important in analysis.

Question: Would you recommend more distribution courses or more science prerequisites for various action careers, or do you think the same result could be accomplished by just making more attractive science courses to be elected voluntarily by students?

Response: I don't like the concept of making "attractive" science courses. For example, one course here called "Physics for Poets" is useless for learning physics.

Comment: There are, scattered around the country, courses that are very successful in attracting students because one instructor with a great deal of charisma can excite the students and give a course with huge enrollments, but when he stops giving it, the course just goes dead because the success lay with the teacher, not the course.

Response: Two earlier speakers said that the problem with the physics course was not with the course itself but with the professor. They are not having problems with physics; they are having problems with the way physics is being taught to them. Starting in the seventh grade, we had labs, once a week every year; and I think that a systematic approach--making a hypothesis, refuting or accepting the hypothesis--was almost drilled into me.

Response: A physics course taught for humanities majors does not have to be exceptionally technical.

All human endeavors contain a certain basic human quality that is the signature of man's creation, and physics is just as creative as literature is. The whole concept of applying laws of nature to explain our universe can be given a broader level to show that science is also a human endeavor that bears the same qualities of being creative, of being a means for understanding ourselves and our environment. However, I don't think that everyone should be required to take a laboratory course, necessarily. Science can be demonstrated by examples of how it relates.

Comment: You can't really get a feeling for measurements and calculations unless you have done some yourself.

Response: That may be true. But in my lab, people were given a formula; and instead of recording the measurements they took, they put down the ones they knew were supposed to be right. They were working backwards then. I noticed an interesting thing happening between the sociology department and the department of history and philosophy of science here: they pool their courses directly related to science in an attempt to get some science majors to select these courses for the humanities requirements and the social science requirements. I have taken at least two of the courses that these departments are offering for science majors, and I have done the best I can to convince people in my science classes that they are very applicable. One course in particular, "Sociology and Science," is very good. I wonder if the same thing could be done in the science departments to attract humanities people to fulfill their science requirements.

Question: What course titles would you like to see for these courses?

Response: For humanities, a course that has general utility, given a qualitative role. Even at a very qualitative level, a lot of people can be interested if they realize that the course is not going to require them just to sit in class and do formulas. That type of class could be offered. The physics department has a course called "Physics and the Environment" that has incredible potential.

Comment: It was excellent. It was really a gem.

Response: A brief mathematics survey course can be offered in such a way that while the concepts are put across, students can enjoy it without sweating all the time because it is math. Beneficial packages could be put together so that all people take the same courses but are able to interrelate the various disciplines.

Question: Would you have such a course designed for voluntary enrollment?

Response: Maybe you could make different types of packages. You have to be able to give students a choice, but also you have to have limitations. I don't advocate the voluntary approach. It is essential for a college to say, "We require our students to take certain amounts of science and certain amounts of math." When we enter society, it is important to be able to say, "We require our students to have a base of all of these."

Question: May I ask why you did not graduate from Maharishi?

Response: Their major programs lacked astrophysics. I had broad interests when I left high school--a very broad high school background, too--and those first two years made an impression on me.

Question: But again, we said there is the mixture of the common philosophical approach and the academic approach. You are implying that the academic part could stand improvement. Would I, as a student, have been able to get a good academic grounding?

<u>Response</u>: You can always do that. If you are antagonistic, you are not going to learn; but if you are neutral, you could learn a lot.

<u>Comment</u>: Part of my problem is that science is presented often as dogma, and that was one of the reasons I left. You do not have to go as far as Maharishi did and make these things truth, or absolutes, in order to have that kind of program.

Also, Indiana is a better school for getting your degree, not just in terms of reputation but also in terms of the upper-division classes, which are going to be better. However, I don't think there is any comparison between those first two years there and here; I am really glad I attended Maharishi first.

<u>Response</u>: I think you could go to Maharishi and extract from the courses not just the philosophy (it gets carried away to extremes sometimes) but also the basic idea. The core courses it offers are so important. Even Harvard was talking about reinstituting a core course system.

<u>Comment</u>: They have changed the distribution.

<u>Response</u>: You abstract it even from the fact that everyone there meditates. The programs are basically set up that way.

<u>Comment</u>: Some very skeptical people go there, but a lot of them are convinced the first year that academics involves a little bit more than what they thought.

<u>Question</u>: I wonder, Dr. Crane, where the committee could implement change, if it is needed in the systems. We could suggest that universities add more requirements for humanities majors and develop courses that are more creative, somehow modified, or thematic. But is this an idea that we could propose to the physics community, for example, for them to try to stimulate physics teachers to change the courses or the content? Maybe we are discussing an unachievable goal.

<u>DR. CRANE</u>: It seems that the way to get a lot more liberal arts students exposed to some science will be to change the distribution requirements or the prerequisites, but you can propose that idea to the teaching community and not see much action.

We could also recommend for the National Science Foundation to support the development of some courses for non-science students to take voluntarily; that has been done in the past, particularly in the 1960s.

<u>Comment</u>: In the '60s, they didn't try to do this with the National Endowment for the Humanities. Now they are trying to do more cooperative work as agencies to bring the two cultures together for course development.

<u>Response</u>: There are a lot of instructors, especially on the university

level, who would object to having these things taught without a mathematical background; but that is exactly how they were taught, and we did learn a lot of the basic concepts in the English language not found in the mathematical language. You do not need a Ph.D. in research physics or in quantum mechanics to teach that kind of class. There are people who could teach several different science courses of this low-quantitative type not involving math. For example, we learned about the theory of relativity, the nature of space, and the nature of time. You don't have to see those in mathmatical formulas to understand just exactly what the import is, to see a result.

Comment: Such courses exist, but they are sporadic, existing only where a person is inspired to teach a course of that kind; but you can't make them happen at any particular place because there might not happen to be that kind of an instructor there.

Comment: It ought to be more respectable to teach that. There may be a lot of non-tenured people who would love to teach something like that, and they might make a greater contribution at the university to the physics community.

Economics

MS. BONSER: I don't have a strong background in the sciences at all; because I took the traditional biology, chemistry, and physics in high school, I did not have much of an interest in taking them here. I took geology because I was interested in it; to fulfill my distribution requirements, I have taken one of the two required biology courses, LB-59, which studies heredity, evolution, and society and is mainly concerned with human genetics. At first I was not real thrilled about taking it because I would have preferred taking an introductory geology course; but afterwards, I was very glad that I had taken it. I found that what I was taught was not terribly technical; designed for non-science majors, it is applicable to my life in general, teaching me about problems with genetics and how scientists interact with society. That was very useful to understand; for as a social scientist, I am concerned with society as a whole and its interaction with genetics.

Now I am taking a second biology course which satisfies the distribution requirements. It ties in with the genetics course I took before and also exposes me to anthropology. Because this bio-anthropology course ties in with the course I am taking in the social sciences, demography, I understand population genetics and demography better.

I cannot say too much about the hard college sciences--chemistry and physics--for I took them in high school. My interest in math evolves from my interest in economics. I have taken calculus, linear algebra, probability theory, mathematical statistics--all of which are relevant to economics, actually. I am going into economics as a graduate student and will study econometrics. When I worked with an economist this summer, however, I realized how deficient my mathematics background was and decided to get on the ball and take more. I have not taken a formal course in computer sciences here; but in a couple of jobs, I learned some things that are going to be important to my economics work.

Question: The committee has to consider your major with the social sciences in general as well as the need for more natural sciences besides the social sciences; in addition to biology, how do you feel about physics and chemistry as electives?

Response: When I took physics in high school, I enjoyed it very much. I had a good teacher who did not get too quantitative and who applied things on the general level, and that interested me. I don't know about "Physics for Poets," but I would be interested in having more physics. I have never had a great interest in chemistry because I couldn't relate molecules and atoms to the problems in the world today.

My background in biology is very weak. I could have learned to handle biology if I had had a good course in it because I have been very interested in what I have studied. Both my chemistry teacher and my physics teacher were good. However, people should be aware of all the sciences. For instance, the possibility of the test-tube baby apparently is affecting people, and they should be aware of it. The genetics evolution is important; understanding how people are evolving is something people should be aware of, too.

Question: Do you think knowledge of the mechanisms of salvation has much to do with the knowledge of or attitudes towards test-tube babies, any more than the knowledge of nuclear physics has to do with their attitude towards Three Mile Island? It is always said that citizens can exercise much better judgment about all these questions if they have some science.

Response: I think that is true. But then, you have to realize people's limitations, too; some people cannot handle the math and the labs perhaps. But that should not deter them from trying to understand and to appreciate the basic issues involved.

Comment: There is such an enormous gap between really understanding what goes on in a nuclear reactor, let's say, and the amount of science that any liberal arts undergraduate possibly learns. You can't possibly learn about that unless you take three or four courses.

Response: That's right. You have to have specialists in every field.

Comment: I think there is just one half-hour lecture in physics that tells the students what half-life is, what "intensity times duration" means, and what energy means--just a half an hour lab.

MR. STROMMEN: I had a bad experience in chemistry. It was the worst course I ever had. The course emphasized memorization over learning the theory of chemistry, and that was a turn-off to chemistry.

Question: What high school science and math did you have?

Response: I had five years of math, including calculus, and five years of science--two years of physics, two years of inorganic chemistry, and biology.

Here, I plan to continue the chemistry and biology. I took the same genetics course and got a different view of the whole role of genetics and Three Mile Island.

Question: What do you feel are the strengths of the science background you have?

Response: The physics I took in high school was not a problem to handle. Rather than giving one set of problems, the instructor would give us slightly different things to figure out, exactly the factors involved and, from them, the answer to the problem. It centered around problem solving. College physics was just regurgitation of the same points of the high school course.

My other college science courses are ones I didn't take in high school. For instance, I took organic chemistry here because I found out through the grapevine that it did have application. A lot of the pre-med students dislike classes that are not memorization; what they really get are classes that are not memorization but, nonetheless, easy to understand. They are not easy for me because I have avoided all memorization courses; but the distribution of the grades is sort of viable.

I do a lot of investigation before I take courses. I take what I want when I want it; and if there is some reason why I shouldn't be taking a course, I try to get around it. I do that across the board with all kinds of courses--science, humanities, social science courses.

Question: This organic chemistry curve that you decided not to follow is interesting. Was it because you were afraid you would not get a good grade and that would affect you when you got out of school?

Response: At that time, I was not a very good student, and I decided not to jump that fast into my first college experience. I chose the chemistry course, but it turned out to be mostly memorization of the formulas and was not very interesting.

Comment: That same course changes a lot of pre-meds' minds. The chemistry department thinks that it is a wonderful course and that they are doing a great service by selecting the best and the greatest to go to medical school.

Comment: A lot of college students are inarticulate.

Question: Did many other erstwhile pre-meds lose their enthusiasm for becoming doctors?

Response: Some did. Others switched over to optometry. I switched to economics because it allows me to take what I know, to organize and develop it, and to arrive at a solution. Part of the switch had to do with the chemistry class' being so large. There are many lab sections of 200-250 students, but only one large lecture--I guess there were 1,000 students.

There are good and bad semesters with chemistry. The computer was used to grade tests and check lab results. It was all very impersonal, but the large number of students forces them to use that system. In one course, the instructor gives tests containing right sentences and incorrect sentences. Then, the students put down the numbers of the sentences believed to be right. And then those numbers go into a computer, which takes all the data from the experiment and issues statistics for grades and how you match up with the statistics.

Comment: Sounds like 1984.

Comment: The rumor in my classes is that the whole program is structured to weed out pre-med people; and from my point of view, this is very unfair because I need chemistry and astrophysics. I was not interested in med school and felt like I was being pushed back. Before I took that course, I loved chemistry; but I came away very sour towards it. A first experience such as that is very bad for freshmen.

Question: Do I hear a desire that this committee make a recommendation that courses for non-specialists in science be non-computer graded, non-multiple choice?

Response: I am not really asking that question but relating my theory that science does not have to be mathematically-oriented for instructors to evaluate how students are interpreting what is going on. I think that is more useful.

Comment: They certainly need to know more than how to take a test; but from the professor's point of view, there is not much difference which way he determines the final grade. However, you are saying there is some psychological drawback to multiple-choice tests.

Response: You have the answers; you don't interpret the problem, for you are sure of getting one of those answers. There is no chance to reason as to whether you are doing the right thing. You need to be able to work out some solutions in order to know what is going on, but you can't do that with multiple-choice tests.

Comment: Speaking as a citizen, not as someone in medicine, I see my doctor's job as basically technical; he/she has to look at symptoms. I can see the utility of multiple-choice exams as opposed to essay because the doctor has to have a store of data to match against what he observes. On the other hand, a medical researcher interested in the implications of genetic changes has more of an opportunity for theorizing than the regular doctor. I can see from the medical community's point of view the utility of a course weeding out people who don't resonate to memorization. That is a big part of the medical training.

Comment: And that is the justification that the instructor has always used.

Comment: They are really technicians; that is my impression of roommates who were medical school students.

Response: Maybe that is what med school and being a doctor is all about. I agree that we need some memorization but not just straight, cold memorization. There are some biology courses that require students to memorize the Latin names of different organisms, and I can see some purpose in that; but I can see very little application.

Comment: There is so much more to medicine than that. Half of medicine is your state of mind; whether you are going to be well or not may depend on whether you think you are going to be well or not.

Comment: That is health. It is not medicine, though. What you are describing is the person, not the doctor.

Response: Given your state of health, the doctor has to interpret the symptoms.

Comment: Yes, but a lot of the same symptoms apply to the care of different diseases; and many of the ills are psychosomatic to begin with. So I don't think you can treat people that way. In Oregon and Idaho, there are satellite paramedics who (when the doctors are not available) enter a person's symptoms into computers and then the decision is made at the hospital somewhere whether a helicopter should be sent out to retrieve the person.

I am not arguing for it. I am just explaining how I could see it would be difficult for the medical school to give up the chemistry course if its goal is to weed out people who are not, or to select people who are, capable of memorizing.

Comment: Physics or physics departments, of course, are accused of the same thing, only people say that we give a stiff physics course for pre-meds in order to weed them out. We hear that the medical school does not care whom they are teaching so long as they weed them out.

Comment: This committee is traveling around and asking questions because a lot of people have made statements that liberal arts students are not getting enough exposure to science. The committee should suggest some mechanism, some way, in which liberal arts students can either be made to take or be induced to take more science.

Response: Non-scientists do need more education in the physical sciences and the natural sciences. The only thing that would allow me to take more was if the course was not made to weed out pre-med students and pre-optometry students. Since they are made that way and are so fastidious--there are not two classes, one for weed-out students and another for those interested in the subject--everyone is worried about grades. If instructors are trying to weed out pre-med students, it is very tough for students to get an "A." They really don't get the satisfaction of learning because they are more or less trying to get the grade.

Question: Does Indiana have a pass-fail system for some of the courses?

Response: You cannot take required courses, or distribution courses, or major courses on pass-fail. You can take two classes (or a maximum of six hours) a calendar year as pass-fail. I took a pass-fail because then I was not worried about the grades and could sit back and learn what I wanted to. I would like to take a science course on that basis, but I used that option for areas such as accounting and telecommunications, some of the classes that I really didn't know anything about.

Comment: I feel that you think liberal arts students should take more science courses, but science courses now are unattractive because they are dominated by the professional schools.

Response: For example, there is the regular physics for pre-meds and there is "Physics for Poets," in which you really don't learn anything. I would like to take a slightly higher level of physics, but I don't want to learn differential equations in order to take introductory physics.

Question: But if more appropriate physics courses were offered, do you think they should be offered in a more voluntary way or as part of the distribution requirements?

Response: If they were on a list, ranked by difficulty, more people--maybe not the hard core engineers--would take them voluntarily.

Comment: What bothers me is that so far the only successful way of getting large numbers of students to take science is by compulsory methods.

Response: Maybe that is the whole problem.

Comment: A better way to get the students to take science courses is to eliminate this required system.

Comment: We can test the hypothesis. We can identify a couple of schools that have abandoned distributive requirements. For instance, Brown University did that in 1969, substituting integrated-type courses that are more thematic. We will find out what is happening. It seems to be a kind of Yin/Yang here: if you have a requirement system, then the department of science doesn't feel obligated to design the course particularly for the students; but when you remove the requirement, then the schools may work harder to make the courses attractive or useful in order to keep the enrollments.

Comment: That is one of the problems: so many persons are captive audiences that departments don't worry about enrollments.

<u>Comment</u>: I am sure it occurs in the majority of schools.

<u>Comment</u>: In our school we have 1,000 students taking introductory physics because they are going to be pre-meds or pre-this or pre- that. We just give a straight physics course, not oriented toward any profession or even with any regard to what the medical school people think their students ought to have. If we had to depend on voluntary enrollment, we would have to get on the ball and re-look at what we are giving.

<u>Response</u>: The same applies to mandatory mathematics: everybody takes at least one mathematics course. In business school, everybody has to take finite math and low-level calculus; and there are a few students who do really well and others at the bottom who are taking it only because it is required. They are really not learning anything; they are just hoping that they will pass so they can get some credit. And if you replace mandatory requirements with voluntary ones, people may take some mathematics classes as options.

Finite math and calculus are required for those students going into statistics. It is a hidden requirement; but the student has a choice between the mathematics or the physics, depending on what area he is aiming for.

<u>Question</u>: What happens when kids who have had very poor preparation in mathematics enroll in an undergraduate course such as finite math? Is there any opportunity for remedial course work or a tutor system?

<u>Response</u>: There are a lot of tutors; the university has to provide review time. There is also a non-credit math course which some students still don't pass, although they are allowed to take each exam--exactly the same exam--four times.

<u>Question</u>: What happens to the students, then? Do they change their majors? Do they decide to take something else?

<u>Response</u>: Lacking the quantitative ability, they can't go into medicine, economics, or psychology so that they often switch to the humanities.

<u>Comment</u>: And I think a lot of them drop out if they can't pass a remedial math course.

<u>Comment</u>: Thirty years ago, there were certain courses, such as "A" courses in social sciences, and a package of electives, some in science, some in history and so on. And then 20 years ago, when students wouldn't enroll in these courses, the faculty offered superficial ones; now survey courses have just about had it.

<u>Comment</u>: In the way that they were implemented there, they were effective.

<u>Question</u>: One trend was for certain schools within the university to

do their own math courses. For example, we had basic math courses given in the engineering college and naturally oriented toward engineering; and the engineering college even gave us some English courses --engineering English so students didn't study literature but instead studied how to write.

The kind of enthusiasm produced by this science sequence suggests that other parts of the university might be able to learn something from the education department. A sequence of science courses like these might be applicable to more people than just those in elementary education. Students in English or history might like to learn science this way. What do you think of having some of the science courses taught within a discipline such as economics?

Response: Teach a math course that is an economics course? A math course in the economics department is econometrics. It isn't a low-level theory, but I am not sure how low-level you can get.

Comment: The math that is taught within economics is connected to economics so that it might be more enjoyable or more to the point.

Comment: An interesting 300-level course, the history of mathematics, is being offered to juniors next semester by the math department I was surprised when I saw it. This sort of thing, having history taught in the math department, is good. I have one astronomy course that required labs to be written up in the form that would have been presented to a journal for publication, and that was a challenge. It was something I was totally unfamiliar with; and if the college offered even a four-week course in that kind of writing, it could be very beneficial. Those are the things that would be better in a division.

Response: I had a history of math course that bordered on the lines of the conservative course that you are talking about; some of those math history courses are not math. Instead, students look at some of the ancient theorems to see the beauty of math without all the equations.

Question: That is the point, though, isn't it? Isn't the point to see the history and not to learn the math?

Comment: It can be offered either way, romantic or very technical, if offered for a certain result.

Response: A history course like that would be very good because you are not dealing in the technical area, but you are looking at the old theorems, how things happen, all the beauty of mathematics and then the sciences, and how people actually found them.

Comment: I guess this came about because someone in your math department had a hobby dealing with history. That is how a lot of good courses get listed.

Comment: Not necessarily, I think. In my department, we have a professor of history of biology.

Comment: But many of those courses really are used to satisfy a distribution requirement.

Comment: I don't really feel that offering that sort of thing on a 100-level course would satisfy a math distribution requirement, though. That defeats the purpose of having a distribution requirement.

Comment: I know, but it is for math majors.

Response: No, no. It is not that technical, although it is a 300-level course.

Comment: You have to have had enough math to be able to appreciate math history. After all, you have to talk about things that were invented in math.

Comment: Yes. When teaching science courses to non-majors, one sort of compromises.

Comment: The problem is that unless the students already have a good sense of chronology, they get very confused as to what happened.

Comment: A lot of music majors and fine arts students really are not required to know any mathematics other than for daily living; they can get their education and get out without having to do any mathematics or science.

Response: Music majors have so much theory here that there is no way they could get out and not know math.

Question: Could they avoid math by taking a physical science to fulfill a requirement?

Comment: Music schools have their own mathematics. The School of Music is really known as being a very good one, but they don't happen to have many requirements outside their own school.

Response: Except that they just changed the rule this past year; and one course from the math department, not music, is required to graduate.

Faculty and Alumni Comments

Law

DR. CARRICO: I spent one undergraduate year in the basic engineering program at Rice University and had the opportunity to take two semesters each of physics, chemistry, and calculus and to complete three semesters of lab work, two in chemistry and one in physics.

At that point, I promptly turned away from sciences for many years, getting a Bachelor's in Arts at Tulane University in political science and history and then my law degree from Yale. For the last three and a half years, I was with the estate planning group of a large law firm in San Francisco. Frequently, I had an opportunity to reflect on the true relevance of the science courses that I had taken. I now teach in the area in which I practice: wills and trusts (the property law aspect of estate planning) and transfer taxation (federal estate and gift tax). Next semester I'll expand even further and teach an actual planning seminar.

The one real advantage my science background has given me in this field has been in the area of quantitative analysis. As soon as you get into any sort of sophisticated personal or financial planning, you immediately have to deal with concepts and instruments that have their basis in the same sort of things encountered in my first year of engineering courses--that is, how a computer operates, what its capabilities are, and basic number theory. Believe it or not, some mathematical concepts are hidden in the Internal Revenue Code, and to be able not only to extract those but also to transmit them to your client (and in that way, create a better environment for dialogue) is absolutely essential.

In teaching in the law school, one real problem is that the students do not have any substantial ability to work with numbers. They don't feel very comfortable with them. People in the science departments become quite anxious when doing their tax returns; but I think that once they get over an initial irrational anxiety, they can readily understand the concepts being discussed in the tables. The problem I have with students lacking a quantitative background is that as soon as they hit a mathematical concept, not only do they recoil but they have nothing to draw on as a basis for approaching the problem. One of the classic examples in the tax business is the simultaneous equation. When you have a variable on each side of the equal sign, what the hell do you do? Aside from those students with backgrounds in business or accounting, they are lost and have to go to some sort of table or to an accountant who can do the numerical work for them.

Another problem we have in law is the student who has no appreciation of statistics, who lacks empirical grounding. We say a lot of things in the law, but can we really evaluate the decisions that are made by the policy makers? In almost all areas of law, the answer, unfortunately, is "No," so that when we write articles for the Law Review, we can't really tell the reader what the situation is. When we try to move into this in the course work, we discover bits and pieces of empirical data rather than any sort of well-thought-out, consistent grounding or basis in human experience.

The other chief problem is that more and more the computer is beginning to replace the traditional avuncular attorney in estate planning. More and more, it is the projection that appears on the CRT that tells the story, rather than maxims that have been tossed around the law office for the last 50 years. We find ourselves, then, competing directly with accountants who, in a very specialized way, have taken advantage of the broad scientific foundation given in undergraduate science courses but who, lacking the basic understanding of how the computer works, could use a basic course in physics prior to getting close enough to the machine to do an estate plan on it.

The one imponderable question that I have asked myself and that the students ask me involves something very substantial in estate planning. That is, in many situations clients have trouble making decisions, not just because they don't understand their situation but perhaps because they have psychological problems. Consequently, in the classroom, when I have to talk about competence, I must rely on some ordinary commonsense maxims rather than sophisticated discussion of the thought processes actually necessary for rational consent. Until we get attorneys who can, in a reasonable way, use existing scientific evidence, we are going to continue to have that sort of judicial decision; until we get students who can appreciate and digest scientific data, we are going to continue to have in the law schools a shying away from the basic biological and chemical questions that determine the validity of all the instruments that we draft. Given the relative sophistication of our knowledge insofar as this decision-making process goes, and given the incredible sophistication of available analytical tools, law schools are really operating at an insufficient level by taking students who have not had a solid background in the basic physical and biological sciences and trying to teach them how to adapt in a rapidly changing world.

The general gripe is that those who specialized in the sciences don't know how to use the English language and don't know about liberal arts. I disagree; most of the people I have met who have had a grounding in the physical sciences received this basic information and more. However, the typical liberal arts graduate today has not been forced to confront the basic problems of quantitative analysis that has to be done in the physical sciences and, for that reason, just can't cope with the quantitative analysis that is beginning to creep into every facet imaginable in the modern world, including estate planning.

<u>Question</u>: Courses designed for the so-called "non-science" major are often survey courses about science instead of courses in which the student actually works in science. Can quantitative ability be gained by a course about science? Or are we kidding ourselves that that kind of course can help the student?

<u>Response</u>: We aren't kidding ourselves necessarily, as long as we know what that kind of a course is and as long as we disclaim all responsibility for producing an individual who can reason quantitatively.

But when I must analyze medical testimony on capacity, analyze the state statute that talks about the rights of the developmentally disabled, or evaluate a rather complicated tax statutory section as it relates to a process of wealth accumulation and consumption by a client, those general ideas are of virtually no use. In fact, the best thing about my chemistry and physics courses was not gaining all of the substantive ideas, but the quantitative techniques and the rigorous thinking involved with solving problems. Preparation in that kind of rigorous thinking is what I am not finding in my students.

My experience in estate planning has shown my own small advantage over other practitioners and, more often than not, that advantage develops from my ability to use rigorous methods of quantitative analysis. For example, if there are three different ways of viewing something economically at a settlement conference, you are a much more valuable representative of your client if you understand all three of them and can determine which one is going to be of greater benefit to him.

Comment: That is interesting because when planning science courses that will attract the non-science major, the first step is to remove the mathematics. But if you do that, then it doesn't serve the purpose.

Question: Do any law schools plan to make some hard science a prerequisite?

Response: No, no. At most, there are plans to require a better mathematical background of students, but I wonder whether mathematics without application is really what we want. Instead, there has been a salutary increase in courses dealing with economics and the law and with medicine and the law. Although a step in the right direction, they can't attempt to remove the deficiencies of undergraduates.

Question: Do others share these concerns?

Response: I am in the minority. However, Roger Dorkin, on the medical school staff at the University of Washington, is quite intent on trying to inculcate in the students some appreciation of the actual biological processes that determine, in fact, some of the legal conclusions reached by the courts and the commentators.

An ideal undergraduate curriculum in science would require law students to take at least two semesters of a quantitative approach to one of our physical sciences. That requirement will necessitate that some prior mathematical background be obtained, perhaps in the senior year of high school or the freshman year of college.

Also, I would prefer to have a student with a knowledge of calculus and computers because many lawyers now rely on data retrieval systems to save time searching cases. The search logic being used in such systems as the Lexis System is basically a primitive word search. This kind of technology has revolutionized the practice of administrative law. For instance, the Internal Revenue Service issues private rulings to people who write letters asking for opinions on questions. These letters are not indexed anywhere other than on computer retrieval systems; and in fact, if you want to get at that administrative law, you have to understand something about how that computer works and what its capabilities are. To that extent, then, due process will require an appreciation of computerized retrieval systems. But it is very tough to understand the way a computer operates without understanding limits and a number of other concepts.

Also, every law school is running into a space problem because of the proliferation of cases. In a legalistic society, the logical way to store information is to look at microelectronics.

But if you had to draw a line somewhere, perhaps it would be at a rigorous application of analytical geometry and then the basic principles of statistics. In determining criteria for admission, many individual law schools, such as those at Yale and Indiana, are placing more emphasis on the student's ability to take advantage of statistical and computerized tools for analysis.

Some of the things that I am saying would certainly apply to the political science field or sociology. Yet, a lot of people still think of lawyers as witch doctors in some mystical area of alchemy.

Question: When you explain the plan to a client, do you have to explain in detail how you arrive at all these conclusions and alternatives?

Response: Clients usually are not very insistent on rigorous proofs such as those of a calculus course; but when the case becomes complicated, I use flow charts or Venn diagrams to explain to the client. Again, my use of flow charts comes from trying to figure out the way reactions worked in a chemistry course. However, very few law schools teach students how to use symbolic representation.

Question: Suppose the IRS is contesting a case involving a dead person whose estate you are settling. How detailed and how rigorous do you have to be with the IRS? Is this very beneficial in helping heirs in the settlement and distribution of estates?

Response: It is in two particular areas. If you understand the notions of competence and some action taken by your client is challenged by the Internal Revenue Service, you can frequently get your explanation across at the administrative level and keep it out of court. The other important area is valuation, the ability to evaluate statistics on sales of property. Also, when valuing a corporation which has certain intellectual copyrights or patents, that basic ability as applied to particular questions is critical--again to understand the different sorts of statistical approaches to a scatter of data on the Cartesian coordinate and, thereby, pull a line out of that and get some sort of valuation pattern. If you can do that and educate the Internal Revenue Service agent about it, you will not only help your client but help the agent to explain that settlement of the matter to his superior.

DR. TANFORD: I will certainly be speaking from a non-science perspective. I did my undergraduate work at Princeton, where the only science course I took was a remedial physics course designed for sculptors, art majors, and football players and requiring no math prerequisites. I did fairly well because, again, we looked at Saturn. The only thing that I remember seriously from the course was that if you throw an elephant at a ping pong ball, the ball, when it is struck, will move at twice the speed at which you threw the elephant. That was the level of the example used to explain the basics of physics to us. To people who had no conception of mathematics, the course presented some of the basic principles that underlie that kind of reaction to the equalization of forces.

I teach evidence and trial practice in criminal law (I am actually a criminal trial lawyer), and there is a point in my lecture in which I use that example to illustrate the reconstruction of an auto accident and the forces involved. This may be excessive, but students have to understand this; and I am continually amazed by the fact that immediately, half to three-quarters of the class argue that it is impossible for the ping-pong ball to go any faster than the speed of the elephant. Although they don't argue that it is impossible to throw an elephant, the point is that somewhere along the line, they just didn't have any physics.

Also as an undergraduate, I made a futile attempt to take introductory calculus, the lowest level of mathematics offered. The problem with that, of course, was that instructors expected me to be familiar with something known as trigonometry, a subject not taught in the Durham, North Carolina, public school system when I attended.

I understand that the committee wanted to learn from non-science faculty--which I clearly am--their views on the type of science and technology education that would be useful to students in their careers. I must confess that this was not the kind of issue which had, prior to my receiving your invitational letter, occurred to me. I am probably here as a result of my constant griping about the lack of rigorous, logical thought and discipline that goes into academic law and my constant advocacy of the rigorous hypothesis-forming and hypothesis-testing research that, from what I know about it, is followed in the sciences.

Mine is a two-fold concern. First, to be a successful lawyer, one must understand the subject matter of litigation. However, because lawyers tend to have been undergraduate business, economics, political science, or liberal arts majors, the result is disastrous. If I were drawing law school students, those are not the majors I would select; I would draw them from math and science. One reason is that the law has become more complicated, and more technological issues are being litigated; but many lawyers have little conception at all of the basic laws of physics.

<u>Question</u>: Are you suggesting that law schools ought to change their prerequisites for admission?

<u>Response</u>: I am not sure that they could. A large number of lawyers go into specialty fields--for example, security regulations or tax law. They must understand why somebody was thrown through the windshield in order to understand whiplash. You know, the car is hit from the back and the head goes back, but many people don't understand why.

The problem with changing the prerequisites is that the problem is much broader; for example, physics is involved not only in automobile accident cases but also in environmental lawsuits, which require a basic understanding of chemistry, biology, and zoology. Lawyers also need an understanding of medicine. All cases that involve injury involve dealing with doctors and medical experts as witnesses who use language that law students do not understand.

<u>Comment</u>: Over the years, law schools do change what they are looking for in terms of their admissions.

<u>Question</u>: What are the requirements for admission? What does an undergraduate need? Does he have to have a science course?

Response: He usually has to have a bachelor's degree. He could have taken science courses. Law schools prefer people who have taken at the undergraduate level as broad a variety of courses as possible, a good liberal arts education with some history, some economics, and some science. But law also tends to be a dumping ground for people who find they cannot succeed in their original area of interest.

Comment: We call it the pre-money-making, where a student starts out in pre-med but, because he or she can't quite make that, becomes a generalist; and pre-law comes next.

Question: What about the LSAT? What does it emphasize?

Response: LSAT is essentially an evaluation of how well one will perform in law school. Although I took it at different periods of time, my scores were exactly the same; everybody seems to experience that. Some people do tend to do more poorly on the LSAT, and the result is a panic, last-ditch alternative.

Comment: Also, as you get older, it is harder to do.

Response: I am not really sure about that; but we get people who, if they perceive of law as a career, are concerned primarily with undergraduate grade-point averages rather than the subject matter that they take. That is my reason for having avoided science, particularly a laboratory course. Many students try to work their way around those courses, being helped by the general elimination of the distribution requirements.

Students from different disciplines would benefit from science courses if not for the substantive knowledge, then for systematic, procedural knowledge. Law, for instance, is method. Despite the irrationality of some of the general principles, law is essentially a system of logic. It provides both what students find most difficult, deductive law logic (how to guess a result from an irrational principle, or what students perceive as counter-intuitive principles), and the law of inductive reasoning (applying a new fact situation to certain isolated cases and deciding what is relevant in the preceding cases). This system of logical thought is necessary, and the LSAT tries to test whether one is able to think logically. But then, so does the SAT, for different reasons. The biggest gap that law students have is this logical method of thought.

Question: When you are a faculty member, your hands are pretty much tied, then, as far as correcting absence of this skill, although you have suggested ways to pepper a lecture with examples. But what other options are available to you when you think a student is deficient?

Response: The first year of law school involves learning what lawyers egotistically call "legal reasoning," which is nothing more than deductive and inductive logic from irrational principles as opposed to rational ones. The entire first year is a classroom method of instruction and constantly either gives a principle and demands that the student state the argument to a certain result or gives some previous results and demands that the student argue to a specific principle. Thus, the first year is designed to enable everybody to operate on these two analytical principles. Law school faculty meetings, reports on law schools, and accreditation reports all express constant concern about students' inability to use logic worn down to its basic components.

Comment: The law department really has sought out areas of need and tried to satisfy them.

Question: When you say that law school students should have backgrounds in the sciences and mathematics, are you thinking of any specific course such as physics or biology?

Response: I am thinking more of the traditional course. Probably because of my own experience, I was thinking specifically of the laboratory science course in which students get beyond the point of simply copying the steps out of the workbook and begin to see if something explodes, turns blue, or rolls across the table at the end. Sometimes the situation requires going through the thought process: students have to work out the steps, one after the other, and then the problem has to be reviewed to see if the steps are logical and if the results overlook something that is basic. If an omission becomes apparent, they have to go back and figure out what obvious thing was left out, where their logic broke down. That kind of almost sub-talk, hands-on experience, and methodical thought would have long-term benefit.

Question: Because of what you just said, learning to program a computer would facilitate not leaving out a step. What is both the value of computing and its potential in law?

Response: As the technological half of the science and technology, it might be a very attractive tool, an alternative. The field of law is becoming computerized; and when a lawyer must gather, sort, store, and be able to recall information, he can be aided by the use of a computer. I am convinced that just because of modern life, no undergraduate should be able to complete college without completing a computer course. No matter what career one pursues 20 years from now, everything is going to be computerized, and he will need computer experience. It has been some time since I was an undergraduate; but at that time, computers were interesting novelties used by the aerospace engineers to predict when the Polar Cap would melt because of thermal pollution. The computer is much more a part of everyday life that people are going to need, even having one in their homes.

The other reason that computer courses will be good is pedagogical: the computer is merciless at detecting a mistake in logic, the choice of a wrong word, or the putting of things in the wrong order. Basically, anything that requires the student to use technical, rigorous thought in a system that does not allow for the typical lawyer's argument, "Gee, Judge, it's unfair," is an answer to a problem. It is something that would greatly benefit lawyers.

Comment: You want students to have the concrete experience of actually having to look at something and then to reason from what they saw. Maybe you sense that some students try to reason without seeing: they often can't think fast because they need to have the concrete in front of them and to practice going from the concrete to the abstract. Then, maybe when they get to law school, they can commence to think abstractly.

Comment: You are right: my experience confirms that students respond much better when courses combine the abstract and the concrete. Also, some people deal better with one than with the other, and all students profit from this combination; at the end, they see both sides.

I know nothing about the computer, but at least once a week something happens to make me wish that I did. Soon, I am going to take a course in basic computing.

Question: Why don't you just buy a computer? Everybody does.

Comment: Assistant professors can't afford to buy themselves Apples.

Comment: Get somebody to bring an Apple for the teacher.

Comment: One person in the law school just bought a computer for about $2,000, and we have had a lot of fun with it.

Response: That is an expense, but it just seems to me--partly because of my own weakness--that a person should not be allowed to be released on society as a lawyer unless he understands computers.

Comment: That is the kind of quote I hope somebody is writing down.

Question: Various schools or colleges have reexamined their entrance and exit requirements. Should law schools in general do this?

Response: Yes, but only in certain directions, in certain ways. In terms of minority-disadvantaged admissions, there has been reexamination of entrance requirements.

At the end of the Vietnam War--when a much larger percentage of people entered law school straight out of undergraduate school, military service, alternative service, or graduate school where they had stayed for a few years to dodge the draft--people returning after a few years out of college had more maturity. After the average age of law students dropped significantly, strange things happened in education that law schools did not like. This led to a reemphasis on looking for people with outside experience, but still nothing more than an undergraduate degree is required for admission. Historically, law required no undergraduate degree at all, and to require one was a big step, for many lawyers felt that they were in a self-contained system.

Question: Does being out in the world a couple of years before going to law school prepare a person to understand the physics of whiplash better?

Response: It depends on what a student has done. Most things that one does when he finishes undergraduate school require him to operate logically; and students do bring to law school, then, that ability to operate logically within a system. They also pick up some experiences and common sense not available in a somewhat isolated college environment. It certainly does not give them substantive knowledge, but it does provide some analytical skills that they don't otherwise have.

Comment: Lawyers just have no conception that other fields have anything to offer them.

Question: Do you ever put on any demonstrations when you, for example, get a couple of things on the lecture table and bump them together?

Response: I haven't really, though I suppose I could. We do have an expert witness problem where students are given a problem and forced to think it through and find an expert witness. I suppose we could start some demonstrations.

Comment: Maybe you could contact someone from the physics department.

Comment: As a matter of fact, physics has a person that sets up experiments and is willing, on occasion, to lend his services.

Education

DR. WINSLOW: I have to approach this representing the Department of Science and Environmental Education, where we deal mostly with undergraduates. Five department members consider it a service department for elementary and secondary education; the bulk of our students are pre-service students looking for that first bachelor's degree and teacher certification. We are talking about one group of 180 freshmen and sophomores in an elementary methods course and another group of 167, primarily juniors and seniors, being readied for their student teaching experience. Our students do depend on the college for providing the basic science courses as well as courses required by the state department of education.

Our old program called for 15 hours of basic science and then a three-hour education course to provide the methodology for implementing those sciences. Students usually chose courses lacking extensive laboratories and laboratory experiences, particularly biology courses where they might get their hands dirty or chemistry courses where they might have to deal with more mathematics; and it was almost impossible to steer them into physics. Looking at the students that I have in class and those that I have to watch practice-teach in the elementary schools today, I would prefer science courses that had an interdisciplinary approach. One of the basic genetics courses for non-science majors gave a good foundation in genetics, but yet, all of the course's resource materials were those with which students should deal every day. That is what for elementary teachers need. That course was described in the January 1980 Bulletin of the Secondary School Principals Association.

Besides basic science, I would like to see all elementary teachers have a chance to develop in those courses what we call "science process skills" (inference, observation, manipulation, experimentation, and so forth). Also important for teachers are good question-asking skills, formulating probing questions and evaluative questions and not the narrow-type questions that most undergraduates and some graduates seem to develop. They need to be able to find data, to recognize good sources of data, to analyze it, and synthesize it. Among the most important skills that I would like to see science courses develop are communication skills.

What we have attempted to do, interestingly enough, is called the "Indiana Model," developed by Hans Andersen and some of our colleagues. This new certification pattern requires an 18-hour sequence, the first sequence being basic science skills that we had assumed students pick up in high schools. We are doing simple measuring, weighing, and other needed laboratory skills. Students can take courses varying from one to three credit hours, but then they must take courses in each of the following areas: biology, physics, astronomy, and earth science. The chemistry department did not wish to participate in this model, but students are getting chemistry, both in the biology and the physics. They are also having to deal with mathematics in these courses. At the same time they take each of their science courses, they take one hour of methods courses. In addition, instructors attempt to go to each other's classes with these students. For instance, I'll pop in on an astronomy class most days or a geology class. We have team meetings every three or four weeks to compare notes. We try to prepare these students to get some pre-service practice in the public schools.

Today, I spent the full morning watching several of these kids give 10- and 15-minute lessons, some with whole classes and some with small groups, trying to really interpret science to elementary school students by using the materials currently worked with in their own science classes.

Comment: That program is working with the students, if we can judge by their enthusiasm. They were not enthusiastic about the math, however, because they thought it was too simple. But they really liked the science and the way you tied the methods course to it so that they could see the its applicability immediately. To just turn people loose, giving them just a smorgasbord opportunity to shop carte blanche, and then to expect them to make all the connections doesn't necessarily work all the time.

Comment: It doesn't work in physics or math either. For 100 years, physics teachers have been saying that if you are given the basics, then you can apply them where you see fit; but you can't apply the basics unless you have been shown how to do it and have made the connections as you went along. One of the greatest mistakes in our physics courses is teaching all the basics and then leaving the students high and dry.

Question: Does your group have any clout over the science departments in choosing either the course content or instructor?

Response: I don't know if you would call it clout, but we were careful when asking persons on the faculty to join this team and participate. We did write the curriculum, so that we did have some input, but two of the departments have changed the persons teaching it because they are taking it as an overload.

Question: Do you follow this same plan for secondary teachers, too?

Response: They follow the old plan because their requirements are much different. An elementary teacher needs only 15 hours of science whereas the secondary education people majoring in science have to have a minimum of 51 hours for certification. Most of them are very enthusiastic about becoming science teachers. With 50-some hours of science under their belt, a Bachelor's degree, and a rigorous methods course, they ought to be well-prepared.

English and social studies people will take a minimum requirement of 10 or 12 hours and steer clear of everything else that has science in it.

Question: Do elementary schools in Indiana use science specialists to teach science courses?

Response: Some of the larger systems do, but that is a small number; I would say less than a dozen.

History

(Some of Mr. DeWitz's opening remarks were lost when the recording tape was changed.)

MR. DeWITZ: The math that I use every day is very elementary. I use a lot of arrays and tables that sometimes are introduced in a high school or college mathematics class. Many times when I write a program, nobody cares how well-structured it is as long as it works: many programs are sloppy and take more memory or more C.P.U. time, but nobody cares because they work. In this field, finding people who can write good programs is not the problem; it is finding people who can communicate to upper-level management. A lot of programmers and analysts are whizzes with the machines and the technology but just cannot write, cannot communicate. The kind of skills that I use every day are more business-related and analytical.

My training in history better prepared me for this work than my training in the sciences and math because to get the facts, I have to interpret what I have read or heard, and there is no right or wrong answer.

Comment: You shattered one favorite myth of academic types like me. You said that the biology, botany, and microbiology courses you had taken had really been for zilch.

Response: I would use those courses in my leisure; if I need to know biology, I have a background for it. Also, the courses in computer science were very mathematically oriented, but I don't use that knowledge except in text processing.

MS. DeWITZ: I did take some science courses, but I don't feel the same way my husband does. I read the newspaper, and I read about scientific advances in fields such as genetics engineering; and the science courses help me to understand what I am reading. In college, I took a basic physics course which was invaluable because I had never taken one in high school, although I wish now that I had because it would have prepared me better. Seeing a demonstration that proves Newton's law of gravity is amazing. That sounds ridiculous; but if you have never had that sort of background, it is important.

It does not help me, however, in my everyday work as a graphics designer. To do the mathematics in my everyday work, I use a cheat rule for percentages, or I use a few basic equations and measurements learned in eighth-grade algebra. My college math courses were so bad that I should not have bothered. For instance, in "Probability Statistics" the instructor, a regular faculty member, assumed that everybody in class was a mathematics major; we were assumed to have an enormous amount of information which I did not have. In a basic theory class, taught by a graduate student, if you got ten percent correct, you still got a "C." I was not real impressed with that.

Journalism, Science

DR. LAMBETH: Of all the non-specialist fields that you may be looking at, journalism may be one of the most strategically placed in terms of your purposes, since journalists are in a unique position to influence public attention or public appreciation of science as sort of a cultural and economic force in our society. Agencies in Washington such as the Public Understanding of Science Program within the NSF and the AAAS media intern program have emphasized this at the level of practicing journalists.

Maybe we need to examine the science education offered to the great body of journalism students in such programs, for journalism graduates fill about 80 percent of the jobs positions in the media. These are the students who one day will be the editors and publishers that decide how much in the way of resources will be given to science reporting. They are reporters who, though they never even darken the door of a AAAS meeting, will write countless sentences and thousands of stories that influence scientific literacy. They write the stories on food, on local high school curriculum, on what government is doing about pollution, and on the neo-William Jennings Bryan who wants to eliminate the teaching of evolution. This is just merely a list of suggestions of the many ways that these mainline beef-and-potatoes journalists have of influencing how the public thinks about science. Obviously, the overall science education of the journalism student is important.

Nonetheless, very, very few journalism students carry minors in science. Even fewer carry what we at Indiana call "double majors," that is, 27 hours each in journalism and in one of the sciences. Until recently B.A. students were required to take the minimum of two courses in mathematics and the physical sciences and two in the biological sciences. Now, they must take at least one math course and four courses in the natural and physical sciences. I.U., like some other colleges, also has a series of courses for non-science majors called "Excursions in Mathematics," "Excursions in Physics," "Environment and Physics," The Strategy of Life," and "Heredity, Environment and Society;" but we must look at these courses and determine what they teach or don't teach non-majors. We haven't asked whether certain students might profit from taking courses such as biology, chemistry, and physics beginning with those three introductory courses. Nor have we looked at the possibility of designing and testing courses such as science for journalists.

The University of Missouri School of Journalism has adopted a popular course called "Business for Journalists." It is not a sandbox course, but by the time you have a freshman or sophomore in your office to talk about the courses he will take for a minor or even a major in journalism, all the damage has been done in high school.

A recent report by the National Science Foundation states: "The current trend towards virtual scientific and technological illiteracy, unless reversed, means that important national decisions involving science and technology will be made increasingly on the basis of ignorance and misunderstanding. Science and technical literacy is becoming increasingly necessary to our society." Yet the report notes, "More students than ever before are dropping out of science and mathematics courses after the tenth grade. This trend shows no signs of abating. In fact, there is a growing discrepancy between science, mathematics and technology education acquired by high school graduates who plan to follow scientific and engineering careers and those who do not. Only 17 percent of all high school students take 11th- or 12th-grade science and math."

This is the result of very bad teaching. My two children have never had a mathematics teacher that really turned them on; it just breaks my heart. Usually in high school, the coach teaches science; and ironically, there are good science teachers. Therefore, by the time students reach journalism school and college, they are turned off to science, leaving only a few students who have interest that we can nurture.

Here at Indiana University science journalism consists of only one permanent course in science writing offered to seniors and graduate students and one topics course that may become permanent. In science writing, basically students write and critique one another's work--writing as much as we possibly can, reading as much good writing as we can, getting the best criticism we can. Thanks to the generosity of a School of Journalism endowment, we have had a distinguished science lecture series, whose speakers were Alan Hamlin, Barbara Phillipton, and Luther Carter from Science magazine. Because of these three very interesting presentations, most of this room was filled with journalism professors, science professors, science students, and journalism students.

The seminar entitled "Science, Society, and the Media" appealed to a rather eclectic group: journalism students who are not science majors, journalism students who have double majors in science, science majors who are taking two journalism courses, and Ph.D. candidates in the sciences who want to take a smattering of courses. For example, Hal Kibbey, an ABD in history and philosophy of science, took three of our courses and is now covering science at Indiana for our news bureau. Ricky Lewis, a Ph.D. in genetics who took both of these courses, is now writing for Miami University part-time and doing free-lance around Dayton, Ohio. Terry Fortunato, editor of the Indiana Daily Student's Science Page, had a B.S. in biology. She took some of our journalism courses, worked at Science Trends Newsletter in Washington, and is now a writer at the Johns Hopkins University Medical School in Baltimore. Clark Brown, an M.A. candidate in health and physical education who also had taken some journalism courses for a master's degree, now is with the U.S. Park Service at the Indiana Dunes, writing and giving lectures to visitors. Mary Jane Myers, a journalism major and science minor also active on the local Indiana Daily Student, works for a New York advertising agency, writing specialized advertising to a broader audience for pharmaceutical firms.

A lot of the work that needs to be done must be done by ourselves. Rather than federal money for it, perhaps we need to have some good, long, hard studies that include experiments and evaluations in teaching. We need to do some real in-house education in the journalism education fraternity. Journalism education, which in this country is really about 80 years old, has evolved from journalism's being a technical trade to its being part of the liberal arts. Indeed, only about 25 percent of the typical journalism student's courses are in journalism.

Paul Dressel, the director of institutional research at Michigan State University in 1960 and later its provost, wrote a pamphlet entitled "Liberal Education in Journalism," in which he advised journalism educators to consider the nature of their advising students to get into liberal arts courses because the courses that he looked at were doing a lousy job. We need to do in science in a more narrow sense what he did in the liberal arts. He concluded, "There are few experiences in which a student is forced to organize knowledge from a number of different fields, relate his own opinions and values, and produce a well-thought-out statement."

There is some point to the view that an individual really does not know his field well until he can begin to write and talk about it in such a way as to be understood by others. Following this line of thought, we come to the possibility that well-planned professional journalism courses will provide the student with the kinds of experiences which, in many ways, are more nearly consonant with the aims of liberal education than what we, in fact, find in most liberal arts colleges.

Question: Are there special kinds of courses available for medical background, the area where science reporting is really lousy?

Response: Not to my knowledge. Medical schools and journalism schools just have not had many conversations with one another. They don't address the kinds of things that are implied by your comments.

Comment: In general, the reporting of biology news is not all that bad; but in medicine, it is irresponsible. No filter of truth is used.

Response: We have made a small beginning here at I.U. Our medical school is located in Indianapolis, but we have interconnected television, and I have made arrangements for a number of the medical school's doctors and researchers to talk with science students here to give them experience of interacting with doctors. Also, I invite into my class science writers, such as the news bureau employee who has to deal with doctors from the PR point of view. However, these experiences are not curricula that do what you are suggesting.

Comment: One of the big problems here is that doctors are notoriously bad communicators. Whether they want to create a degree of mysticism, or whether they don't want to bother, or whether they are incapable, most doctors are very bad at communicating with me when I am paying them for their services, and they are equally bad when I try to interview them. Maybe that is something to take into account: How do we get scientists to communicate better, not just in the classroom but to the general public? Communication must be a two-way effort. Doctors are supposed to have liberal educations before they reach medical school, but they are not learning to write or to communicate effectively. Maybe that is part of our whole problem.

Comment: Part of the problem may be that much medical research is funded on a slightly spurious basis so that the right press release can bring in cash while an honest press release may not.

Response: Terry Fortunato, now at John Hopkins, was in the special seminar, and we had a required paper on the guise of biological and medical research, a 97-page collection of the trends of spending, research, and definitions in some of the more important areas of research. I told her, "Let's assume that you were assigned to the health and medicine beat for a major medical metropolitan newspaper and had the time equal to the amount allotted in this course to do this paper, to do a reporting job on what you ought to be looking at or the kinds of things that you would need to know about (agencies and so forth) for the next five years." When she left here, she had something to go on. I am not for a moment suggesting that this is an appropriate substitute for the series of courses that your remarks apply to, but it is a start, and that is what we are trying to do.

Comment: There is another example. AIP, an umbrella organization of all physics societies, publishes a handbook for science writers, a little encyclopedia that explains all different kinds of terms, ideas, and concepts in language that science writers will understand. If other societies would do a similar thing, that would add a good deal to the intelligibility of articles because reporters would get the right terminology and the right ideas.

Comment: Complementary to that, a year ago Neal Miller, a physiological psychologist at the Rockefeller Institute--as a result of some seminars that he organized--created a pamphlet for scientists on how to package information for use by journalists. People from all areas of the media talked about how they would approach the scientists and therefore educate them in what to look out for, who to phone, what kind of quotations they looked for. It presents lines of the scientist's responsibility to the journalists.

Response: If your group is interested in pursuing this, specifically the subject of medical writing, there is an organization called the American Medical Writers' Association, which hopes to develop a series of courses designed to equip writers in the field. Once you go through this course, you get a certificate of completion similar to what has been developing in the field of association management: people can get a degree, or they can go through an intensive course and become certified as a way of telling employers, "I have completed this unit successfully." Maybe journalism education ought to look at that method. Every journalism major should have a certain literacy in science and a certain command of vocabulary, but we are not doing a very good job of directing our students to the right courses, or having the right courses designed for our students.

Question: What can you say about whatever it is that determines whether a school establishes more prerequisites in science? There must be internal politics of all kinds when another science prerequisite is proposed, since it would take away from some other kinds of courses.

Response: We need to know more about the content in some of these other courses and distribute a detailed flyer from our colleagues on what is and isn't.

Comment: For a while, frankly, the liberal arts got so loose that some people just gave up on any standards. Advisors, not knowing, would put a student into a course and think certain matter would be presented, but it wasn't. In political science, for example, we would expect the student to get a knowledge of courts, the executive branch, the judiciary, and the legislative branch; but that is not what the student is being taught. It might be called "American Government," but instead it is some research project that that professor has at the given moment on some minute problem. And some of that was happening in the sciences, too.

Question: I was interested in several remarks today about the poor quality of teaching in mathematics for non-science students. Does this cover high school teaching or just college?

Response: It begins in the elementary school.

Question: How much do you think the so-called "new math" has influenced this?

Comment: The worst thing with the new math is that the parents can't help the students with it.

Response: We had a meeting here two weeks ago with a group from the American Society of Newspaper Editors to discuss the coverage of education, particularly local education, and one of the problems is that even the brightest people in a community don't know what their kids aren't learning. This reflects on the coverage of education in the local school district.

Comment: They report the politics--busing, budgets, and so on--but they don't report what is going on in the schools.

The Tucson Star, a Pulitzer paper, had over a period of time an education section that was very well done and really showed continuity. The team of reporters looked into what was going on in their educational system, visiting schools and interviewing teachers to discover the successful ones, and they presented an in-depth analysis of education that I have not seen done in very many cities. Papers in most cities report only the politics of education, partly because most journalism schools teach students to report politics. That has been the guts of journalism. However, one I. U. professor reported the discussion from a meeting of top editors in Washington, D.C.; editor after editor said that our best writers are not reporting government now but, rather, are reporting in the lifestyle, economics, business, and living and leisure sections.

Response: This committee needs to consider one thing. This state may be typical and may be atypical, for the politics really starts in the Department of Public Instruction for the elementary and secondary schools, which requires one laboratory science course for a high school diploma. So about 80 to 90 percent of the kids take a freshman course in biology, and that is their last exposure to science until they get to college. Those are the kids who, unless they are really pushed into a college science course, are going to forcefully choose their way out of all science courses that might have teeth in them. Meeting minimum requirements is their only concern.

Comment: We have watered down the high school curriculum, offering things that students don't necessarily need while ignoring what they do need.

Comment: The national average is two year-long courses in science in high school, but it used to be three.

Response: My family was privileged to know Claude Lapp, a member of the National Academy of Sciences. When he visited our home, he would bring green sand from the Pacific Islands and explain why it was green. He would look at objects in our home and talk about them from the point of view of a scientific principle. All of a sudden, the kids would become excited or interested about everything around the house because Claude Lapp was a great scientist. I wonder if you could have a TV program in which you would go right through your house that way.

Another thing to consider is the textbook adoption system in many states. This year happens to be the science adoption for Indiana so we have textbooks from the floor to ceiling. Salesmen make all kinds of promises and commitments, but you really need to look at the new books, all descriptive science, which avoid the laboratory inquiry approach on the high school level.

Question: Who sets that policy with the publishers?

Response: The sales department; you have to sell so many books to recover costs. The Houghton-Mifflin salesman told me they weren't even going to sample their old entry science series in this state because it cost them $100,000. Not many publishing companies can afford to finance such a sample, not knowing if they will get a bid and win a contract.

Question: Do high school teachers not want to do laboratory experiments? Do they just want to instruct?

Response: The high school teachers don't necessarily want to. Many of the good teachers do, and they are going to continue to do them; but the administrators say it is a lot cheaper to teach a descriptive course than to buy laboratory equipment and materials.

Comment: And kids like it better because they can merely memorize facts.

Comment: That is what is happening in the writing courses, too. Educators talk about writing, but they don't teach students to write.

Question: This committee wants to look at nonconventional kinds of science education for the public--things that happen outside the classroom--to use newspapers as a systematic way of getting science information across. What is your view about that?

Response: This really needs to be tested. I would love to see a well-designed science course coordinated with a newspaper and test and then to compare that course to a traditional science course on the same subject. An organization within the American Newspaper Publishers Association promotes the use of newspapers in classrooms. It has picked up momentum in the last five years, as the penetration rate of newspapers in large metropolitan areas has declined. Newspaper publishers, worried that young people are not going to buy their product, have been pushing this idea; and some states, Florida and others, have really gone gung-ho.

Comment: But there is no change in the editorial policy of the publishers; the classroom merely studies news which has already been selected.

Comment: There is a new twist to it, a series of classes taught by newspapers, too, almost as an "Ann Landers" of science that explains science in intelligent layman's words.

Question: It is a kind of serial?

Response: That is a different approach. Many of the newspapers in the classroom use stories already in the paper. They are not pre-packaged.

Mathematics

DR. KERR: Although I have done a lot of different things, my main thrust right now is mathematics education for college students. I am responsible for the basic skills instruction in the mathematics department and for elementary teaching.

The problem in science education is that in learning mathematics, students need to do many things, and mathematics can play different roles in their education. First, mathematics can help students acquire basic skills necessary to do other sciences--arithmetic, elementary algebra, and maybe some very elementary geometry and calculus. Students also need to acquire knowledge of usable mathematics--for example, probability, statistics, calculus, and linear programming--learned at a very elementary level or a more advanced level, depending on whether one is trying to get a little background or trying to become facile with it. An important idea recognized much more now is that of a mathematical model and its role in the world. One must create that in order to apply mathematics to a situation; and because it gets more attention now, we actually try to deal with that in the context of teaching probability, elementary calculus, and so on. And the fourth category is the "experience of playing mathematician," or the actual problem-solving--if somebody actually wrestles with a problem for which he doesn't have a solution or explores a new area in a way analogous to the way a professional mathematician would.

My comments will focus on the basic skills. Many students come to a university like I.U. with a quite satisfactory command of the basic skills: they know how to do fractions, deal with complicated numbers, and solve equations. Some of them even know a little about logarithms, exponents, and trigonometry. They come here and go about their business, never coming into my clutches, and proceed quite happily. Many don't, however. We have over 1,000 students a year here at Indiana take elementary algebra, essentially a review of the first year of high school algebra and of some second-year algebra. Of those students, 925 are non-science students; and the truth is, that 990 of them are non-science students in terms of what they ultimately graduate. Very, very few science students start in our elementary algebra course and go on to succeed in science. So these are essentially all non-science students. Another 2,000 non-science students each year (a conservative estimate) get a DF or a W (withdrawal) in a 100-level mathematics course.

Minorities exist in this program, but they are present in a smaller percentage than their percentage on campus because many of them are in a special program involving another 300 students not even included in my statistics.

<u>Question</u>: What is the other program?

<u>Response</u>: It is called the "proof program." Students with potential and with good background have been brought here and given a head start in order to be integrated into the program during the first couple of years.

These are rough statistics, but about 30 to 40 percent of the students in the basic skills course for those in my unit, 114, do quite well: either the course is a brush-up for them, or they work hard and do well. Only 20 to 30 percent of them really struggle, are hopelessly lost, or just get through by the skin of their teeth and then get stomped on in the next course: they are just very marginal students who, as a group, tend to see mathematics as lots of bits and pieces and each day's assignments as something totally unrelated to yesterday's assignment or tomorrow's. Some of them do become able to do today's assignment today; or they have sufficient facility to look at the examples and acquire a pattern so that they can work the exercises for the day and then tomorrow they can work the exercises for that day quite well. But when they have a test, they are just lost.

<u>Question</u>: What high school level does this correspond to?

<u>Response</u>: This corresponds to first-year high school algebra, and 90 percent of the students who have trouble get bogged down right off the bat, not waiting until we reach more sophisticated mathematics at the university level.

<u>Comment</u>: And most of them had the same algebra course in high school.

<u>Response</u>: 85 to 90 percent of them have had at least a year of high school algebra. Actually, a surprising percentage of them had two years of algebra in high school, and a surprising 20-30 percent got B's or better in those courses.

Many of them seem to have fallen into a pattern of memorizing mathematics in order to try to do it, often beginning with a crisis period somewhere in their mathematics education--in the fifth grade, or the third grade, or even the freshman year in high school--when they have a teacher they don't get along with or they become sick for two weeks and don't catch up. Very bright persons in those situations will be facile enough to fake it for a long time, memorizing the math, because they are brighter than the average kid in the class, and they do well. It is a kind of Peter Principle: each one goes along until he gets to the point where he or she no longer can handle it by memory but is crunched. This may be totally false, but I think that something along those lines is happening.

There are some other reasons that people have trouble in this course. When you are trying to acquire a skill, as contrasted with information, the congruence of your background with where the course starts becomes extremely important. Students just trying to acquire information can start stacking it in a new place; but to acquire a skill, they must build it on something. Some kids, somewhere along the line, weren't ready for the mathematics that they encountered. They were here, and the mathematics started there and went along; and they tried to track along behind, but they just never got it together.

In some instances, there is a real cognitive style problem: some people think in a way that is different from the way other people think. For example, my wife, an artist, can look at certain geometric puzzles and solve them like that while I can solve them only after analyzing them. Of course, she has been an artist all her life, and I have been a mathematician only a fraction of mine so whether that is congenital or experiential is hard to judge. But she thinks differently about those puzzles than I do, and I talk to students who clearly think differently about problems in mathematics than I. A lack of mesh exists between the instructional style in elementary algebra and the thought processes of some students. We can conjecture whether this is congenital or acquired, and a lot of research has been done in that area.

Question: Do you have any way to estimate if students have been put into the right section?

Response: Well, there are definitely ways to pre-test them. There are tests--Joe's paper says that this test says that, and Sam's paper says that this test says that, and so on--but there is some consensus in the literature. You could test students. One missing ingredient is a carefully thought-out pedagogy congruent to different cognitive styles, and another missing ingredient is proof that it would make a difference. I suspect it would.

Comment: Algebra is particularly difficult because a lot of research these days confirms Piaget's ideas about different levels of thought processes and action, depending on one's age. For example, we must go from concrete to abstract thinking, and this happens at different ages for different people. Algebra, clearly an abstract-thinking subject, is taught in 9th and 10th grade, although we find that many of the college freshmen and sophomores are still at the concrete level. What Don is talking about as memorizing is really saying, in a way, the same thing: if you can't handle it at the abstract level because you are not at that stage of mental development, you handle it at the concrete level. All you can do is memorize, but that will only take you so far.

Question: Are a disproportionate number of women enrolled in basic skills?

Response: What is amazing is that it is--almost to a number--even, although there are more women on the campus.

Comment: About 55 or 56 percent of the undergraduate students are women. That statistic would indicate that the women are doing better than the men.

Response: I have an interesting statistic, though. I arranged for a meeting with two psychologists from the Health Center and half a dozen students who were supposed to be math-anxious students, ones having emotional problems with math. I asked six of my instructors whom I felt would be particularly perceptive of students in their basic courses to deliver me a math-anxious student; within whatever package it was required to get them, they indeed did deliver me math-anxious students. There were six students (five of whom were women) who had had a hiatus in their education.

Question: Were all the instructors who made these selections male?

Response: I had three females and three males.

Question: Would you be unlikely to turn up specific learning disabilities?

Response: Oh, we do turn up some--everything from students with dyslexia to students with a real I.Q. deficiency, those right on the bottom edge of our educable college students. We are just trying to ease some students who come into my office out of college. Clearly, nothing in my school can help them.

Comment: I wonder why they come to college.

Response: That crosses my mind, too; but you know, there always has to be a weakest person somewhere. I suppose somebody was convinced that these students had some potential and wanted to give them a shot at it, and that is the only thing that worries me. As long as we can arrange for them to leave here in a positive way and do something useful, then I don't mind their having been here. It worries me a little to have to set up a kid for failure when, statistically, you are pretty damn sure that he or she is going to fail.

Question: What fraction of students fall within this category--one or two percent? I ask this because when I screen grade repetitions for the biology department, I note an awful lot of learning disabilities claimed in mathematics.

Comment: It depends on how broadly you want to define a disability. Given recognized disabilities, such as physical ones, the number is certainly very few. We do encounter such people and try to accommodate them, however. But if you accept having a totally dysfunctional approach to the subject as a disability, then the number is larger. If you just told those students to do the math the right way, they could not do it; a more profound intervention would be needed in order to get them on the right track. We have quite a few students (15 to 20 percent) who have a problem that transcends just good teaching; they really have a profoundly bad approach to the subject.

Response: Again, we have 13,000 math students a year, and we are dealing with the bottom thousand. What to do about that is important, and we have been doing some research here in the math department, interviewing students in the basic skills courses in detail. We give them a math problem to work down the left-hand center of the page, and then we circle key steps in it and ask them to describe in writing what they did then and why they did it. We have been interviewing students and looking up SAT scores, high school grades, and similar statistics in an attempt to profile the kids that we have and to understand these problems. We are trying to identify, again, the relevant dimensions with which they seem to be having trouble and maybe even the classification so that we can have different sections, for example.

We are going to have a first-stage report out this spring. The next stage, running from this spring through next fall, is to follow these students on into the next math course and, again, interview them and follow up their experience.

Comment: It seems to me that asking the students to write a mini-essay on how to solve this stage of the problem would benefit them, attacking the second hurdle of putting it into words.

Response: Oh, yes, that is right and, of course, what we do is very informal research. This is hypothesis generating research as contrasted with hypothesis validating research, but we also, of course, try to infer from what they say they do when solving a problem. We also probe into their questions. We do not just rely on that, for you have to account for the articulate skills of the individual; but most of them can say something.

An example of a symptom of this dysfunctional approach to mathematics occurs when students are asked why they did something. They will say, "The book told me to," as contrasted with "Because, you know, it makes sense to factor here," or "It seems to me like this is the right thing to do because of such and so or something." Instead, students appeal to authority, saying, "Well, that is what you told me to do," or "That is what the book said."

A tremendous improvement to the course would be to slow it down. We cover a lot of material in our basic skills course, essentially about a year and a third of high school algebra in one semester; and of course, the problem is that it is a non-credit course that students don't even want to take. We are thinking about breaking the course into two parts where two-thirds of the students will take a slightly more sophisticated course and one-third will take a course somewhat less sophisticated, leading into the more sophisticated one. My own prejudice is that that will be a good move for us.

Question: Have you tried any programmed instruction?

Response: Oh, a lot of people have. The written materials we use here are in a workbook format; but they are not programmed in the strict sense so that if a students gets answer A here, he goes to one place and if he gets answer B, he goes to another. Maybe five or six years ago, the mathematics department had the students actually do programming in the basic math skills course. Then they would give the students some elementary programming assignments to confirm or to apply those skills. They were not actually using programmed learning, but rather, learning by programming.

There are instructors, but students don't sit at their feet. The class meets for two one-and-a-half-hour periods a week. About a third of each period is a lecture, and two-thirds of it is a tutorial session in which three instructors move around the room and work with individuals. It is semi-self-paced. There are four main tests in the course, each of which a student has to pass. Because each one is offered five different weeks, students have an interval in which they can pace themselves. They can fall behind, but only to a certain point. Another safety valve in the course allows the striving student who is not succeeding at the pace of the course to change gears, moving to a non-credit course where he isn't risking any bad grade but can just take advantage of what he can learn in the time he can learn it. It is a way to pressure the students, but they have a way to take it off when the pressure is becoming dysfunctional.

Comment: We have done some cost analyses of using the PLATO system versus using an instructor because periodically one has a feeling that we should be able to do something with PLATO, not only in this line but also with base data. But the trouble is that every time that you actually put the numbers into PLATO, you really don't save money over traditional teaching; therefore, if you had to choose between people and PLATO, almost everybody would choose people, especially if the ratio of instructor to student is one-on-one. It seems that most people actually doing this kind of teaching feel human instructors are better than machines, which would be nice supplements.

Response: They would be a very nice supplement, but we rely very heavily in this course on pressure from the instructor to the student. In other words, we try to get the instructor to develop a relationship with the students. For example, if the student doesn't come to class, the instructor calls on the phone and asks him why not. A sort of personal commitment to the instructor develops. Nonetheless, I tell my instructors to tell the students, "When your frustrations peak, we don't want to take away your inalienable right to fail." I only tell the instructors that because the students become so frustrated that they become dysfunctional.

<u>Question</u>: How many years have you had this program in operation?

<u>Response</u>: Vestiges of it have been going for about six or seven. I have been involved in it for four. Four years ago, there were fewer people who needed this program. Nonetheless, now there are certainly fewer people taking it, proportionate to enrollment.

<u>Comment</u>: A number of things have happened during this time. One is that enrollments have grown a lot in the business school, which has a rather hefty math requirement; and students choose to take this as a pre-requirement to be able to pass the others. Another change is that we have instituted in the College of Arts and Sciences a math requirement; and many of the students, knowing they have to satisfy it, think that they had better take this first.

<u>Response</u>: That last requirement has nearly done us in. Apparently, we acquired about 100 students--including sculpture, theatre, drama majors and so on--off the bottom of the deck mathematically as a result of that requirement, creating a hassle of much greater magnitude this semester than ever before.

Mathematics has characteristics which are the basis of its strength. Namely, it is abstract, general, and precise. But the same characteristics make it difficult to teach and difficult to learn because a lot of attention has to be given to making concepts concrete for students. They are not, on the face of them, concrete. Even in a physics course, if you start talking about temperature, everybody knows what temperature is because they experience it, whereas in mathematics, we often introduce an idea for which nobody has any concrete embodiment at all. Thus, in exploring the different things one might teach in mathematics, teaching people information without giving them concurrent experiences with it is senseless--applying it in some setting, giving students some activities to embody it in some application. As a consequence, in every mathematics course for non-science poeple--including finite math, which teaches probability and linear programming, and calculus courses--the nature of the subject matter forces students to solve problems in order to get anything out of the course. Therefore, everybody needs certain mathematics to bring to those courses.

Different sciences would feel that way to different extents. For example, one can read about Saturn this week and get a certain amount of excitement and pleasure just out of the information acquired; there is no particular concrete experience related to it. I don't know whether the astronomy department would be satisfied with this as a given course about astronomy--you know, Carl Sagan or whatever--but apparently mathematics does not have the luxury of being able to even consider such a course. As a consequence, any department that wants students to take mathematics courses is buying for their students quite a bit of time somewhere along the line. In other words, either they have certain prerequisite skills and then go ahead and take the mathematics courses, or they have to acquire the prerequisite skills. And this is a time-consuming undertaking. But I don't see any way to shorten the process. In fact, we do it too quickly now for a lot of students.

Whether they should be in the shape they are in is not the issue. They are in that shape; and to give students a meaningful experience in math, the course would have to be slower paced and much more concrete than it is for a number of students.

Physics: Judith Franz

(Portion inaudible on tape)

DR. FRANZ: The only large group of students that the physics department has to service are the pre-medical students. Our teaching order has not been as heavy as those of physics departments at universities where the engineering school is very big. Therefore, because there is no place where students can pick up any sort of technological base, we have made a concerted effort to institute courses for various groups of students for whom a physics course would be a useful course. One specifically for the business school students is called "Energy and Technology." Working with the business school, we tried to determine what kind of course might be best for business students. They had a science requirement but no specific courses in mind.

We also have a "Physics for Poets" course that is an almost totally non-mathematical course. It is a one-semester, four-hour course, predominantly physical science but including some chemistry. Only the physics department teaches it because there wasn't anyone in the chemistry department who wanted to. Our problem really stems from having a group of students, many of whom are almost totally non-mathematical, to whom we want to teach physics, the most mathematical of sciences. We, therefore, have courses at all levels of mathematical ability. Our world is becoming more scientific and more technological, and the physics department is very concerned about creating a populace that knows something about science and has some understanding of scientific problems and interpretation of data.

We have done whatever we could, and we are willing to also work with other departments, such as journalism. For instance, we have started a course specifically for elementary education majors, after asking the education department, "What can we do for your students?" After I started to teach it some years back, I asked people in science education for their insights on how it could be made better; and working with them, we instituted a system whereby the students in the class would immediately go out to the local school system. The science education people were responsible for working on that level while I taught the physics course. Research on this showed that students going to the schools immediately had a much better attitude because they could then see the science not just through their own eyes, but through the eyes of the kids who really do get very excited about it. At the same time, Hans Andersen, who was chairing science education, received a grant to develop this integrated elementary education course which has been very successful.

Now, working with other departments is very difficult because whenever a group of departments in a big university must work together, all sorts of problems arise. Just keeping the thing together is going to be a hassle over the years, although we hope that it will survive.

Another difficulty is that within the physics department, assignments are always rotated: you can't randomly select the person who teaches a particular course. I am not teaching the physics course now and probably won't next year.

Question: What are the incentives specifically in the physics department that would induce an individual faculty member to become involved in something like that? What does the chairman of the department get out of it, and what does the individual get out of it?

Response: The chairman of the department gets nothing. The department just gets enrollment; science education doesn't take a fraction of the salaried members. The people involved in this as faculty members were often ones who had kids in the elementary schools; that is the source of their incentive. For instance, I became an evangelist because my own child was getting no science at the same time that I was becoming aware of the nationally developed programs available for but not utilized by elementary schools, and I became angry. Most of the people in the program had some experience like that.

Question: Do you use any of the materials from the national program?

Response: Yes, exclusively. All of our laboratories use materials actually developed for elementary school children. There are three NSF-supported programs that we have material from: SCIS (Science Curriculum Improvement Study), SAPA (Science, A Process Approach), and ESS (Elementary Science Study). SCIS is my favorite.

Question: Is the course planned by picking the elementary school curriculum that you would use and then talking about the physics aspect of it? Or do you handle the physics course in the traditional way and then pick the material that will illustrate that? Which comes first?

Comment: We plan both ways, back and forth. But we plan a complete science program of topics that are chosen according to what could be used in the elementary school classroom. Then, I try to fit those topics into a coherent group. The college students go into the laboratory first and are introduced to the material as part of our inquiry approach. Then we lecture. The basis for this approach is the Piaget-type theory that says these students can't think abstractly. Therefore, they go into the lab, see equipment, experiment with it, and play around with it. I bring the equipment in and lecture about it afterwards, trying to bring things together and to teach the curriculum the way that we would want these students to teach the elementary school children. We do not give them an hour lecture on something and then give them the equipment.

Question: Do you feel that these are watered-down courses, or are they substantive and rigorous?

Response: Neither. They are certainly not substantive and rigorous as far as the physics course goes. Compared to it, they are totally watered-down; but as far as what the students will need in order to do a good job of teaching science in elementary school, they are substantive and rigorous. In other words, the purpose and the emphasis is different. We use almost no mathematics because the education department has no math requirement.

Comment: The three math courses that those students take are not focused on developing their individual skills in mathematics but rather on developing background in the mathematics that they are going to teach in the elementary schools.

Comment: One of them said the lab was ridiculously insulting and simple.

Comment: But we deal with students in a wide range, from being very bright to being totally illiterate mathematically. If they take four and divide it by a half, they often get two. This is the kind of thing that they can't deal with but that they will be teaching our children.

Comment: So they can take the math courses and get D's in them in high school and come on to college.

Response: But we have to teach them science in which they have to use math skills. Yet they want to divorce the math skills from science skills completely, although I expect them to be able to work with unit systems and to be able to solve the most complicated equation when given two of three variables. Many students, having very limited skills, find this almost impossible when they start the course; and again, success is a matter of personal commitment. Working on an individual basis enables some of these students to do this quite readily by the end of the course.

If the nation were going to do something about science education, it should be done at the elementary school level first and at the middle school level second because science teaching in the elementary schools is appalling. First of all, there is almost none of it. Second, it is all based on textbooks, rather than hands-on experiences. And third, the teachers are essentially scientifically illiterate themselves and have no competence. This is called the "245" series of science teaching: science is typically scheduled for late afternoon, and then the teacher looks at his or her watch and says, "Oh, my gosh, it's 2:45! I guess I'll have to go now." Even science textbook publishers know about this syndrome.

Comment: Our committee will have to address the pre-college abilities somehow in our report, but what I am concerned about after hearing these enthusiastic "Q" series students is that I did not hear anybody want to do the same thing for secondary school teachers, who are the people we lose in the system.

Response: We lose them in elementary school, the time when their scientific curiosity has a peak. You find that by the time the kids get to middle school, many of them have decided they don't like science, which is not the highest thing on their minds. In the elementary school, the curiosity is there; and, if turned on, it would carry them through middle school and into secondary school science.

Comment: Secondary education majors do not get this wonderful hands-on experience that I see the elementary school teachers getting. I wonder whether we need to do the same thing for secondary school teachers.

Response: Our approach with elementary education majors is unique. I did a survey of the state requirements for elementary school teachers and discovered that 24 states have no science requirements for elementary school teachers--absolutely none. Furthermore, the average elementary school teacher tends to stay away from science and math if given the freedom to take what he or she wants.

Comment: Many go into elementary school teaching for exactly that reason. That is one of the two havens where they don't have to take any science courses.

Response: While they all will take some history or sociology in college, they will avoid science if they can. In fact, even states having science as a requirement for certification in elementary education usually require no more than six hours. Sometimes the requirements say, "Some science required," which may mean two hours. That means that the vast majority of the states are not really requiring any training. We have specialized music teachers, specialized art teachers, and specialized gym teachers; but in science we have kids being taught by people who know nothing and are terrified of what they are teaching.

There is not much science offered here. Now, there are a couple of ways you could go. One is to have more science done by science expert teachers. Another option is to use the pre-service teachers.

But to get back to other points, that doesn't mean that there are not better things we could do for secondary school teachers. The trouble with secondary school teachers, of course, is that they major in a particular science. For example, we have only one or two students enroll in physics education per year, and we can't set up our physics program with so few students. There is a dearth of physics teachers. High schools use part-time teachers--the coach or the math teacher who teaches half math and half physics.

Question: A future report like the White House Report on Science Education but by another committee of the National Academy of Sciences is going to discuss the shambles of high school education. The gap is widening even further there, and I am sure that the staff will emphasize that we have thrown lots of federal money at the elementary school level and will suggest that now is the time to throw more at the high school level.

The Congressmen's perception, I guess, is that we have done an awful lot in education at the elementary level with programs such as

Head Start and Follow Through. Now, based on these other reports, let's see what we can do for high school education. My question is "Can anything be done?"

Response: I am saying, "Not in physics." I am sure that because there are a lot more secondary school biology teachers, more can be done there.

Comment: There was a big push in high school physics during the 1960s in the PSSC and the government projects in physics, the Math Summer Institute and PSNS.

Response: The problem is a lack of standard requirements. For instance, Russia has a national curriculum, mandated by the state; and 98 percent of all Russian citizens, we have now learned, take a couple of years of physics. Only 19 percent of kids in this country take any physics at all. Although theirs is only a 10-year system versus our 12-year system, 98 percent are taking a couple of years of physics courses and two years of calculus.

Now, as long as we are a democracy and have electives--and physics and chemistry are electives--something must be done to get students interested, or we will never get them to enroll in the courses. Although we have 19 percent taking science courses, the rest are going to be scientifically illiterate.

Comment: In high school, physics is the last science course that students take, in 10th grade.

Comment: They need some decent biology, too. Students in Q-201 are biologically illiterate, having had a single high school biology course in 9th grade.

Response: Well, according to governmental statistics last published in 1972, 19 percent took physics that year, but I think the percentages have gone down since then.

Question: What would you think of the status of remedial self-help in physics? Can we get an overview of all the sciences? What do you think the condition is, generally speaking, for non-science majors?

Response: One of the most important things that we did was to institute this requirement in math programs for computer science majors. Staffing it uses a lot of our resources, but we are doing it so that students coming in this year would have to have it.

Comment: Yes, but first-semester freshmen are very impressionable. University division advisors were told to urge these kids to confront their math requirement early. Only the most willful of the freshmen have put off their math requirements.

Comment: The honor students that I counsel are not taking any math. I talk to them about meeting the requirements, but we don't have records on them.

Response: Now, something that we have done as a whole is to drop the laboratory-based science courses for non-science majors.

Comment: Of the number of persons we have been talking to, we have had two law professors who feel the laboratory experience is valuable for a law student.

Response: It is not that there are no laboratory-based courses; we have merely opened up the option of non-laboratory-based courses so that students wanting to avoid labs go off to the non-laboratory courses that last 3 hours instead of those 5-hour ones having labs.

Question: So what do you lose in the process?

Response: In the physics and math, of course, students get problem-solving, which is valuable in itself but different from the laboratory experience.

Question: Do they substitute the demonstrations?

Response: Yes, we do in physics, very much; but the chemistry department here has done a rather poor job of science for non-science majors. The students are not as satisfied with those courses as they are with biology, geology, and geography. We do not know whether this occurs because the courses are particularly good or because the students see them as a way of avoiding the more mathematically-based courses; it probably varies from student to student.

Comment: Some literature on teaching children mathematics suggests that a demonstration, well-done by a teacher in front of them, is as effective as their actually manipulating the materials themselves. I do not know if this theory has been tested by any comparable research among physics students.

Comment: Can you go one step further and have it in a movie?

Comment: No, no. Unless Donald Duck is doing it. There certainly is a point where having an instructor do an experiment ceases to be effective.

Comment: Of course, we are just talking about a demonstration. We are not talking about the problem-solving experiment in the lab.

IMPROVING COLLEGE SCIENCE EDUCATION

Proceedings of a Conference
on Science and the Professions
National Academy of Sciences
Washington, D. C.
December 16, 1980

Summary

The Committee conducted an invitational conference on December 16, 1980, to discuss past and future efforts to improve the undergraduate education of non-specialists in science and technology. The 48 participants included members of the earlier college science commissions as well as others concerned about science education (see Appendix A).*

<u>Theme 1: Learning from the Experience of the College Science Commissions and Other Curriculum Reform Efforts of the 1960s and 1970s.</u> The first session of the conference concentrated on the former commissions, which had developed from earlier studies at the secondary school level, and ways to implement some of their programs after funding from the federal government, primarily through the National Science Foundation, had decreased dramatically. Several advantages of the commissions were cited: they (1) focused on ways to communicate with and to provide some direction to science teachers, providing information about "new concepts in undergraduate education"; (2) acted as intermediaries between university faculties to build a real interest in science education--identifying problems, conducting regional subject-matter conferences regularly each year to promote direct involvement by large numbers of people, acting as information exchanges, and stimulating individuals to begin projects relevant to science education; (3) acted as a catalyst to produce more scientists as a result of "the Sputnik scare"; (4) fostered a greater public understanding of science, publishing materials useful both to science educators and to the public;

*Advisory Council on College Chemistry (AC-3), Commission on College Geography (CCG), Commission on College Physics (CCP), Commission on Education in Agriculture and Natural Resources (CEANAR), Council on Education in the Geological Sciences (CEGS), Commission on Engineering Education (CEE), Commission on Undergraduate Education in the Biological Sciences (CUEBS), and Committee on the Undergraduate Program in Mathematics (CUPM).

(5) promoted cross-disciplinary activity; and (6) assembled distinguished people in a particular scientific field "to discuss issues and make recommendations that might have been avoided if this opportunity had not been given."

Conference participants noted that the commissions were not without problems, however. Among those discussed were (1) the lack of direction evident in the activities of some commissions, (2) the lack of strong professional societies with which some commissions could work, (3) the feeling that some commissions were elitist because programs that they advocated could be implemented only at a few schools, (4) a productivity rate lower than expected by educators within some fields, and (5) insufficient time to complete projects.

Nonetheless, speakers felt that the federal government's reduced funding of education activities such as the commissions had had negative results, for the most part. For instance, innovative activities have not been sustained because many professional societies often lack the necessary funds or the incentive to sponsor such functions as interdisciplinary meetings at which many science educators can discuss important questions. Another result has been a lack of communication among science educators: worthwhile projects at one school are often unknown by faculties at others.

As a result, the participants felt that activities such as those of the college science commissions of the 1960s need to be implemented --perhaps by a single "umbrella" commission operated through the Council of Scientific Society Presidents, the American Association for the Advancement of Science, the National Research Council, or the National Academy of Sciences and providing strong interdisciplinary links. It could be designed in such a way that scientists interested in education would work with teaching scientists to stimulate innovative activity, for as one participant noted, "Those of us who teach also need rejuvenation that comes from participating with those people whose primary concern is the extension of knowledge." In addition, such a grouping together of different specialty areas would be expected to save time, effort, and money for the participating societies.

Theme 2: Examples of Development in Science and Engineering and Their Implication for Undergraduate Science for the Non-Specialist. This session dealt with three basic questions: (1) Is the scientific community's concern great enough to promote constructive activity? (2) Is the education of non-specialists improving or getting worse? (3) How could the federal government promote improvements in the science education of non-specialists?

In response to the first question, several currriculum developments were mentioned, including the following: the Chautauqua Short Course Program for college science teachers that developed such programs as "Science, the Media and the Public"; biology programs tailored to the needs of students in the various types of college; non-traditional science courses dealing with energy, the environment, communications, and transportation; cooperation of geoscientists with social studies teachers to discuss such resource and environmental problems as the shortage of minerals; NSF's Chemstudy Program and the Chemical

Bond Approach that led to new materials as well as summer institutes designed to familiarize teachers with them; and physics courses for non-specialists taught by the historical case method.

However, the participants concluded that these developments were insufficient to meet the needs of non-specialists and that several problems had arisen:

1. In engineering, tremendous pressure had been placed on institutions to prepare engineers, so that not enough time existed for attending to the education of non-specialists.

2. In physics few non-specialists took the courses designed specifically for them so that they had to flounder along in courses designed for physics majors after the special topics courses were dropped from the curriculum.

3. In many science departments, courses developed by one professor are not continued by others when that teacher no longer teaches them.

4. Elementary school teachers are given inadequate preparation in the sciences.

5. Worthwhile new projects are not used in the schools because teachers are often afraid of the unfamiliar or are incapable of implementing new materials.

6. A lack of knowledge of already-developed curricular materials leads to duplicative effort.

7. Often, after projects have been developed with federal funds, there is no money left to promote their implementation.

8. Undergraduates planning to become secondary school science teachers seem to be controlled by the faculties of the education departments, with faculties of the science departments having little input into their education. This is also true as far as admission into science programs is concerned.

9. The job market for science majors is better in industry than in the school system.

One participant felt the problems of undergraduate science education had their basis in the "very few outstanding educators, outstanding teachers, and curriculum innovators. Of that group only a subset is concerned about undergraduate education. Of that group an even smaller subset is concerned about education of non-science majors."

Much of the discussion then centered on what needs to be done to promote undergraduate science education of non-specialists. Among the several actions proposed were (1) to appeal to vocational education because learning more about science and mathematics is necessary for one to earn a living, (2) to compile for science educators a list of available, but less well known, science materials and curricula, (3) to provide means for making curricula portable, (4) to concentrate on the capabilities of the computer and on the necessity for one to become familiar with advanced technology, (5) to emphasize the potential contributions of science historians to the science education of non-specialists, (6) to recognize the importance of television in the teaching of science, and (7) to increase the monetary incentive for teachers to participate in activities such as summer institutes in science. In addition, participants felt that steps should be taken to make faculty members more enthusiastic about innovative materials and to encourage untenured college professors to devote time to curriculum development by recognizing their contributions.

<u>Theme 3: The Role of Undergraduate Science Education in the Preparation of Non-Specialists for Professional Careers.</u> The gist of this session was that science courses are not preparing non-specialists adequately for later work assignments, mainly because of the "mismatch" between curricular materials and the reasoning abilities of the students with whom they are used. It was noted that "at the college and university level, we are taking material that requires abstract logical reasoning of various kinds . . . without any attention paid to the fact that the recipients of the material do not execute these processes of reasoning." Speakers said that in mathematics, chemistry, and biology programs, little effort has been made to help students to distinguish between observation and inference or to develop their deficient deductive reasoning powers. Instead, students have merely been expected to possess capabilities that are beyond them. Several speakers felt that science faculty, familiar with programs that develop abstract reasoning abilities (perhaps in some of the Chautauqua Short Courses), could help students to expand their abilities by relating scientific principles to real-world situations or by relating policy issues to underlying topics of science.

To help students to understand technology and its scientific aspects, as well as its relevance to their professions, other suggestions included (1) implementation of a science course that would concentrate on systems rather than on particular disciplines, (2) improved methods for teaching the courses now presented, (3) promotion of research that would determine student misconceptions about science in order to dispel them in course materials, and (4) interdisciplinary attempts to deal with scientific topics. In conclusion, the speakers felt that undergraduate science education should develop clear-headed thinkers having the ability to read about the unfamiliar in order to understand it as well as the capability of unraveling today's "highly complicated, interdisciplinary issues involving politics, economics, technology, science, human nature--absolutely everything. . . . If they have the experience once in confronting a very complex systems problem and penetrating it a bit, they might have the courage at another stage in life to confront another issue.

Theme 4: Revitalizing Undergraduate Science Education for Non-Specialists: The Next Step. One speaker suggested to the participants that they "find those areas where the federal government could appropriately and artfully support the improved quality of learning related to those kinds of things that need to be learned." He explained that the Department of Education was attempting to address problems in undergraduate science education by conducting regional conferences that would invite citizens, scientists, and members of the professions to examine the issues from the standpoint of their particular region and by promoting the forming of a national commission to deal with the quality of pre-college science and mathematics education, which ultimately determines the quality of undergraduate instruction in those two disciplines.

Once again, participants offered several suggestions. Among the 4eans for revitalizing undergraduate science education for non-specialists, the following were discussed: (1) establishment of a multidisciplinary commission working with the professional societies, rather than the many college commissions of the 1960s, and (2) greater funding by the federal government of programs such as the Chautauqua Short Courses, teacher institutes, curriculum development projects, and demonstration projects; subsidies for laboratory equipment; and research in the kinds of science and technology needed by people in the professions. Participants realized that the situation is becoming critical but that federal funding is limited, so that individuals, department chairmen, and faculties may need to seek other kinds of support for these projects.

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Participants

Speakers

Arnold Arons, Department of Physics, University of Washington
Henry A. Bent, Department of Chemistry, North Carolina State University
Donald Bushaw, Department of Mathematics, Washington State University
Homer Folks, College of Agriculture, University of Missouri
Edward A. Friedman, Dean of the College, Stevens Institute of Technology
Arthur H. Livermore, American Association for the Advancement of Science
William H. Matthews III, American Geophysical Institute, Lamar University
Martin Schein, Department of Biology, West Virginia University
Arnold Strassenburg, American Association of Physics Teachers, SUNY at Stony Brook

John G. Truxal, College of Engineering, SUNY at Stony Brook
Harold Winters, Department of Geography, Michigan State University
Gail S. Young, Department of Mathematics, Case Western Reserve University

Invited Observers
American Anthropological Association: Thelma Baker
American Chemical Society: Janet Boese
American Geological Institute: A. G. Unklesbay
American Psychological Association: L. Kaplinski, Kathy Lowman
American Sociological Association: Lawrence J. Rhoades
Association of American Colleges: Mark Curtis
Association of American Geographers: Sam Natoli
Department of Education: James Rutherford
Federation of American Societies for Experimental Biology: Robert W. Krauss
Institute of Medicine: Karl Yordy
Mathematical Association of America: A. B. Willcox
National Academy of Engineering: Randolph W. King
National Research Council: J. F. Blackburn, Catherine Iino, William Kelly, Samuel McKee, William Spindel, Russell B. Stevens
National Science Foundation: Alfred Borg, Alphonse Buccino, Rita Peterson

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Introduction

Dr. Gray introduced Dr. Crane as chairman of the workshop, noting that he has been involved in science education for many years at the University of Michigan and in the work of the Commission on Physics in the 1960s.

DR. CRANE: As you know, during the 1960s a great deal of support was given to the development of curriculum and all kinds of educational aids, mainly stimulated by the College Commissions. However, near the end of the 1960s, that support decreased very substantially, reaching its current low level. The mission of the committee is in two parts: (1) to re-examine what was accomplished in the '60s, when there was a great deal of support, to see if promising activities cut off for the lack of funds deserve to be revived and carried further; and to determine whether the support of science at that time was good--in other words, to do a little post mortem and see what ought to be preserved from that period; and (2) to recommend, if possible, what the future federal role of support should be. We could decide that these earlier activities addressed the problems existing at that time and did a good job of improving education according to those problems. That does not mean that no new problems exist: therefore, our mission is not just to find out what things should be revived but to find out what is different now and what new things might be addressed.

DR. BUCCINO: My office at NSF is administratively connected with this project, but other representatives from the Foundation perhaps have deeper thoughts on this subject than I do. This study was Academy-initiated, and under the circumstances I would suggest that the appropriate demeanor for NSF personnel is to listen more than to talk.

I would make a couple of observations. At NSF, we believe that the main concern of science education has traditionally been with the specialist; for the past 20 years activities for non-specialists have never really been crystallized in terms of our priorities. Science education for the specialist and the non-specialist tend to mix in all of our programs. For example, in the audit program are activities of both types. On the other hand, because there may be new needs in this area, certainly education of non-specialists is a timely topic to be examined.

The second observation, an objective statement of fact, is that the question of priorities is very important because the very tight budget means increases overall will not exist for some time and any increase in one section will be accompanied by a decrease somewhere else. Thus, the question of priorities in pure budgetary terms is a very interesting one.

Related to that are the purposes of science education for the non-specialist. One is the utilitarian category, which is cognizant of certain aspects of science and technology, particularly the cultural. An important intellectual development has to occur that education can contribute to; and for some broad cultural purposes, science is important to consider. Also, the cultural purpose does not have high priority with reference to government funding: not considered important, it may be considered a frill, and there is some question about what the proper federal role is. As an aside to this, at an interesting meeting of 250 or so deans, half of them from engineering and half from business, the general subject of technology management emerged. The idea there was that business people, finance people, marketing people, and lawyers have significant roles in technological industry and need to know more about the technological side of the business while technological people need to know more about the business aspect of technology management. That suggested to me that indeed some new issues relating to the utilitarian aspect of science and technology education for non-specialists may have arisen in the last few years.

DR. CRANE: I have been very concerned about how we might implement something if we decide it ought to be done. If we decided how teachers ought to teach science, what science students ought to take, what curriculum committees ought to decide about distribution courses, what deans ought to do with their money and so on, we would be almost wasting our breath. These people are very refractory when anybody tries to advise them what to do. If this committee reveals new problems in the education of non-specialists, then the National Science Foundation and other agencies might gladly encourage applications in those areas, possibly announce programs, and in many ways encourage people from the grassroots to start projects and apply for support. That is the mechanism, not jawboning the teachers, by which our ideas can be fed into universities and other educational institutions.

The situation is a little different now than it was in the 1960s, when the large complex of commissions involved a great many of the teaching faculty all over the country, providing a mechanism by which ideas could be propagated down into the faculties. Now, we lack that large complex and the pipeline from the top down to the active faculty.

Theme 1

Learning from the Experience of the College Science Commissions and Other Curriculum Reform Efforts of the 1960s and 1970s

DR. CRANE: Our main concern is that the commissions, a very large activity at the time, in many ways were a good mechanism for developing science courses for undergraduates. Granting that something needs to be done for the non-science student at the present time, the main question is whether the system of the commissions is an effective one through which to work.

DR. BUCCINO: About 1970, priorities in science education and budget cuts were reexamined, the consensus being that the commissions had somewhat run their course. From an administrative point of view, one difficulty with them was that they appeared to be sustained, more or less, by indefinite support. Many of their projects were very good, but NSF had supported them for quite a while, and the principle that NSF does not continue sustaining indefinitely was a significant factor in its decision to cut back. Not many of the commissions have continued, although one or two have continued with reduced activities as a result of reduced funding.

DR. STRASSENBURG: I was a staff member of the Commission on College Physics (CCP) for two years and later, as an employee of the American Institute of Physics (AIP) and the American Association of Physics Teachers (AAPT), cooperated with the Commission in order to transfer some of its ongoing activities into a framework that could continue.

The commissions all operated on the same pattern. A number of eminent educators in a particular discipline were elected to its commission (there were 17 commissioners on the Physics Commission). Then each commission developed a staff (for instance, the CCP started with one executive officer back in 1960; but by the time it ceased to operate in 1971, it had a staff of six physicists and an equal number of secretaries). They met approximately four times a year to discuss an agenda of problems. (The CCP sometimes focused on the problems of two-year colleges, sometimes concerns for upper-division work at four-year colleges, and sometimes concerns for graduate education.) Sometimes a commission focused on mechanisms of presenting information, such as greater use of audiovisual aids and computers in science education. Sometimes it focused on problems of communication--how to communicate the problems to college teachers, possible solutions for them, and ongoing activities that they might take advantage of. The commissions were reasonably well-funded by the federal government--several hundred thousand dollars a year, varying perhaps from discipline to discipline. This money was used to support the meetings of the commissioners, various subject matter conferences two to four times a year, and then some sustained activity undertaken to improve communication channels. Using large mailing lists, we sent newsletters fairly frequently to thousands of physics teachers across the country, stimulating ideas for ways to attack problems filtering down from the commissioners through the staff to individual college teachers.

One example of a continuing activity undertaken by the CCP was the film repository. They encouraged physics instructors who were making films on their own campuses primarily to interest their students. Although these films did not have a commercially viable market, the commission would acquire the film creator's permission to reproduce and distribute them, then undertaking a marketing and advertising operation. Today this activity, under the aegis of the American Association of Physics Teachers, makes the creative output of college physicists--films used in anywhere from 10 to 200 places across the country--available at costs generally lower than they would be from a commercial operator.

DR. CRANE: With a few exceptions, the commissions operated as intermediaries. They did not undertake the development of curriculum themselves; but they successfully identified problems, conducted conferences, acted as information exchanges, and stimulated either their own members or members of other institutions to propose contracts to the NSF and start projects under independent contract. Also at the beginning, they were dedicated to producing more scientists because of the Sputnik scare and the prevailing feeling that we must increase our scientific manpower. They benefited to the extent that they were able to attract top educators as well as research people because of this high pitch of feeling that science ought to be improved. Only in later years of the commissions did the interest drift toward the non-science student: during the last few years of its existence, the Commission on College Physics spent a good deal of its effort on the non-science student.

DR. HARVEY: At the time of their demise in 1971, was there a feeling that programs of real value were being lost, not being spun off into the professional associations?

DR. YOUNG: Absolutely, for mathematics. I was President of the Mathematics Association of America (MAA) at the time of the ending, and we at least did not die a natural death: we died kicking and screaming. At the time we were working on problems of mathematics education for minorities, women, the junior college--all things which have been neglected completely since then. The massive implementation and education objectives that we had carried forth simply were lost.

DR. SCHEIN: I was with the Biology Commission as a commissioner when it started, following it not quite to its demise, but I was afraid that when I left (we had a fixed three-year term), the commission would have its throat cut; and it died, as Gail [Young] says, kicking and screaming.

The real failure with the Biology Commission, almost from the outset, was not knowing what we were supposed to do. We did hope to revitalize education in biology, and we started right away with biology for the non-major as one of our main panels. But a big item on our agenda, really a kick in the teeth, was to plan when we would go out of business. We hadn't started yet, but we had to put a time limit on ourselves. Many of the commissioners fought against it; but the story is that NSF can't stand something that works, and we felt we had really worked.

Unlike Mathematics, Biology had a very difficult job in that we didn't have (we still don't have) a professional organization strong enough to handle our programs. A hidden agenda for the Biology Commission for many years was to become strong so that we could vitalize the professional organization and then move our program into it. Unfortunately, the demise of the commission was much too abrupt: programs were moved into the professional organization, but within a year both the programs and the professional organization were reasonably dead. If we had had a few more years, we might have done quite a bit more.

DR. MATTHEWS: In 1964 Geostudy, based first at Baylor University, evolved into the Council on Education in Geological Sciences, which went to Stanford and then returned to Washington under the aegis of the American Geological Institute. We felt, too, that we didn't have enough time; but, although I can certainly understand NSF's position that these things just can't go on in perpetuity, we were just beginning to make some strides. We produced a great deal of material and were beginning to deal with public information aspects, which today would be very useful in view of the potentially severe strategic metals shortage. A public understanding of such things as Mt. St. Helens and earthquake prediction is needed, and we were just beginning to move into that area of public understanding when funding was reduced and eventually eliminated. Nonetheless, a large amount of materials were produced and published in the Journal of Geological Education of the National Association of Geology Teachers; and when I wrote the program's final report, I realized that we had made a much greater impact than even I had thought.

DR. TRUXAL: As a member of the Engineering Commission, I feel these commissions were basically formed as end-runs around the professional societies--homeostatic organizations that didn't do very much--as a vehicle to get things moving. When the commissions died, scientific and professional societies by and large didn't do very much to carry the ball. Is that a fair statement?

DR. SCHEIN: For biology, that's correct. The two biology societies were sort of competing; and because neither one of them was terribly interested in science education, the commission filled the gap, trying to build a real interest in science education within them. We tried to create an education group there; and at the termination of the commission, as a matter of fact, one society took over some of the commission's activities and even published a professional journal for almost a year.

DR. STRASSENBURG: That same issue in the physics profession had a slightly different perspective. Quite a large number of physics educators were happy to see the transition take place, probably because the commission was perceived as being elitist by many physics educators since many of the advocated programs could only be implemented at affluent institutions. That isn't the perception that the commission wanted to project, but nevertheless it was very common in the physics community.

A very serious effort was made to assume some of the commission's activities, but it has not been accomplished exactly: the innovative activity of the commission simply has not been sustained. Being a membership organization, AAPT must be responsive to a very diverse audience. A large percentage of members pay dues primarily to get the journals, not to see large fractions of their money spent on innovative activity, and the result of that is a lack of such programs.

DR. BUSHAW: In mathematics the situation was not as you have suggested. The commission also functioned as a committee of the MAA, where it still has several projects; but clearly it cannot do many things for lack of funds. For example, it cannot organize the large conferences that seemed feasible ten years ago.

DR. CRANE: Arnie has discussed the transition period at the end of the commissions. I might say a word about the beginning and the reason for the formation. An "end-run" would imply that somebody was blocking their way, but I don't think that was the case. In reality, the societies were in no position to receive government funding, but the possibility that the National Science Foundation would finance the commissions was a different ball game. In that sense it was not really an end-run defense, but rather a new mechanism made available to the societies.

DR. SCHEIN: In biology this couldn't happen because at that time biology was in a rather embarrassing financial situation with the government.

DR. MATTHEWS: The American Geological Institute is an umbrella organization representing 18 different societies from the Geological Society of America (basically academic research-oriented) to the American Association of Geologists. There was no "end-run" there: we had complete support because we were the one body that could represent the entire geoscience community.

DR. FOLKS: The Commission on Education in Agriculture and Natural Resources (CEANR) was similar in structure to the geology commission, in that a diversity of interests needed to be represented. This commission provided a convenient and important umbrella that brought the issues to focus and did, in fact, publish some very important documents that have continued to provide some direction. But those of us sitting out in the "boonies" felt that much more could have been done had we had a little more time to bring to full realization what some of these documents really meant. However, when CEANR disbanded, we expected everyone to pick up the publication relating specifically to his interest. The result was a lack of an integrating force, a real focal point that caused the changes that should have occurred.

DR. SCHEIN: One of the very interesting developments with the commissions is the way that they worked on a lot of cross-disciplinary activity.

DR. BENT: The Chemistry Commission had some distinctive qualities: the chemists didn't call themselves a commission but, rather, AC-3 (Advisory Council on College Chemistry). However, much of what has been said about the other commissions holds for AC-3. It was viewed as elitist by some who, therefore, were not too disappointed when it expired. Nonetheless, it did publish some useful materials, although many would have been published anyway, and was an appropriate idea for its time. I was always a little uncomfortable with the Advisory Council for the very reason of its strength--namely that it served as an intermediary and that good people working there weren't as productive as I thought they would be if they were doing things other than expediting other people doing things. That is, when the commission eventually died, then I thought they really began to do their best work again. Starting over, they wouldn't have done differently--it was a natural direction to go--but for me it would be an unnatural direction to continue.

DR. HARRISON: I had very limited contact with AC-3, since as far as I know no women were invited to participate in any of their affairs. I was invited to one rather innocuous conference, but at the same time, I was coming into a leadership role in the American Chemical Society's Division of Chemical Education. There were some problems because, in a sense, we had two groups that would draw from the same people, interest, commitment, and so forth--one which had money and the other which did not--and that made the leadership role within the American Chemical Society, quite frankly, difficult.

When the commissions phased out, the American Chemical Society made every effort to pick up as much as it could with absolutely good intent. One of the programs, for example, had to do with the visiting scientists--the consulting service--and the strength of those programs has grown extensively both in the Division of Chemical Education (a membership group) and the Office of Chemical Education (a department in the national structure of the administration).

DR. WINTERS: The Geography Commission, early on, got involved in some publication programs; and as they evolved, they provided more information about new concepts in undergraduate instruction. Those were well received and continue today. Thus, commission activity was a catalyst that really helped our undergraduate instruction program, and the big loss is this lack of opportunity for innovation, which--while not very efficient--can be quite exciting. Our profession really misses that opportunity.

DR. BUSHAW: The Mathematics Commission, and I suspect it wasn't the only one, had as one of its strong points the direct involvement of a large number of people: some 300 very good mathematicians with various professional backgrounds were not merely expediting things, but were meeting to discuss issues and make recommendations that might have been lost if this opportunity had not been given them. And, as has been suggested, having had this experience, many of them continued to take initiatives in the area of innovation and evaluation, having calculable effects. One thing missed is simply having the resources to bring people together in those numbers to discuss these very important questions.

DR. ALDRIDGE: I don't know how long it takes a commission to reach the stage where after-effects will occur, but I would like to cite some evidence in the case of the Commission on College Physics. The director of that commission has been involved in more than a million and a half dollars in funded projects at my office since he left the commission. He currently is involved with Bob Tinker's project involving computers in education and the concept of the instrumented laboratory. In addition, I was a director of a million-dollar project that arose as a direct consequence of a brief, two-day meeting of the commission; it produced materials used throughout the country. Similarly, bringing together competent people who represent properly a discipline and its teaching generates this kind of activity with existing sources of support.

DR. YOUNG: Since the late 1960s, our organizations [in mathematics] have grown hardly at all, although there has been at least a 50 percent increase in the population. Raising dues is very much counterproductive. Thus, we have no very large sources of income other than book sales, and they have decreased. If we hired one full-time competent professional to work on this, we would have to raise dues $2.00. If we also hire a secretary and pay for an office and a telephone (and don't let him or her leave Washington), the expense is tremendous. We do not even reimburse speakers at our professional society meetings for their travel expenses. Therefore, we can't hold interdisciplinary meetings because when somebody has to go to the other person's meeting, the money has to come from somewhere. I can get money from my department to go to the math meeting; but I can't even ask to go to the biologists' meeting, and vice versa.

DR. KELLY: No one has mentioned yet what was going on at the secondary level at the same time, and it's very important to keep that in mind. In fact, the commissions on college science were an outgrowth of, or a part of, the earlier studies at the secondary school level. Many of the same individuals were involved; and conceptually, this is regarded as a wave of reform that started at the secondary level, went back to the elementary level, and then up to the colleges. When thinking about education of the non-specialist, one must remember that there was some recognition of the continuity required in education. After all, many of the people being educated in the secondary schools were going on to college, and the commissions at the college level weren't ignorant of their needs. In physics a concern for the education of public school teachers led to good efforts to improve their college education. Some recent reports have pointed to a continued need for that. We need to integrate so that the people at the secondary level talk to the people at the college level and vice versa.

DR. CRANE: When the commissions were created, the focus was on producing scientists. The charge of this committee is on educating the non-scientist. We want to think about the usefulness of the commissions' ideas in terms of the non-scientist, whether they can be a useful mechanism and what the alternatives are--whether, for example, the professional societies can do as well or better. In other words, this committee is looking for some indication as to whether commissions are a good mechanism to pursue.

DR. SCHEIN: As I look at one of the Biology Commission's final reports, if the commissions were to start again instantly, there are only two of the eighteen panels that would not be activated right now in view of your emphasis on the non-scientist: pre-preparation for the medical sciences and the agricultural sciences. All of our other panels deal with the non-scientist in some way; in fact, one very interesting thing started was "Biology for the Non-Major." When commissioners talked about the biology that non-biologists get, they played a few scenarios of the training and background that the non-scientist should get and discovered that they wanted it to be the same as the education of science-oriented students--whether they are going to medicine or agriculture or professional research.

Towards the later years of the commission, we abolished the idea of a biology for non-majors as opposed to a biology for majors. We talked about biology and how to persuade the working public and people that we had contacted that a biology course organized primarily for the non-major would be the best service to do for the major. When you talk about reactivating the commissions, don't emphasize the non-major alone; what happens for the non-major affects the program for the majors as well as the preparation of biologists in general.

DR. BENT: Science is hard. You can't make it too easy; and if you try to reach out to those people who seem to be having the most difficulty with it, you end up with something that is very useful for everybody. In our own schools, we have a program in science for the non-scientist, and you have to do things differently. We discovered in the School of Education that programs designed for these particular students are now exceedingly useful.

DR. LIVERMORE: Bill Kelly made a very important point when he said that the college commissions had not taken full advantage of, or had not considered fully, what had been done at the high school level. Whatever is done as a result of this meeting and other activities of the committee, full consideration should be given to what is going on at the high school level because of its tremendous effect on the science education of non-specialists at the college level. As things stand now, most high school students take no science beyond tenth-grade biology. The low numbers of students in chemistry (40 to 50 percent) and in physics (an even smaller percent) have an impact on what the non-specialist science program is going to be like at the college level.

DR. CRANE: Whether to consider science education in a new light is an appropriate action for the committee that is responding to the White House directive.

DR. ALDRIDGE: There is not much chance, based on what I have heard recently, that funds would be made available to create the kinds of commissions with the kinds of budgets which existed previously. However, the structure of NSTA, my own organization--as well as some of the scientific discipline organizations--provides for committees charged with specific responsibilities regarding science education, its problem areas, and areas of opportunity. Their problem, of course, is inadequate funding. As a model, one might create a joint committee between a society like AAPT and the American Physical Society, with scientists interested in education working with teaching scientists, and provide modest support for that kind of activity. Lacking the heavy cost associated with the staff support, the overhead, the facilities and so forth, a model of that type might be possible if it also contained a clear mechanism for phasing that function into the organizations.

DR. CRANE: Are you saying that the mechanism of funding for this type of activity might better be through the societies?

DR. ALDRIDGE: Yes, jointly among the societies of a given discipline such as the American Physical Society and the American Association of Physics Teachers.

DR. WILCOX: Now Executive Director of MAA, I was at one time a member of the Commission on the Undergraduate Program in Mathematics (CUPM) and served on its staff for a while in the 1960s. The question perhaps --at least from the point of view of mathematics--is not so much whether the commission can be revived but whether it is important for the commission to be revived. CUPM, for instance, still exists as a standing committee of the MAA; and I believe that our experience in mathematics is a good laboratory experiment along the lines that Bill was suggesting. In fact, many of the activities of CUPM during its heyday were spun off into other committees of the Association; CUPM still has many of its original panels, at least one of which got a small grant from the Sloan Foundation and will very shortly issue a set of recommendations very much like, at least in style and structure, those produced by the commission during the 1960s.

DR. GRAY: Is it possible--in light of the structure, politics, and psychological atmosphere within the societies--to engage in cross-disciplinary efforts concerning the non-specialist and secondary education? For example, with tightened budgets and tightened restrictions on tenure and promotion, are the societies becoming more focused inward, looking to the society as the place for having papers read and research recognized? Does that cut back on the kind of outreach that the commissions had, and is it possible to do that within the societies in light of these new trends?

DR. BUSHAW: In mathematics, yes.

DR. YOUNG: Certainly mathematics is more outward-looking now than it has been in my whole professional life.

DR. HARRISON: The American Chemical Society is clearly more outward-looking in that the chemical profession finds itself in a position of fantastic capabilities and tremendous social responsibility, and we have to reach out.

What I hear in the discussion here is a limitation on the ability to convene, and my experience is that remarkable people will gladly donate their time at considerable sacrifice. They will meet on weekends and they will travel all night, as long as they don't have to pay out-of-pocket expenses. Coupled with that is the need for some kind of glue that holds the thing together, an office. Now in the terms of the American Chemical Society, that capability is there. But how long we can continue to support it financially without really killing a dedicated staff, goodness only knows. But it is of necessity to convene.

DR. TRUXAL: This desirability of a new structure for commissions is preferably tied in with the scientific or professional societies. It is really essential because, even though the societies and the senior chemists may be interested in social responsibility, the young faculty who are creative and imaginative can't afford to be, unless we can give them professional and scientific stature by such contributions. Professional societies are a long-standing structure which can do that. I can't picture any sane assistant or associate professor on our faculty developing a course for non-majors unless his or her scientific and professional society will really get behind this effort and push it.

DR. HOPKINS: That may be true, but one of the most important influences of the commissions was a very subtle one, providing high visibility for distinguished people in the field to people out in the boondocks. Seeing--at least in my own case, I was just out of graduate school when the commissions came into being--distinguished researchers concerned about teaching and doing something about it provided role models for a lot of us at that age. I am not sure that the professional biology organizations really have that kind of dynamic character evidenced by these commissions of distinguished people who were solving problems and working hard at that particular point. They weren't the professional guys who made their living at a professional society; they were people who saw being busy in lab as equally important.

DR. CRANE: Innovation has been the question--that is, whether the societies can provide the same innovation provided by a commission. The point about communication with the faculty has been raised: the commissions formed a bridge, a link to the faculties at the universities, which seems to be missing to some extent today. And the question of the ability of societies to have cross-disciplinary activities has been raised.

On the other side of the ledger, societies hold regular meetings, a very convenient way to bring lots of people together to hear talks on teaching innovations and to ensure a much larger participation. The societies have longevity, can plan far ahead, and carry on long-term work; but the commissions are always in fear of being closed out. So far the societies have not been funded for that work in the same way the commissions were in the 1960s, but that is a question beyond our control.

DR. SCHEIN: Frankly, during its tenure the Biology Commission had involved more biologists around the country than the societies had because we specifically pushed for regional meetings at least twice yearly for people who would not necessarily have gone to the society meetings that often were too far away. In fact, from a meeting aspect, this is a commission plus and maybe a society minus.

DR. ARONS: It is, in some societies, the reverse: AAPT and APS both carry on activity in teaching development, and they have large audiences at their meetings.

DR. HARRISON: We have regular, well-established, regional meetings.

DR. ARONS: Physics has both--not regional, but sub-discipline meetings.

DR. HARRISON: There is a limit to the time you want to devote to doing the work of a commission, not in that structure but in the activities that will pull people away from also participating in the science meetings. Those of us who teach also need rejuvenation that comes from participating with those people whose primary concern is the extension of knowledge. You can use the national meetings, but you could overuse them to the extent of defeating what you want to accomplish.

DR. STRASSENBURG: Commission-type activities that involve conferences trying to stimulate new innovative activity and funded by some agency would be very appropriate; we do not have enough of them now, but they could very profitably take advantage of the framework of the societies. I don't find this incompatible at all.

DR. WINTERS: I agree that the reestablishment of the commissions would be marvelous; we could get back to the innovative work that they have done. But I don't see any reason why it couldn't go through our associations, which haven't really tried such work that much. We have the experience of the commissions to fall back on; if we could relate the best of that to developments in our various associations, there is a lot of potential.

DR. FOLKS: Commission work and professional societies are compatible. However, you can do some things through a commission structure which may be virtually impossible through a professional society, and I would opt for a commission structure along with a professional society. I have some problems in terms of going only through professional societies for implementation of what we might need to consider.

DR. ALDRIDGE: The kind of support that I have described would improve substantially your ability to attract very good people to those committees. The other very important point is that you already do have an umbrella organization which would provide the necessary opportunity to communicate--the Council of Scientific Society Presidents. Essentially all of these organizations are currently members of that society, which does include the education components as well as the scientific discipline.

DR. FRIEDMAN: There are approximately 300 accredited colleges of engineering in the United States, while there are about 3,000 colleges and universities. Therefore, in order to promote the technology education of the engineering schools, some mechanism for linkage to all the other areas of education that do not have engineering colleges is needed other than work through the professional societies because the engineers have to be in contact with a broader segment of the educational community.

DR. LIVERMORE: That is a very important point. When we think about science education for non-specialists, we have to be particularly concerned with interdisciplinary activity. Whatever structure is set up to deal with this problem should provide for strong interdisciplinary links.

DR. WILEY: Given the fact that resources are quite limited now--and as Al Buccino said, they might have to be reallocated from other areas in order to engage in any kind of activity--would another kind of less expensive commission be an appropriate alternative to the activities that occurred in the 1960s? Perhaps something that would capitalize on the last few comments about the interdisciplinary character of undergraduate education for non-scientists? Would it be feasible to establish a single commission which might only cost $200,000 or $300,000 a year to integrate the disciplinary areas and treat the issue of undergraduate education in ways that linked to improvements in undergraduate education for scientists? With the limited funds available, it seems impossible to proliferate large numbers of commissions, and tne question would be "Is the social organization of the scientific fields such that one could profitably create an interdisciplinary commission mechanism that would serve any kind of valid function for the money invested?"

DR. YOUNG: I have been wanting to say something on alternative methods. Since the demise of the commissions, NSF has contributed a fair amount of money to mathematics education at the collegiate level. The projects are worthy, but what the money bought was improvement at only one school or a couple of schools in a state; it did not affect the whole community. Two other programs involving technical questions of master's degrees in mathematics got attention almost just because of that. We just don't hear about new programs for the non-mathematician. Most of the money that was being spent was on propaganda; and too much of it won't work.

DR. MATTHEWS: The geoscience community would be very much like the physicists at NSTA, inasmuch as AGI is an umbrella organization; and even within our own discipline, quite a bit of interdisciplinary action has to take place because we are different breeds of cats in many different respects. We could operate very nicely again, but the basic problem is where to get the money to do it. If we had the funding, we could carry those things out.

DR. SCHEIN: Speaking for biology, I am very much in favor of restarting a commission-type organization or some sort of commission activity in the biological sciences; but unhappily for us, we cannot follow the model established by physics or math. We cannot operate in a professional society, for we have no professional society, really. However, by establishing a commission or some similar operation, we could in fact pick up where we left off a few years ago and--perhaps in time by working slowly with the professional society--build it to the point where it can eventually take over the operation of the commission.

I am further intrigued by the idea of saving money by grouping the disciplines into one office with one set of overheads and shared resources. We were moving toward that, talking about it even casually, when we put out this common document on the college commissions in 1967. At the time, sharing an office or sharing resources seemed to be a little too far-fetched because the commissions were geographically spread; but if it were to start de novo, a great deal of time, effort, and money could be saved by one organization, one grouping together of the different specialty areas. There would be an awful lot of profiting from each other's experiences if such were the case.

DR. BUSHAW: The original funding format for the commissions was a large, umbrella sort of grant for a period of a year or so, and a great deal of discretion was left to the commissions about how this could be used. Then, toward the end of the commission era, we were told that funding from the Foundation would continue if the commissions would submit separate proposals for well-designed projects. Our impression was that the policy that led to the dissolution of general support for the commissions also led to attaching priority to the separate proposals; and in our case, the funding issue was not very bright. But one might consider some sort of a project-to-project funding system as a middle ground between the old system and now.

DR. HARRISON: The board of AAAS has recently made a very strong commitment to addressing science education, including science education for the non-specialist. That organization has developed well its capabilities to convene. It is an umbrella organization to which, I suspect, most of the professional societies mentioned here are in fact affiliated, and I would hope that one would look to the capabilities of that organization to supply some of the things necessary in the interdisciplinary interaction. The most successful and perhaps the best-known activity of the AAAS has been the Chautauqua Program, which has in fact been supported by funds from the National Science Foundation; and the nature of those Chautauqua programs indicates its interest in interdisciplinary fields.

DR. TRUXAL: You ought to consider the AAAS, the National Research Council, or the National Academy of Sciences as a base for a single commission having multidisciplinary responsibilities.

DR. CRANE: This set of opinions seems to fall into two groups. Some societies are monolithic or have an umbrella structure, and most of the comments from persons speaking about that type of society have been in favor of the societies doing the job. Where societies are fragmented, the problem is much more difficult.

Theme 2

Examples of Development in Science and Engineering and Their Implication for Undergraduate Science for the Non-Specialist

DR. LIVERMORE: Returning to what John Truxal said earlier--I think he said assistant professors would be crazy to spend a lot of time on curriculum development--I feel that the general attitude of scientists, particularly young scientists, is that they have to get on with their research and therefore don't have time to spend on undergraduate education for non-specialists.

There is, however, some indication of growing interest by the younger scientists in interdisciplinary activities. We have the Chautauqua Short Course Program, operating for college teachers for about 10 years. Most of the teachers coming to the courses are fairly young, in their thirties and forties, and many of the courses are interdisciplinary. For example, this year we have "Science, the Media, and the Public," a popular course on communication through the media. Even though the general attitude may be "Don't bother me with anything but my research," some seeds have been planted among the younger scientists to do the things that we are talking about here.

DR. SCHEIN: In biology--perhaps taking some issue with what Arthur has just said--a young assistant professor who does not devote time to some curriculum development is probably going to be fired fairly soon in most institutions throughout the country.

Now let me put it in this framework. Very early in biology we learned that we deal with perhaps four types of institutions. Type-one institutions are those that generate ideas and are impervious to outside influence. They consider themselves much, much too elite and too good to learn from others: Harvard will not adopt anything that Purdue develops. Across the country, there are perhaps 10 or 15 of these institutions that are considered superb, pay well, have great people, and so forth. However, these are not the institutions that the commission was working for, but they are the type of institutions that the commission drew some people from.

A type-two institution has both good people and some who aren't top-notch. Many of the major institutions throughout the country are this type: there is a give and take of ideas, and Purdue perhaps will learn something from Penn State, and back and forth. Throughout the country there are perhaps 75 or 100 such institutions with which many of us deal in the course of our daily activities.

And then there is a large number of type-three institutions, primarily teaching institutions. Research is not favored at them; in fact, there is no money for research. Thus the job of the assistant professor is essentially a teaching job, which means that many of the people, if they did not get involved in curriculum development and in course development, would be out of a job fairly soon.

The type-four institutions form a lower category, and they are almost beyond help. There is nothing that we can really do for them.

Now this sounds very chauvinistic, but these are the realities: in fact, in our commission, we recognized the different types of institutions and tried to tailor programs for them. If we set up regional conferences on curriculum development, we aimed at type-three people. If we set up a program to explain science as a job, we aimed at type-one people. Our programs might have been more effective be- cause we tailored them to the type of people, recognizing the kind of audiences that we had to deal with. Therefore, in the type three's and to some extent in the type two's, we found a great deal of curriculum innovation going on, good ideas at one institution that could be transferred to another, and one of our roles was not so much as a catalyst but as a communicator that picked up the idea of a person at one institution and dropped the seed at another, letting them develop it on their own. If it worked out very well, we patted them on the head, picked up the seed from there, and dropped it still some place else.

Specifically in regard to undergraduate science education for the non-specialist, in biology again we have three types of students. First is the pure biology type who is pursuing a biology-oriented career; this is a reasonably small share of the student population with which we deal. A somewhat larger group of students is going into some area of science that has a biological base: nurses, some agriculture students, dental technicians, and med students. However, they are not going to do research at the National Institutes of Health. Then the third group (and I guess we share these with math) is a much larger population of non-science students who, although they really aren't poets, attend the interesting "biology for poets" courses that develop. Frankly, these people are our bread and butter. Because of the large enrollments of the non-biology students in our beginning courses, we are able to support the rest of the department: this is where we get our lab fees and our student credit hours. We need the bodies so that we can support the upper-division and the graduate-level programs that we have for the biology majors. Thus, in biology, quite frankly, we are very interested and very concerned with non-specialists, both from a selfish point of view and because we have something to contribute to the way they will function throughout their lives. In fact, this concern is making itself known by a fair amount of curricular innovation and experimentation throughout the country in a great number of institutions.

DR. ALDRIDGE: As a long-time faculty member in a class-four institution, I would like to point out that the quality of innovation in science education is directly proportional to the numerical value of the institutional class, and it is inversely proportional to the level of research activity going on. That seems to be the categorization that I just heard, and that's the kind of elitism that gave the commissions great difficulty and would give one now even greater difficulty. You have to be very careful about those kinds of generalization.

DR. FRIEDMAN: Although the engineering schools now have almost twice as many students as they had at the beginning of the 1970s, they do not have many more faculty. Therefore, a tremendous pressure occurs within engineering to keep up with the teaching needs in the engineering institutions themselves. As a result, although there is a great interest in technology education for non-specialists, it is extremely difficult for engineering colleges to come to grips with it, except for a few schools doing outreach programs on their own campuses. That represents a resource that perhaps could be made more available to the larger educational community.

In addition, during the past year I have been in contact with a number of liberal arts schools that are experiencing a great deal of pressure from students and trustees to offer courses dealing with applied science and technology. In many cases they do not have the expertise; but many faculty in mathematics, physics, chemistry, and other areas of science are developing non-traditional science courses dealing with energy, the environment, communications, and transportation. These courses are being very well-received on college campuses around the country and seem to have a natural momentum of their own, but that effort needs help.

DR. MATTHEWS: I would say very much the same thing as far as the geoscience community is concerned. We are making a very concentrated effort to do just the sort of thing you are talking about there. Because our commission--an Earth Science Curriculum Project from which the Council on Education in Geological Sciences was a spin-off--was concerned, we had people from all four institutional types involved in all of our efforts. Now, we are trying to work with social studies teachers, bringing in environmental problems such as the shortage of minerals and trying to make them realistic to kids. We are doing this not only through AGI, our umbrella society, but also through a number of the other societies. And I think that as scientists, particularly in my field, we are very remiss in our duty if we do not follow this trend now because, as you are saying, in so many institutions non-specialists are not being given this. I don't mean to get up on the soap box, but we should let them know that they are indeed part of the world and that we have problems.

DR. TRUXAL: I am sort of amazed at the discussion because it sounds as though there is no problem, and we are just being naive. There are terrible problems. There are in the United States very few outstanding educators, outstanding teachers, and curriculum innovators. Of that group, only a subset is concerned about undergraduate education. Of that group, an even smaller subset is concerned about education of non-science majors. There is a tremendous sterility nationally. Textbooks and reports are dull, unrelated to the real world in many cases, and often superficial. So we shouldn't talk as though every organization and every scientific discipline is doing a great job.

DR. CRANE: Let me describe the situation in physics at a large institution with which I have been associated. We have, at any given instant, about 2,000 undergraduates taking a beginning physics course. Virtually what we call "captives," they are taking it as a prerequisite for engineering, medicine, or whatever. When, from time to time, we have offered a course for people who are not satisfying prerequisites--in other words, for nonspecialists--we had about 100 students, a drop in the bucket compared to the 2,000. The negative result is that those who want to take this substantial portion of physics (but are not pre-meds or engineers and so forth) have to do it within this competitive group of engineers or pre-meds. The course is slanted toward their needs, so that a person who is not one of our group has a bad deal in taking one of these courses. Yet, that problem is not being remedied.

The other comment I want to make deals with the very sporadic and spotty support for courses. Here and there someone--usually an older professor--gets fire in his eye and does a beautiful job of teaching a course. Well, that course is a great success as long as he teaches it, but the course is not going to be taught the same way by everyone. The next guy that comes along can't imitate the originator: every course is different, and every professor's teaching style is a personal and a very individual matter. So we do not have, for non-science students, the good courses which are transferable.

DR. YOUNG: One thing that I worry about is exactly what has been brought up here. When science people talk about courses for the non-scientist, they always speak of "Physics for the Poet," etcetera. That is not the need. The problem is physics for the man who is going to be a corporation executive and make decisions about energy, for example. Almost all our courses are for the education of somebody else, not mathematicians. "Mathematics for Poets" is a very small, vanishing part of what we do.

But I think we have to face the question not from the cultural education appeal but from the necessity for earning a living, of learning more about science and mathematics and computers than they do now.

Concerning involvement of the young people, I have noticed a tremendous change in the pressures in recent years while I have been a chairman in three institutions. This is a form of compulsive, repetitive, self-destructive behavior that worries me, but in the 1960s the pressure from administrators was all for research. Now the pressure emphasizes better teaching in the freshman classes and making the place more attractive to possible students. I agree that a young mathematician (except in type-one schools) who is not concerned with teaching will not make it to tenure while the young mathematician who does something innovative has that counted as a very strong plus. The natural sciences are all that way, but I don't think it has hit the physical sciences yet.

DR. CRANE: Let me just kind of phrase three parts to the question and see if we have an agreement on that. First, we have this concern of the scientific community's adequacy: Is there enough concern and enough constructive activity? From the discussion, I understand that the answer is no and that you are not satisfied.

Secondly, is the situation getting worse, or do you think it's getting better to the extent that we should leave it to itself?

And third, just what kind of a handle should this committee have to instigate improvements? In other words, how could the federal government promote some improvements within the constraints mentioned at the beginning? We can't pretend to have any influence over professors or curriculum, at least. This means that we have to work through a chain of influence which goes through the federal grant institutions.

DR. ARONS: From the standpoint of physics, I would like to address a class of non-specialists not been mentioned at all this morning, confessing my prejudice because I myself have been involved with this group for the past 12 years. We have said nothing whatsoever about elementary school teachers. Yet, it is through that class of non-specialists in science that we have, by several orders of magnitude, the biggest lever with respect to developing any public understanding on a broad base, any sensitivity toward the nature of science, even the grasp of a few scientific concepts.

Now, with considerable expense in the 1960s, we developed elementary school science curricula pedagogically oriented toward what the learning process is and far more sophisticated and able to produce an impact on awareness than anything that we have at any other level. Three of those curricula funded by NSF are the Science Curriculum Improvement Study at Berkeley, the ESS in the Educational Development Center at MIT group, and the AAAS's Science--A Process Approach. There are others, but they are not being used in the schools. In some cases where the materials have been purchased, they stay locked up in closets because teachers won't touch them. They are mortally afraid of them. In other instances, they are being converted into the same old debilitated lecture courses that do nothing whatsoever. As no materials are teacher-proof, the only way those materials can be handled properly is by a teacher who understands the subject matter that they contain and understands the structure of the particular unit that leads to a grasp of what it contains. We don't have teachers capable of implementing those materials. As a matter of fact, what happens over and over again --as some revitalization or "innovation" generated in some of the schools is being supported--is that, in complete ignorance of the materials that have been developed, they sit down and write more material on curriculum development.

Curriculum development has been mentioned over and over again in the last few minutes with respect to the college/university level. What happens is that someone with fire in the eye decides to bring enlightenment and insight to the non-scientist at the college level. He proceeds to write a book like Physics for Poets--out of a clear sky, without any reference to anything that has been done before, without any examination of the questions of intellectual development, or the problems of implementation of some of these curricular ideas. The university faculty member proceeds to write his own materials in ignorance of anything else that has been transpiring; and what he produces at that level is exactly the same kind of junk and garbage that the elementary teachers produce when they begin to write their own curricula. We have exactly the same problem arising and being drawn out in the same way in two entirely different echelons, or layers, of our cake. They are absolutely parallel to each other: the incompetence is quite equivalent regardless of the professional stature of the faculty member who proceeds to do that writing. We don't need that kind of curricular development; and if more of that sort of thing were going to be massaged by additional commissions and so forth, I prefer to have no part of it, and I won't participate in sanctioning it. We have other problems: problems of implementation and with modern knowledge of intellectual development (understanding the capacity for abstract logical reasoning and the time and pace at which a mind comes to the materials).

To come back to the elementary teachers, we are generating, year by year out of these courses for non-specialists in the colleges and universities, elementary school teachers who cannot handle those competent and potentially effective curriculum theories. They need remediation the instant they graduate. These non-specialists have had astronomy courses in which they have been told about pulsars, quasars, black holes, and stellar nucleosynthesis, although they don't know what is meant by noon and midnight, north and south. They have no idea of the development of the phases of the moon, and they can't engage the children in discourse of the elementary science materials. The same applies to those who have been loaded with all the latest word about DNA, big molecules, genes, and whatever else when they have no idea what is meant by oxygen and carbon dioxide.

This goes on and on. Let me give you one concrete illustration of the behavior of a teacher who came out of one of these stream-of-words courses, which I call "name dropping"--the vocabulary without any of the substance. (Incidentally, John Gardner, while he was in HEW, made a beautiful remark in connection with this sort of thing. He said that in our courses, particularly for non-specialists, we insist that the students cut flowers, but we never allow them to see the growing plants. I suggest that we absorb that significant metaphor.) But a concrete example concerns a fifth-grade teacher who came out of this stream-of-words regime. One of the students, who had found out somewhere that the earth is farther from the sun in the summer than it is in the winter, asked the very reasonable question as to why it is hotter in the summer. The teacher's unhesitating response was "In the summer the earth is above the sun and heat rises." Now I submit that that is genuine, although I could never in God's world believe it. (However, reading between the lines, you have to give that individual some credit for some quick thinking.)

Nonetheless, that is what happens in our existing framework. Students pick up disconnected words and phrases memorized from the verbal inculcations that they receive without having had the opportunity to observe or to do anything themselves. In addition, they always look for juxtaposition of words and phrases on multiple-choice tests; that's the way to pass the course. And so in classroom circumstances of this kind, the teachers proceed to string together those words and phrases in some sequence that makes syntactical sense, and that is their answer to the question. This is fairly typical of what happens, although some individuals will always go through any net. At the present time, the amount of what I have just illustrated is phenomenal.

Now let me come back to the different groups of non-specialists: among the people taking our general education science courses, we have the potential for exerting tremendous leverage through competent teaching in order to deliver to the high schools (and eventually from the high schools to us in the universities) students who might help us to change what is happening now. Nothing is happening. The National Science Foundation has supported some development of programs for elementary school teachers, but in their rampant fear of sustaining anything in perpetuity, they sustain things for so short a time that nothing develops the continuity necessary to produce real models advantageous for someone else. It is not all monolithic, though. In eight or ten places, some effective, respectable, and sensitive things are being done in different ways for elementary school teachers, with a potential of being adopted elsewhere and influencing others. In summary, there are serious problems that could be handled through funding, and they could have a non-linear growth and impact.

DR. CRANE: If we should want to implement better science courses for non-specialists in education colleges, whose bailiwick is that in? The Department of Education certainly does have what they call "discretionary programs," and of course NSF has a mandate in the science community which includes teachers and the elementary student.

While Arnold was speaking, I couldn't help but agree with everything he said, for a recent study we conducted shows that our elementary school problems are really very formidable, in part because science is just not an important part of elementary education. And changing the curriculum or changing teachers to make that situation different looks like an extraordinarily difficult task simply because it is not perceived to be important enough to worry about, at least in the first six grades.

DR. ALDRIDGE: I would like to comment on the point of existing curricula. Let me preface this by saying I am going to overgeneralize. I spent three years with the NSF's Division of Science Education, Development, and Research until a year and a half ago. In the course of that time, our Division spent a fairly large amount of money on curriculum development at the college level. We required that a proposal include a dissemination plan, but we were very careful to distinguish between the words "dissemination" (which was in) and "implementation" (which was out). Somehow that dissemination was to occur but without any money. As a consequence of that (this is the oversimplification), it looked as though the Foundation had funded a substantial number of high-quality projects and then let them die without implementation, orienting the teachers to the use of those materials, or distributing the materials in any sensible fashion. And the materials are still waiting to be disseminated. I don't think we should redo that kind of effort. The Foundation should distribute those materials or find some way of providing implementation for the good-quality, existing materials.

DR. NATOLI: The same applies to the Association of American Geographers. Some years ago, they ran a program, with funding from the U.S. Office of Education, which had to do with improving the introductory geography course. For one thing, very little geography is taught in science education, and generally what is taught is only fair. Knowing that, we sort of took responsibility for it because we thought that most elementary school teachers were required to take at least one course in geography. We thought that one course might be their only contact with the discipline and the greatest effort of any college professor must be in the introductory course. There merely could not be, let's say, a survey kind of introductory familiarity with geographic terms in that course; there had to be an introduction to geographical science including knowledge of the scientific principles related to understanding the earth and its relationship to people.

We also were involved in a precollegiate program for high school geography courses. Responding like many other professional associations who are involved in developing curricular materials, we provided a lot of money for development of materials, not realizing until toward the end of the project that that was not the important thing. More significant were how to deliver the materials to the classroom teacher and how to implement them. The crucial point again is how do you get materials into the hands of people? How do you overcome their fears of using them? By giving them the kind of knowledge they need.

DR. TURNER: In the 1960s when a supervisory system was established, at least there were liaison people between the colleges and universities and the elementary and secondary schools. I am an educational psychologist in the "honest" part of my living--that is, when I am not administrating. Therefore, I believe the assumption that memory and self-initiation for elementary teachers will carry a curriculum is a very faulty idea. Unable to support their own behavior, they need external support; supervision has a lot of impact on teachers. In the same vein, if you improve an undergraduate science curriculum, you must have a support system--through supervision--and change within individual districts and elementary schools. In the absence of that, you can develop forever curricula that simply will not have any effect on the instruction in lower schools unless there is a person that facilitates its use and, in effect, retains the teacher-user at that level. It's a critical mechanism for both elementary and secondary teachers.

DR. ARONS: Because science often is not considered important in the schools, we have a formidable obstacle. But that can be influenced. Most of that obstacle, at least in the local schools (which have been both inner-city and suburban, incidentally), is based on a fear of the material. And once you get a few teachers trained and not fearful of it and have some supervisory structure in the schools themselves, they start using some of the good new curricular materials in class, and the children start asking, "Why can't we have science every day?" Then, the parents come around and discuss it at parent-teachers association meetings. We saw the whole circuit take place. This attacks the formidable obstacle that was mentioned, as well as the implementation of it.

DR. CRANE: This has opened up an important segment of this committee's mission, which is college education for the non-specialist. I assume that college students learning to teach are non-specialists and, therefore, fall into this category.

Comment: When NSF sponsored the Chemstudy Program and the Chemical Bond Approach, they developed new materials that many high school teachers were not familiar or comfortable with. Along with that was a major program of summer institutes which ran anywhere from two to seven weeks. Their purpose was to make high school teachers familiar and comfortable with the Chemstudy material, and they were successful in that respect even though the Chemstudy material is no longer being used in its original form by very many people. It had tremendous impact across the world at one time, and the summer institutes were from the chemical community's point of view (and I think I represent a general consensus here, for two years ago a conference proposal was made urging NSF to reinstitute the summer institutes) the best thing that we had done in chemical education.

Comment: There is an aside to that. One of the direct objectives of the Office of Education's summer institute program for teachers was not only to give teachers new methods and materials, but also to develop model courses which would be automatically incorporated into the new teacher-preparation programs. We discovered that as long as you provide federal funding for these super-innovative summer programs (and some of them were absolutely tremendous, innovative, experimental), they never became part of the regular college curriculum. Why they did not we were never really sure--for instance, whether a little extra federal support was needed, or whether the people entering their courses were different. But for some reason or other, these innovations never moved over into the curriculum for new teachers, the teachers who were ongoing, or those who were in regular teacher-preparation programs. They did a tremendous job for retooling people who were out but, for some reason or other, the innovations never became a part of the regular preparation program.

Comment: That might be true of the Chemstudy Program. That is not to deny, though, that it had a tremendous impact on teachers already out across the world. It was translated into many languages and is still the main syllabus in some parts of the world.

DR. ALDRIDGE: The NSF/Department of Education report to the President did include a recommendation that summer institute programs for teachers be reinstituted. Those of us concerned about teachers feel that that recommendation is lost among a large group of other recommendations, and its priority isn't made adequately clear.

As a representative of teachers, I am convinced by the overwhelming evidence that the science education situation in both secondary and elementary schools is at crisis proportions. It is so serious that problems at the college level will be of major proportions very soon. Now I realize this isn't the place to talk about that unless we are willing to consider the in-service education of science teachers as education of non-specialists. So if that qualification is made in our definition, I am prepared to talk to that point quite a bit.

DR. WILEY: I assume there is not even an annotated index or list of undistributed science materials and curricula across all the subject matter fields. It might be a good idea to produce such a list so that, when individual college instructors or administrators are looking for resources, they would at least have a central location where they could find a list.

DR. BENT: It's like music. Unless you hear someone like Dr. Arons doing it, it doesn't come across. An individual faculty member has to convey the enthusiasm and spirit.

DR. WILEY: I don't know how broad such a thing could be, but it seems to me that there have been large amounts of federal dollars spent, not just from NSF but from other agencies, and that there have been fair amounts of internal resources at some institutions put into the creation of things intended to go beyond the individual faculty member.

DR. BENT: But they are not portable.

DR. WILEY: Whether they are portable is irrelevant to the question of whether they can serve as a resource for someone else.

DR. BENT: But it has to be someone excited.

DR. CRANE: When the commissions were active, they kept pretty well on top of the resources, tabulating them in their newsletters and so on, but since then I do not know whether anybody has kept track of them.

DR. LIVERMORE: There is at least a partial list; we published two years ago (with funds from NSF) an undergraduate directory of programs and courses in ethics and values in science and technology.

DR. HARRISON: Can I make a comment in reference to the question, "Is undergraduate science education for the non-specialist a matter of concern for the scientific community?" The chemical community has a number of subcommunities, but less than 25 percent of the chemists draw their checks from academic institutions; the great majority of the chemical community is employed by industry. Nonetheless, chemists in industry seem much more concerned about undergraduate science education for the non-specialist than many of the people in the academic institutions. Individuals in the academic community seem to draw justification for their existence in terms of the number of professional scientists they produce, and you will find that even with high school teachers. Only one high school teacher has told me about success with students in general courses. Invariably, chemistry teachers emphasize what institutions their graduates go to and how many major in chemistry. Even people in the liberal arts institution highlight their chemistry majors that go to graduate school. Therefore, science programs for the non-specialist is one of the most serious problems to be addressed in the academic sphere.

DR. TRUXAL: I am just amazed that we have gone several hours this morning without mentioning the most significant scientific and technological field today, the computer science area. Whether we talk about college students, elementary students, or adults, it seems just impossible not to focus on the major problem area: computer familiarity, computer literacy, computer capabilities, and the exploitation of the computer by the public. We have been talking about the science of 1960, and we ought to also talk about the science of 1980.

DR. SCHEIN: We also haven't mentioned one of the major sources of science education for the non-scientist, television; and we need to perhaps pay some attention to the effect of programs like Carl Sagan's show, "Cosmos," and the input of academia into and the influence of academia upon these types of television programs. The question, of course, is "How much should or could or will colleges get involved in the 'Nova'-type programs and public broadcasting programs?" These have a very high potential for reaching a great number of people at all levels.

DR. CURTIS: As an historian who has taught intellectual history and inevitably gotten into the history of science, I think that one thing to keep in mind is the contribution that people in the history of science can make to science for non-scientists. At times when I have been teaching or talking about the Copernican revolution, I have asked people, "How do you know that the earth is going around the sun as Copernicus theorized, rather than the sun going around the earth? Is there proof?" The students were amazed; they had learned by rote and didn't know how they knew what they knew. History of science has something to contribute here in helping people to confront problems basic to scientific thinking and to know how they developed as a means for explaining experience and phenomena to themselves. You have to keep that kind of subject in mind; it might even, in some cases, be helpful for scientists themselves to get this kind of perspective.

DR. CRANE: It's interesting, for in physics there have been some very successful courses for non-specialists taught by the historical case method.

DR. ARONS: Some excellent text materials incorporate these views and these ideas; all they have to do is be used, but they are not used. Each guy writes his own new book about general relativity.

DR. BITZER: I think I heard a statement that the materials would not be used, although there is a great innovation in teacher training and support. And then I also heard that curriculum development dies if it doesn't have such support. And if I am not mistaken, this sort of excludes any possibility of success.

DR. BUCCINO: That's a fairly complicated issue. The implementation problem at NSF certainly pinpoints the need for considerations of "promotion" and "marketing." There is no policy barrier to doing this sort of thing, assuming that we take into account some of the past difficulties, but it really boils down to a question of strategies and, perhaps more important, a question of resources.

DR. CRANE: In physics, at least, several projects for the development of new courses have carried with them a program of teaching teachers how to use them--for instance, PSNS might be a good example.

DR. STRASSENBURG: Initially, Physical Science for Non-Science Students (PSNS) was a project stimulated by the Commission on College Physics, one example of their productive activity. A conference largely involving physicists and chemists, but educators, too, identified a need for such materials and some kind of a mechanism for generating them. Then, the Commission staff met with interested parties, ultimately submitting proposals to the Foundation. One funded proposal, housed largely at the Rensselaer Polytechnic Institute, resulted in the development of some textual materials, apparatus, and supporting teachers' guides which were published by Wiley. Designed primarily for prospective elementary school teachers, these materials can be used for other non-science majors as well. For a while they were fairly big sellers. Now, although those materials are used in few places, one can still regard that effort as a success because new textbooks have incorporated some of their ideas, primarily the importance of observation and reasoning by students.

A number of institutes were supported by Foundation funds in many cases, as well as shorter sessions held quite widely for one or two days: local teachers who might have some interest in implementing those materials were called in, and the focus was on the apparatus itself--some of the complexities of its use, mechanisms by which one could procure it and experiment with it. Probably that was quite essential to having it adopted at a number of places.

DR. CRANE: The element injected this morning is the great importance of teaching science in college to persons who are going to be elementary and secondary school teachers, provided we are permitted to call them non-specialists.

Comment: Since biology is a required course in virtually every high school in the country, we consider the person who is going to teach it in a secondary school to be one of our specialists, one of our biology majors. We are a little naive in this respect because we have very little control over the education of the secondary school teacher. Even though in some high schools the biology teachers are essentially bio majors, in most schools they are in the education school, and the biology departments have very little control over them. So we do have some problems.

Comment: Whether high school teachers are non-specialists might be debatable, but science teachers in the elementary school are non-specialists.

DR. CRANE: I can only speak for physics: when the very few students come over from the College of Education to take a physics course, we certainly consider them non-specialists.

Comment: You are quite right. We can plead and cajole, but we have very little impact on the elementary school teachers' training program.

Comment: If elementary education majors take any science at all, it is going to be a general education course. They don't take that many courses directed toward science.

DR. HARRISON: Chemists have had a fond longing for high school chemistry courses taught by chemistry majors, or at least people having had a substantial body of chemistry. I would question whether those people --and I think this statement becomes increasingly true, the more prestigious the institution--may in fact be unprepared to teach what should be taught at the high school level. In other words, they are highly oriented towards a theoretical approach and prone to present quantum mechanics in the high schools, which I personally do not feel is the desirable point to start.

DR. STRASSENBURG: Most of us consider prospective secondary school teachers in our disciplines as majors--and hence, perhaps as specialists rather than non-specialists--but perhaps it is worth a minute or two to consider the seriousness of that particular problem.

In physics, the only discipline for which I know the statistics quite well, the absence of well-qualified secondary school teachers has already reached crisis proportions and promises to become much worse in the coming years. The primary problem is that the job market for physicists, even those with only a baccalaureate degree, is quite good; and industry offers so much more money to them that the high schools simply cannot hold them. The result is devastating and will have long-range effects. Many high schools have simply stopped teaching the subject. Others give up the possibility of finding a qualified teacher and assign that task to somebody whose primary competence is completely in some other area. Even worse, colleges that used to be the sources of such teachers are giving up programs in some areas be- cause the enrollees are so few and significant resources are needed to run them. Therefore, even when we decide that it is important to try to reverse this situation, it will be very difficult to do so because the mechanism for training those teachers just isn't in place any longer.

DR. BENT: We have evidence that the same situation exists in chemistry and to a lesser degree for people who are teaching the general physical sciences, particularly computer science; we don't yet see that evidence in the life sciences.

DR. FRIEDMAN: I don't believe that's entirely the case. The kind of interest shown for teaching science at the time of the institute programs has an impact, for a variety of reasons, on the number of well-qualified people that we can keep in the schools. Frankly, one element of that is the stipend which those teachers receive: although not an insignificant amount of support, it doesn't offset the differential in salary between what they can get in industry and what they receive in teaching. However, it may be just enough with the added interest and the opportunity to refresh themselves to keep them in the teaching area.

We have addressed a number of topics of concern with respect to education students, and the need to provide them with science in the traditional sense is probably a key issue. But with business/management, accounting, and many of the other students, perhaps technology and decision-making in society--the topics needed for evaluation, planning, and management--concern really technological issues. Perhaps some focus could be placed on that very large component of the issue.

Question: We have talked a good bit about the perceived need for those in education, but do people acquiring a formal degree in education perceive that they have this need? If they don't, how would you ever institute a program that would cause them to embrace it as something helpful?

DR. CRANE: That was my concern: we have very little handle on what curriculum committees, deans, and departments are willing to do in order to enhance their requirements.

DR. MATTHEWS: There is a serious problem in the earth sciences, earth science being the middle school's science course and high school geology becoming increasingly important in the secondary schools. We are facing the same problem as the physicists in regard to jobs, and this is hurting us.

But we are facing another problem, too (a recent survey indicates that this is a nationwide problem) of getting people into earth science education, simply because (this is the story we get from most of the states) so many of the education departments themselves are in trouble. Rather than say, "Go ahead and major in physics," or "Go ahead and major in earth science," or whatever, they are much more interested in filling their own classes, saying, in other words, "Why don't you go into reading?" In Texas alone we need 1,300 certified earth science teachers, and the situation is so bad that the Texas Education Agency is considering dropping the eighth-grade earth science requirement, simply because they can't get certified teachers. This is a very serious problem.

DR. BUSHAW: I don't know whether anything like this is happening in other disciplines; but recently there has been a marked move in mathematics to approach this problem through the accrediting agencies, which greatly influence what is taught in the colleges of education. One mathematical organization now has input to the most active accrediting agency in teacher training; and there seems to be a certain degree of receptivity to various proposals, guidelines, and suggested policies funneled to it from the various mathematical organizations. This is certainly much more effective than trying to reach deans and department chairpersons directly, independently of this very elaborate and very strong mechanism.

Theme 3
The Role of Undergraduate Science Education in the Preparation of Non-Specialists for Professional Careers

DR. CRANE: This part concerns the kind of preparation that we should give pre-professional students. For example, our society is becoming so scientific and science is becoming so sophisticated that the question is whether one or two courses in science for the non-scientist can prepare him to actually analyze a scientific situation and come to a decision independently. If he can't do that, how can he make wise decisions and, even as a kind of secondary process, know how to listen to scientists or how to interpret the available material? What is different today from the way education was in the 1960s?

DR. ARONS: A great many of the committee seem unaware of some of the things I would like to bring out. Committees like this have been brought together repeatedly over the past years. And always there emerges this gnawing discontent that what is happening is unsatisfactory. The students do not learn as we would like them to learn, and the residue that is left is depressingly small. Now the empirical evidence is that a gross mismatch exists between the curricular materials that we generate--not just at college and university level but other levels as well--and the mind of the student supposed to receive it. And very little inquiry is made into the question as to why this perpetual, gnawing sense of lack of accomplishment is present not only in us but also in our predecessors.

About 10 years ago a few members in the physics education community had the idea of administering some tests in abstract logical reasoning to college undergraduates. My impression is that, up to that point, such tests had been administered principally to children up to the age of 11 or 12, based on the assumption that certain kinds of abstract logical reasoning developed spontaneously in the individual at that age. During the 1970s came an increase in tests involving ratio reasoning (for example, using division, using ratios, and interpreting their meaning) and tests involving elementary situations that needed control or an extra variable in order to make a decision about cause and effect (simple situations in which one little bit of information was lacking and one had to be able to recognize that there was missing information). Then these tests were administered not to 11- or 12-year-olds but to college undergraduates and then to individuals across a wide age spectrum, from 13 to 50. What emerged from the existing data on quite a few thousand individuals is that about 25 percent performed successfully on tests of logical reasoning; 25 percent performed in a mixed partial way, showing some glimmers of being able to handle the abstraction; and 50 percent failed the tests completely. Enough individuals are tested now so that one can see significant differences between certain populations: disadvantaged, rural, inner-urban versus suburban. European data, although not over as wide an age range, show exactly similar results; the data are remarkably reproducible. Yet at the college and university level, we are taking material that requires abstract logical reasoning of various kinds--in hierarchies higher and more sophisticated than these rudimentary ones that emerged from the tests--without any attention paid to the fact that the recipients of the material do not execute these processes of reasoning.

Now there are all sorts of things involved besides the few that I have mentioned. One is the tremendous commonality: many individuals show similar failure in similar tests (they are not all the same; not every individual shows the same pattern, the same failures). Another is the ability to discriminate between observation and inference. A specific example follows having students in a laboratory heating a crucible containing copper: they can see it turning black, and as they periodically weigh the crucible, they see that the weight increases. Asking what they have observed, I am told, in a very large proportion of the cases, "We have been observing oxygen combining with copper." Nothing whatsoever has been said about oxygen, but they have seen the copper turning black and the weight increase. However, they don't recognize what is observation and what is inference.

Now this is not by any means limited to our scientific enterprise. For instance, the first assignment that history professors at Amherst often give students is to examine the Code of Hammurabi and to write a paper for the next day addressed to the question, "From this code of law, what do you infer about how these people lived and what they held to be of value?" The students, of course, have had tremendous trouble with that assignment, being unable to discriminate betwen observation and inference. The facts were the laws. Now the historian overlays on those facts a series of deductions and inferences not in the facts themselves, but students cannot do that; they haven't had enough practice. Furthermore, when they are presented with a ready-made situation, a passage out of history, they cannot in that passage discriminate between the informational starting-point and what was introduced by a historian. It takes practice, like any other kind of activity.

There are other things that students do not do. They are completely insensitive to missing information, as indicated on the rudimentary tasks that I mentioned before. For example, they do not self-consciously recognize that they don't understand the meaning of this word and that word in a paragraph that they read. So they read a paragraph; they don't understand what it said; they don't recognize that they don't understand what it said. Their self-consciousness about knowledge and understanding has not been developed to that extent. And they desperately try to memorize the juxtaposition of phrases of that paragraph in order to be able to pass the test. This goes on over and over again.

Another thing that we do in virtually all of our academic enterprises, not just some, is to engage in some sort of hypothetical deductive thinking--confronting a situation of some sort, described however concretely or abstractly depending on the situation, and then proceeding to imagine in the abstract some change that might be imposed on that system. The question is "What are plausible consequences of that change?"

We need to do this in physical science, we need to do this in social science, and we need to do this as citizens in day-to-day decision-making. Trying students out on anything of this variety, you get extreme gibberish. It isn't that they are fundamentally incapable of any of these things, but practice hasn't been emphasized; attention hasn't been paid to any abstract reasoning processes. Nothing is ever attributable to one reason in such enterprises. But at least part of this mismatch between the curricular materials that we throw at students--verbally, didactically, virtually without any participation in mental activity on their part--and the processes that take place in their minds resides in the failure to recognize the developmental aspects that seem to be involved in these various kinds of cognitive performance.

And much of what we are doing at the college and university level drives our students into blind memorization instead of into comprehension and understanding. They have no recourse: they have no choice, in order to pass the course--because of the volume, the pace, the verbal level at which materials are thrown at them. And if we particularly want to reach non-specialists, especially the ones not adept from an early stage in such abstract reasoning, we have to consider giving students time to make mistakes, to discover contradiction, to retrace steps without being punished for being "wrong," to revise a point of view, and to arrive at a conclusion which is testable for internal consistency. We have it in those elementary science curricula; but we don't have that kind of thing in college and university science courses, although we need it desperately. The problem is not necessarily in the curricular material as such, but in how the material is handled (how the students are tested, for example). One can invoke all of these ideas in the most eloquent, compelling, and convincing way; but if one, in the final analysis, tests the student on memorizable end results, on vocabulary and not reason, he is telling the student that all this comprehension, reasoning, and understanding is not important. That is going on in a major fashion in our enterprises.

I plead that we recognize this existing problem about cognitive development. The fact that 25 percent performed successfully--and that percentage doesn't change with age, incidentally--indicates that they have developed the capacity in spite of the system. They are sui generis, doing it on their own just because the opportunities are there. The rest, who might be brought along by self-conscious effort on our part and deliberate help and design (and I am convinced that a sizeable percentage can be brought along), are not being brought along because the system is not providing the kind of help they need, regardless of the lip service that we render to some of the grandiose ideas.

DR. HOPKINS: You said that many of these people could be brought along. What kind of course, or what kind of training, brings them along most efficiently?

DR. ARONS: I will be extremely narrow because I will take one specific case, but I mean it to stand for others. The arithmetical reasoning process involves the ability to divide one number with another and to say what you get and do something with it. Empirically we have found that we must go through the routine about five times. We start with a group of individuals of whom no more than four or five percent can handle that kind of thinking: the word problems in fifth and sixth grade arithmetic is what this corresponds to. Then, we proceed through weighing and balancing--working with ratios; and we invent the concept of density, pi, angles, circles, velocity, and acceleration. Five times during the course of 12 to 14 weeks, we go around that route, cycling back with the same kind of reasoning in a different context. Each time we pick up a few more people until, after five loops, we have about 85 percent of them. The remaining 15 percent we seem to be unable to reach, touch, or shift.

These numerical figures, incidentally, are identical for the undergraduates and the in-service elementary teachers, including the unremediable 15 percent. Now our test for whether they have reached it runs something like the following: we will pose a problem, and they will have to make some divisions and multiplications and explain in their own words the reasoning--and not just, "This is to this as that is to that." They must interpret words: "We divide this number by this number and then find out how many of these there are in one of those." They must explain the reasoning and then make up a problem in one of the other areas--density, velocity, composition of compounds--in which their reasoning holds the same pattern.

Now you can see some less numerical things happening here. You see students begin to do some rudimentary, hypothetical deductive reasoning. They will begin to visualize a change and its consequences. Haltingly, lamely, and painfully, repetition is absolutely essential. If one thinks he can remediate this sort of thing by a few exercises in a two- or three-week session prior to the end of the freshman year, forget it. That is exactly the equivalent to what NSF has been doing for years with the elementary school teachers, giving them quick workshops in which they sit down and talk about the philosophy of the curricula and about what one does in teaching EES, when the teachers are in the same condition as the children. They have exactly the same starting point as the children on those materials--no more comprehension than the children have. In fact, to bring them to the point of being able to handle one of those units in the elementary curricula, we must work them through those units with a pace that is actually slower than what they will use with the children because they are older and they have this overlay of garbage that has to be discarded and because of the condition in which we have left them in our university courses. We have the same problem of time and pace with students right here. We can't expect to remediate it with a few nice words and expect them to go ahead and think abstractly. They haven't had the opportunity; they need more practice and more opportunity.

These things have to be considered, and I am very dubious that we would make any substantial progress toward rendering good service unless we pursue this part of the problem along with many of the other things that have been talked about.

<u>Question</u>: Now let me just pick a philosophical point with you. The students are heating this copper, and it's turning black; but in fact

you are accepting a certain intellectual scheme. Since you won't let them bring in atoms and oxygen yet, how to do they know it's copper?

DR. ARONS: We started with weighing things, and we dealt with how to identify substances and properties but not the difference between weight and mass at that stage of the game.

Comment: So you are accepting a certain intellectual scheme, but I want to point out the continuous spectrum of what you are willing to grant, in this stringing of words together: you let them string some words together but not others.

DR. ARONS: The students that we start with are unable to recognize when they are taking something on faith so that when I start with them, I at first avoid taking things on faith. Later on, when they are able to discriminate--when they can say, "We don't understand what's behind this, but we'll accept it for the time being"--we do it self-consciously.

DR. SCHEIN: We do the same thing in our freshman biology course with 1,000 students. It's oriented toward abstract thinking. We have no facts per se; instead, we have pushed heavily and emphasized the process of inquiry. In fact, we have probably over-pushed (we handle 1,000 students, and we have met a great deal of resistance on their part and a fair amount of resistance on the part of many of our faculty members). Nonetheless, by the middle of the first semester, students that complete this course in fact are beginning to turn around: they are very happy for the first half of the semester because they have all had high school biology, but they discover that college biology is different. They become very disturbed because we are not giving them things to memorize. In fact, there is virtually nothing to memorize: the emphasis is on deductive reasoning, and the first two weeks are spent distinguishing between an observation and an inference. However, by the end of the year, these kids take tests equivalent to graduate-level exams, and they do extremely well, by and large; the rate of failure is very low.

The problem is that the students still grumble, in spite of the fact that they do fairly well, because they have no idea how much biology they really know. This shows up in the next level. Some of these students realize that they have done a rather unusual thing in our course and apply this sort of approach to other sciences where they are not encouraged to ask very many questions, but to memorize the formula and not worry about where it came from or what their observations tell them. Some of the students are grateful for this approach; but many of them still complain. One of the most interesting complaints is "If I wanted a course in logic, I should have signed up for the Philosophy Department. I didn't expect to get logic here in biology." I take that as a compliment.

The point that I am trying to make is that the approach can be done. I wish it were done more broadly. Some of the other courses in our school pick up where we leave off, and I am trying to move the entire curriculum in biology to this sort of approach. It can be portable, but we need a great deal of faculty training to do this. Some of our toughest pupils are the faculty that we are training in this.

DR. ARONS: I don't seem to find as much of the end-point question and the recalcitrance that you describe. Now I have learned to live with it; you have to be able to live through that first period when students and other faculty hate you because this is their only experience in that. If this were an experience generated half a dozen times, that hatred would disappear.

DR. LIVERMORE: Work on testing and concept development all of a sudden made me realize that some of my students, when I was teaching freshman chemistry at Reed College, were not as stupid as I thought they were because they couldn't perform certain things that I thought they should perform. I am now sure that they had not reached the stage of development to handle abstractions.

On the question of portability of this, we have had some experience in our Chautauqua Short Course program; Fuller, Thornton, and Arnold [Arons] have taught a popular course on the development of reasoning through college science teaching. Teachers mainly from small colleges, not only in physics but in other sciences as well, have attended it and--from what evidence we have been able to gather--have actually made use of what they learned when they went back to their own institutions. Whatever comes out of this committee, whatever decisions are made about developing programs for non-science students, one way of disseminating this information is through a program modeled on the one that we have been operating for 10 years. We have even had experience with interdisciplinary topics. One of our Short Course directors has been Henry Bent, who taught a course on "Thermodynamics, Art, Poetry, and the Environment."

DR. CRANE: A familiar saying among physicists is that if you give a student the basic principles, then he should be able to apply them to any situation. Nothing could be less true. We run courses (especially the ones for the pre-med students, whose texts are very crowded with isolated individual principles), and that's the end. The students are never given any day-to-day practice in relating those principles to real-world situations and especially in working backwards (taking a real situation and dismembering it into principles), although this is what you always have to do with a real situation.

We teach physics in exactly the opposite way: we start with the isolated principle and then get into the specific situation. As a result we have students who very successfully learn the basic principles but are not able to do a thing with them when they get out. We have never taught them anything about this very great gap between the basic principles and using them to untangle real-world problems. There is a missing link if we stop at the basic principles without giving something in assistance. They are not able to do anything with it.

DR. FRIEDMAN: Some of the materials that we developed in the project on the physics of technology were handled precisely as you have just described and, in addition, met most of the requirements that Arnold has described.

DR. GRAY: I don't think the problems we're talking about are peculiar to science. I have had the same problems in teaching journalism, for instance. If you ask a student to do things that will require him to give you factual information, that's fine; but if you ask him to analyze it and reason about it, to do comparative analysis, you would have the same difficulty. It's a problem of all education systems.

DR. TRUXAL: We don't know whether successful students in our course are biology majors or non-specialists. One of my good students this year is a journalism major who caught the information, looked at it, put it together, and synthesized it. Also, we have no required text. The interesting thing is that by the time the semester is half over, students come in and ask what books they need for reference. By that time, they are ready to return to the book.

DR. GRAY: A lot of the discussion seems to be focused on conceptual development of science and the difficulty of presenting it to students. Looking at this booklet on the Chautauqua courses, I notice courses that have a very different starting point, problem-solving itself: "Energy and Society," "Alternative Fuels from an Engineering Perspective," "Risk-Benefit Analysis." It seems to me that many courses, taught successfully on campuses around the country and involving great student interest, start from a policy consideration that students feel is confronting them from every side. As citizens, they need to confront these policies; as individuals who will be seeking jobs in various professions, they need to be able to come to grips with issues of this sort. With the high motivation evidenced by experience at a number of colleges and universities around the country, a strategy which perhaps should be considered is to start from these policy issues and then deal with topics of science as they arise in the context of the policy discussion. There needs to be a consideration of how one evolves a policy and how one deals with risk analysis, how one deals with decision-making in the face of uncertainty, so that there is a general approach to systems analysis and problem-solving which has a structure of its own, as well as a need for the development of policy in various areas.

Comment: I agree with the motivation for starting with something like that. However, the courses as given were a very mixed bag that didn't necessarily do any good. Some degenerate into little more than vacuous chit-chat by not going back to an understanding of the concepts that are being talked about. For instance, several courses about the energy problem never review with students what the word "energy" means. That's like discoursing on philosophy and history without any knowledge of the history of anything. Some courses are generated for people who already have a technical background that they can use as a point of departure; but there is a very mixed bag on this, and a great many of these efforts are a travesty of education.

DR. LIVERMORE: While that is true, courses have been developed in that area by engineering schools with engineering faculty sometimes working with faculty from other disciplines; and I would look toward those examples as the model and obviously not to the ones that deal with these topics superficially.

DR. GRAY: I would like to apply this to professional careers, speaking as someone outside the sciences but very convinced that they provide very meaningful and, in fact, absolutely necessary background. I would put this into three areas. One is the cognitive reasoning power. For the journalist to have gone through a science course of this sort is a fundamental necessity, and that kind of rational process can be transferred to all kinds of situations that the journalist has to encounter. For example, empty journalism is the mere reporting of facts, "rote" reporting of what people tell you, going to one or two obvious sources --not making connections, analyzing, going behind the scenes to ask questions, and testing. Because we get too much of that kind of reporting, I am very much an advocate of schools of journalism either being in colleges of arts and sciences or closely allied, not being vocational or professional schools because this reasoning process is of fundamental importance.

Secondly, science and technology have had a dramatic impact on journalism in the operations and practice areas. Computers are of fundamental importance to the field of journalism: I cannot think of any profession that has been more changed within the last 10 years than the field of mass communications, in terms of technological change. For instance, when I took over my present position as director of the journalism school 10 years ago, I was teaching about a system that fundamentally had not changed for a hundred years. Since then, laser printing has come into the field, cold type has replaced predominantly hot type, computers are used not only for printing but for data retrieval systems and for transmission of information from one office to another, and satellite transmission of information is used. A huge dramatic revolution has overtaken our field.

And journalists have to understand this for a number of reasons. First of all, this brings about cultural change. It is changing the way we can find news, and it is changing the history and the philosophy of journalism. Therefore, we need an understanding of the technology and the scientific aspects if we are going to understand our own cultural setting as journalists--that is, as a profession.

There has been as a result, a very fundamental change in the practice of journalism--that is, the power structure of journalism is changing. About a hundred years ago, journalists lost control of the newspapers; they no longer made the day-to-day decisions about whether there would be extra editions and what changes could be in a paper. Persons who understood linotype and the "back shop" (as we call it in the field) began to get the power because they had the technological knowledge; but editors missed the boat and could not argue with these people: the publishers and owners listened to the technical, production people rather than to the editorial side. Now, editorial people are in a position to come back into the power structure. That is, managing editors--if they understand the computer, science and technology, and laser printing--can regain control of the editorial product by telling the computer people what to do and how to do it, not letting the computer people just impose their thinking on them. In the early stages of application of computers in journalism, for example, we simply picked up computer systems that had been designed for banks and airlines and imposed them upon newspapers; and because editors had no knowledge of how computers operate, they took a lot of this nonsense and programmers who would say, "You can't do that," when indeed you could do that. You could design keyboards and control systems to do what journalists wanted to be done, if journalists had known enough to insist that that be done. Thus, it is very important that if we are going to train leaders in our field, they must have a fundamental understanding of technology.

The third substantive reason is that no field has been more dramatically impacted than journalism. Historically, politics had been the main thrust of journalism, but politics today cannot be separated, for the most part, from science and technology. We no longer can simply report on city hall or the police department. Today journalists are addressing chemical dumping, nuclear wastes, energy problems, space problems, environmental problems. Everywhere you turn--if you are a responsible, serious journalist--you have to address scientific and technological issues. But too often, journalists address these issues on a crisis basis. They report Love Canal when it's too late, or they report the problems of nuclear dumping and other crisis problems, jumping from one to another without giving the public a sense of continuity. We do not prepare the public in time to do something about these things. We get on them after they become a political or an economic crisis.

Now, however, if we are going to turn out responsible, intelligent journalists, we have to begin in the elementary schools, in the secondary schools, and in colleges to understand the problems that they are going to report and to give them a background, teaching students how to ask perceptive questions and to identify potential crises before they become emergencies. Therefore, science and technology should have much more of a role than it has had in journalism.

<u>DR. TRUXAL</u>: It seems to me you have raised for these deliberations a much more fundamental question. You have talked about deductive reasoning, modeling, basic concepts of probability, decision-making--the fundamental concepts which underlie systems engineering (information systems science really)--as the basic sciences from your standpoint.

We are working with Syracuse University and NYU on a program for public policy, attempting to teach graduate students some applied sciences; and again we find the same concepts. But if we have a limited amount of time with undergraduates, what concepts do we teach? Does it make sense any more to teach about the classical physics concepts or the classical chemistry concepts? Or should we take selected ones of those? We can reach some of these objectives, the goals of logical reasoning and the concept of a function, in terms of a set of basic concepts drawn from a wide variety of disciplinary fields; but it is a very difficult task. Looking at college courses only, how much of the classical physics, chemistry, biology, and mathematics do we want to present?

DR. CRANE: You are implying another question that I have been concerned with a lot: Does it any longer make sense to have science courses compartmentalized for the students? They don't have time for more than a couple of courses. Maybe the time has come for just a science course that would concentrate on systems.

DR. TRUXAL: And then a very careful selection within them. I still remember Zacharias' enthusiasm for his demonstration of the coupled pendulum for sixth graders and the movies made on that subject. When you stop to think, though, coupled pendula are a very exciting concept, but who really cares? You have to get into very complex space systems before you get into the systems really represented by that model and the transfer of energy between two systems.

DR. CRANE: We, up to this time, really have not been noted for trying to get more students to take science. We would like to have more of them take some. I suspect you would feel that before we try to do that, we ought to learn how to teach the ones we have.

DR. ARONS: To require students to take some of the courses on our dockets would be superfluous and needlessly cruel. At least they shouldn't be forced into the paralyzing situations they tolerate now. I believe in requirements; but when they are not legitimate, I would steer away from them. Actually what we are doing, I am afraid, is not legitimate. To clarify--in light of some of the other remarks that have been made--when it comes to capitalizing on and developing the capacity for abstract reasoning and the various things I was alluding to, I do not see physics as a necessary channel. There are any number of subject matter areas as ways of going at it.

DR. CRANE: Is it more important to get our house in order in terms of the courses themselves than to get more students into the science courses? Are the so-called "curriculum development programs," in the way we have thought of them in the past, the vehicle at all to do that?

DR. ARONS: I expressed very great reservations before about more curriculum development; we have curricular materials that are capable of doing the things we are talking about but just are not implementing them properly. We need good working models sustained over a sufficiently long period of time so that they begin to have impacts on other people. For example, we have a program for elementary school teachers that worked: it develops people in whose classrooms you could observe the new elementary science curricula being implemented fairly much as they ought to be and children responding accordingly.

We have been able to generate some additional colonies, some other operations of a similar nature, but not by going and talking about it. Instead, we have generated several other places doing comparable things by having people from those places reside with us for a while--follow us around the classrooms, talk with the students, deal with the materials that we have generated, go out with the teachers to the workshops, and so forth. Given that kind of background, after several months in residence they have been able to go back to their home bases and generate parallel programs the same way.

DR. CRANE: In government language, is this a "demonstration project"?

DR. ARONS: Yes, I suppose so. But there are different ways of doing the same thing, and you don't want a patent. There are other approaches; there should be several good examples.

DR. PETERSON: A part of the question that we are dealing with also received the least attention--the basic research necessary for each area of science in order to understand what learning processes are and are not in place among the students addressed. We have found out in working with students in physical sciences that certain concepts are not perceived. The same research has to be done with all areas of science before you can begin to develop models that will attack the problems and misconceptions of students; along with models we really must continually support this basic research. And so to answer the question--"Could we develop curricula which would attempt to meet those needs?" --we can, but we also need to do the basic research and find out what those misconceptions and problems are.

DR. ALDRIDGE: We already have developed curricula which will do those things; we don't need any new curricula. What we need are programs, in the NSF and in other agencies, which address the problems of methodology rather than new materials; and if that is the case, that leads us again to teacher programs for both college and pre-college teachers.

DR. FRIEDMAN: Some very fundamental national problems surround us; but somehow a lot of the conversation doesn't seem to be touching those issues. Not only in journalism but in almost every profession, everyone is going to have to deal with computers in some fashion; microcomputers and information systems will be as pervasive as television sets by the end of the decade. What are the fundamental aspects of computer literacy that ought to be addressed in college education today, so that the nation can take maximum advantage of this tremendous resource for productivity and for education? This is a fundamental issue that ought to be addressed in the education of non-specialists.

As an example, recently a bill was passed to implement a $20 billion program in fusion research development and in gaining energy from the fusion process; a great expansion of that effort is to take place if it is eventually funded. While reading stories about that in the New York Times, I wondered how many readers understand the difference between fusion and fission. It was not explained in that article in the business section of the Times. What, then, are the aspects of energy literacy that ought to be addressed in the colleges so that their graduates can be better citizens and be in a position to enter into careers where this expertise is called upon? Issues and questions of that sort ought to be addressed by this group.

DR. CURTIS: I just want to tell an anecdote that may point up the nature of the problem. When I first took over a college presidency, I met a group of key faculty members for a period of six months to talk about the nature of the breakdown in that particular institution and what we might do to improve it. After we concluded our sessions, a rather irreverent classicist looked at me and said, "Mark, if you think that what we have decided is going to make any real difference in the programs of the college, you are fooling yourself."

And I asked, "Why, Bob?"

And he said, "Well, you still have the same old clowns teaching the courses."

I don't mean to make any irreverent comparisons here between that particular faculty and the science faculty of our country, but some attention ought to be given to faculties and some redirection of questions raised about why they are teaching the particular courses they are. Is it in order to provide all that can be known about physics or biology or whatever within the time limits allowed by the number of courses that a person can take in four years? Or is it something about teaching somebody to be a clear-headed thinker in the way that scientists think? There is a very important contribution not only to the field of science but to the nation as a whole as we develop methods for trying to deal with a highly scientific and technological age; a lot of other complications are involved. Perhaps if you teach the people how to think clear-headedly, in a scientific way, then those people who have science as their thing will develop into specialists; you don't need to get over-concerned with them.

DR. ARONS: The thinking, the logical reasoning aspects, are the important groundwork; but there is one addition to that. We can't possibly teach our students all the things they need to know. In the final analysis, the only legitimate function for higher education is learning how to learn, which is grounded on these aspects of thinking. Now when we start talking about specific items--fission versus fusion or computers, as the case may be--I become uneasy. We will never be able to give our students all of those ingredients which we keep listing in the way of knowledge. We must, via one or another of those channels, put them in the position that if they had not heard about fission and fusion, they would be able to go ahead, read, and understand. Having learned how to learn, they can proceed to close the gap beyond the abstract thinking processes as such. That is the only way we will be able to synthesize those ingredients because we can't possibly include all of them in their curriculum.

DR. TRUXAL: But, by the same token, if we combine what the last two speakers have said, we must pick specific material that does three things: accomplishes your objectives, motivates the students first of all (because a motivated set of students will learn almost regardless of the teacher), and motivates the teachers who are anxious to learn and to be motivated. Then we begin to approach both of the problems.

DR. FRIEDMAN: I fully support the concept of learning how to learn;

it's fundamental. I would like to add another concept--learning how to unravel. Many of the issues confronting society today are highly complicated, interdisciplinary issues involving politics, economics, technology, science, human nature--absolutely everything--and many people are completely befuddled and ready to leave the issues to the experts--and worse. What we can teach is that an educated lay person can confront such issues and begin to analyze and unravel; and if they have the experience once in confronting a very complex systems problem and penetrating it a bit, they might have the courage at another stage in life to confront another issue.

Theme 4
Revitalizing Undergraduate Science Education for Non-Specialists: The Next Step

DR. RUTHERFORD: There isn't a lot of talk about science; what we do hear discussed are the fundamentals. What you might want to do, if you want to go past the nice discussion among the saved, is to really address what the federal role might be. And I would hope that you will decide that it isn't too great when considering, in a realistic sense, the times.

As a matter of fact, at the Department of Education we have given some attention to science and technology. We were determined that one of the things that would differentiate the Department of Education from its predecessors was that it would begin to pay attention to the substance and the fabric of education, that we would find those areas where the federal government could appropriately and artfully support the improved quality of learning related to those things that need to be learned--whether intellectual skills, or subject matter, or the new technologies of the day that we all need to come to terms with. That was a main commission that the Secretary subscribed to and supported me in, even though few of us there came from scientific backgrounds. Simultaneous with the Department's creation came developments in regard to the President's concern about the status of scientific and technological training in the country, and he directed NSF and the new Department to jointly prepare a study. That was not generated under the best of times: with a very large turnover occurring in the leadership at the National Science Foundation and the new Department just getting under way, some people were in transition, having a small chance to work on both sides.

In the process of looking at all that information and listening to the talk, we became persuaded that the need is real. All of us in our field have always made claims--on the one hand, how dreadful education is in our field and on the other, how urgent it is for the nation for students to learn what we care about, whatever that might be. Still, the evidence is fairly clear, given our kind of society and the kind of issues and problems that arise every day: there are intellectual skills to be dealt with, new technologies to be mastered by all of us in different contexts, and certain kinds of knowledge--more important than other kinds of knowledge for the times we are in--to be understood in certain ways.

So the question was, after all, "What are we going to advise the President to do and what will happen after that, so that the federal government can make some kind of appropriate contribution that isn't too clumsy and may even be useful?" Now as it turned out, of course, the world goes on, and we are not going to be able personally to see this through to its conclusion. There will be another administration, another Congress, to take up the issue.

We are going to try to get two things under way. One is the effort that will result, over the next year and a half, in regional conferences and meetings that will bring together citizens, journalists, scientists, governors--whoever the major players are--to examine these issues from the standpoint of a particular region (its people and their problems) and consider, "What should we be doing in our schools and colleges here? What is the state role? What should we encourage the federal government to do?" We will try to raise the issue itself to a higher level of visibility and to somehow improve the quality of discourse among our citizens and leaders.

A second action is to start something that will result in a national commission to deal with the quality of pre-college science and mathematics education. The improvement of undergraduate science instruction probably depends ultimately on some improvements in the quality of pre-college science education, and the colleges and universities are not free of the responsibility of seeing that that improves. It simply is not enough to give the same old criticisms about the schools. Something has to be done. We will not be able to generate the whole series, but hopefully we will have them at such a point of design that the next administration will be interested in going forward with it; and we will at least get the money in the budget for that undertaking. Also, the Department of Education will--somehow in the 1982 budget, unless I am altogether wrong--have some funds dedicated to this problem from the programs.

Finally, if you are going to talk to the federal enterprise, my advice now is to remember that you will be dealing with a very large group of new, inexperienced people in Congress--and that you have a new administration that is going to be caught up in economic matters and budget-cutting.

In the best of all worlds, you would want to balance everything, connect it to everything else, but what are the two or three things that the federal enterprise ought to support to encourage the educational and scientific communities to get on with this task? If you can decide something like that, and then prepare it through the scientific communities and work through the public in these regional meetings, I imagine it will take two to four years to get what you want in place. Then, perhaps, the result will be the initiation of some things that didn't just flounder for another period of years, having meetings once in a while to wonder where we are and where we are going. It is a plea for, if not simplicity, at least focusing on what is most needed in the context of what the new federal government might be persuaded to do.

DR. BORG: I hesitate to say anything because I have such an array of reactions stemming back to 1967, when I first came to the National Science Foundation and was the messenger carrying word that funding for commissions was going to be phased out. But it seems that in focusing on the education problem, in a certain kind of political context, it is going to be hard to mobilize much funding. This means, then, that the number and kinds of activities that you would be able to get into, where you would be able to inject something to restabilize the system, would be quite limited.

And it seems to me that, also, one would look for choices to elicit action and results very quickly. Some of these effects on the pre-college area might be quite important to consider, and a lot of things point toward selecting pre-college teacher education as a first area of attack. It would be relatively easy to exploit models that you now have; more than one has been discussed here and could accommodate certain classes of students in addition to those preparing to teach, although you can't take everybody in. This would have a desired impact on the pre-college education levels. Also, perhaps you would get a lot of new blood so that the average age of the people in this room would decrease markedly. That would be very well accepted externally, certainly by funding agencies, because of the natural reluctance to see the same names for 10 or 15 years. It doesn't say anything about the quality of the work; it's just a natural reaction.

DR. TRUXAL: Of course, one way to get around that is to get young people at the Foundation.

DR. CRANE: We brought up several possible lines of attack; but most of them have not received great approval. However, I put them up there anyway because, as Jim Rutherford has cautioned us, we must eliminate most of this and get to a few really important things So as the last stage of this committee meeting, I would like very much to know from you which ones of these should have one star, two stars, or three stars. I have a feeling, and I will ask if you would agree, that a straight revival of the commissions is not a good way to go. Is that correct?

DR. SCHEIN: Strongly disagree. I feel that our commission was cut off too soon. It hadn't quite reached its prime. Given some more time, we might have reached it.

DR. GRAY: To revive the commissions as they were, or updated? Two, three. All right. One multidisciplinary commission? Who doesn't want to revive? Ten.

Comment: Just a blanket vote to reestablish commissions? I am not sure what that really means; and if you say to me either do it like it was or don't do it at all, I'm not sure that's a valid choice.

Comment: Also, are we being pragmatic? It's just ridiculous to think of reestablishing all those commissions. I'm not sure that going back to the commissions as they were is a necessary goal, but I still favor a multidisciplinary commission.

DR. CRANE: I operate on a theory that they would not go back to the way they were.

Comment: Before you vote on the next two, I am uncomfortable about the fact that there isn't either a fourth category or that the third doesn't include the possibility of some blanket organization which would provide the multidisciplinary ingredients in that last category--for instance, a multidisciplinary commission working with the societies. As someone mentioned earlier, the AAAS could serve that function, for example.

Comment: Where would your Chautauqua Program fit into your list? I want to speak on that, if there is a chance.

DR. CRANE: It would have to be in the multidisciplinary category.

Comment: Why was the Chautauqua stuck into the first category? Why isn't it in another? Just so many things ought to be said about that program. I don't think they have been summarized, but somewhere they should be.

DR. BUCCINO: If you identified the commissions' role in terms of facilitating discussion, promoting development, and acting as a coordinating agency, you might find universal agreement that those functions ought to be implemented somehow. The question is "What structure could exist for their implementation?"

DR. CRANE: What about teachers' institutes? I have heard some very strong comments both ways.

DR. BUSHAW: Several of us have long recommended that the Chautauqua Program, probably one of the best programs the Foundation ever supported in terms of its cost-effectiveness and its general ability to reach people in the field, be expanded in scope and size to include secondary school teachers. I hope that will be included in your considerations.

Comment: The Chautauqua Program did, for a couple of years, have a few successful experimental courses for high school teachers. The problem was a lack of money for both the college and the high school programs, but this format would be useful for reaching high school teachers.

DR. TRUXAL: The Chautauqua Program provides the important ability to convene. It doesn't pay a whole lot of money, but it provides incentive (sometimes the ability) for a faculty member to get a little money from his or her own institution. Extended to the high school and the elementary school levels, it would have enormous impact. Those people, even less than college people, have the ability to convene. The possibility exists for this program to move in that direction. It provides role models, senior people as course directors for the younger people who may wonder, "Gee, should I get interested in this pedagogical type of problem, or should I---"

DR. GRAY: Are you suggesting a Chautauqua Program for undergraduates in teacher preparation programs?

DR. TRUXAL: That could be a possibility, but that is not what is happening. Now it's for college teachers.

Comment: Surely the committee at this point is restricted to activities that bear on students enrolled in undergraduate institutions.

Comment: The charge said "non-specialists in postsecondary education," and these people are postsecondary students.

DR. CRANE: Let's not try to define it too sharply at this moment. How many think the Chautauqua-type activity has possibilities for our area of concern?

DR. TRUXAL: So much about the program hasn't been brought up yet. It provides for large-scale faculty involvement at about $250 to $300 per person, not even a tenth of what you put into a person if you support him or her for an entire year. In addition, it can have pervasive impact down the line because the associations that these people develop during the course are probably even more important than the detailed technical information that they pick up. Furthermore, it's interdisciplinary and could serve as an umbrella organization covering all of the disciplines represented here today. It addresses the question of transferability; it provides contact between disciplines and the convivality so essential for external support. Also, it is a good way of implementing existing course materials. You can develop this quickly; if you want to pursue the direction of computers or use of the history of science in teaching non-scientists, all of these things can be brought in so easily. The program is extremely flexible in its content. It could address the problem of preparation of elementary school teachers if you wanted it to, but it doesn't have to. All in all, it is a tested system--a good working model, as someone put it.

The Chautauqua Program is a handle. You mentioned that you can't change the curriculum committees, departments, and deans; but you can influence individual teachers, and that is precisely what this program does. It can be and does tend to be issue-oriented, problem-oriented, having a holistic view of problems. Enormous motivation can be harnessed here on the part of both the teachers and later their own students. NSF might be satisfied that it injects new blood into the program. Almost everything that has been mentioned here today can be addressed by the Chautauqua-type program either in its present form or any expanded form that one might want to move into.

DR. CRANE: Let's bring it out as a separate item. I really know only what you have told us, having been unfamiliar with it before.

DR. TRUXAL: This is fairly representative. You could skim through the pamphlet and sense the magnitude of the effort.

DR. CRANE: Concerning teachers' institutes, I have heard around the table some strong plus and some strong minus feelings about them. Some think that they are a good way of getting a summer vacation, and others think that they are a great educational process. How many of you think teacher institutes are something that ought to be revived and kept going for the college teacher? Seven. How many think no? (No verbal response.)

Comment: Can you ask the same thing at the high school level? Whether it is your charge or not, the implications for the college level are so substantial that you ought to at least get it on the record.

DR. LIVERMORE: The chief weakness of the high school summer institutes with which I was involved was the lack of provision for follow-up. Nobody knew what the teachers got when they got back to their schools. I think if they are reinstituted, that should be an integral part of the program.

Comment: I had eight that I followed up every year to find out exactly what they were doing, but I think that's up to the director.

DR. CRANE: What about curriculum development? That's a term that is always used, usually meaning "course development," although it has meant films and laboratory equipment. If federal agencies were to invite proposals for curriculum development, they would be for a course that somebody wanted to develop. Let's consider course and materials development.

Comment: I don't honestly see how we can vote "No" on this, but I presume somebody will.

Comment: But in the computer field, there is practically nothing available; obviously, somebody must develop materials at the college level.

Comment: But I don't think the federal government has to. Individuals in the field and publishers could develop the materials.

DR. CRANE: It's an item down here: large subsidies for equipment, especially computers.

Comment: Yes, but what do you do with them when you have them? Almost everybody is going to have personal computers.

Comment: I have heard several times that nothing is available in computing. Yet, if you examine the budget of the Science Education Directorate at NSF, you would find that more than half of their money is going for computer projects. Yet nobody is doing anything about computers?

Comment: But we are nowhere near the point where people use computers comfortably.

DR. HARRISON: It seems to me that course development--in a long scale of relatively small grants to individuals and institutions--is the one way of identifying the people committed to doing this; and in that sense, it seems to be a seed program for locating talent. I am just so convinced that a lot of talent out there hasn't really been used constructively but needs a little bit of support to get going.

Comment: But don't we have built-in self-starters? Isn't our personal, professional responsibility to develop our own?

DR. HARRISON: It depends on what institution you're in.

Comment: In 1960 you would have said the same thing in chemistry, physics, or biology.

DR. HARRISON: You need some free time.

DR. FRIEDMAN: I would like to share some information about the computer area. Last year at Stevens, we had a grant from the Sloan Foundation to do a study of computers as an element in engineering education. Some of the information is anecdotal; but as a result of working on this for a year, those of us involved were convinced that more than half of the engineering faculty were computer-illiterate. Although there is a lot of computer activity going on, only a very small number of people are involved with it: even within the engineering fields, where one would expect it to be handled effectively, large numbers of students are graduating without having had reinforcing experiences with a computer beyond an introductory course. They may, in fact, have been turned off in the area of computers because of the lack of coherence in the curriculum; an unfriendly computer environment at their institutions may have detracted. If that is the case in engineering--and we are addressing the need for computer literacy among non-specialists--I would contend that an enormous effort is needed nationally in order to have faculty development and curriculum development. It is a huge area but only one of those that need to be addressed.

Comment: One recurring problem is having the computer specialists fail to communicate with the general public; and there are two sides to this.

DR. FRIEDMAN: But one of the problems is that computer specialists have been able to dictate what is done because no one has been able to analyze their organization, their advice.

Comment: One of the principal recommendations out of the UNESCO Conference last July in Paris was that students should begin to learn about probability in today's world from the time they are old enough to divide and should continue to learn about it through college. There is nothing available, really, to teach probability and statistics effectively to non-science/non-mathematics students.

You say that when the material is ready, somebody will write a book; but that doesn't happen. Books don't get written to change curriculum. That's why I cited the whole curriculum project: instead of a curriculum project, one or two units put into a course stimulated authors of textbooks to adopt this material, and that was the great impact of curriculum developments in the 1950s and 1960s.

DR. CRANE: How many of you think that course and material development, including courses containing computer work and computer courses, is fruitful to pursue? Eight.

Comment: I am completely for computer literacy, but it is the responsibility of the individuals, the department chairmen, or faculties on the whole campus--not the federal government, any more than it should get into religion. The human enterprise in education shouldn't have the federal government pushing it.

Comment: Then the federal government shouldn't be involved in teaching writing.

Comment: We are professionals. That should be our responsibility, not the federal government's. I don't see why the federal government has to teach this fundamental core education, computer literacy.

DR. CRANE: Then we come to the issue of whether we need to get more students to take science courses versus whether we should learn how to teach the ones we have. It leads to the possibility of having some demonstration projects--probably financed by the government--where people could go, spend a certain length of time, and absorb new methods.

Comment: You had this as a "versus." It could be "and."

DR. CRANE: Do we understand enough about that to be able to say whether we like it or not?

Comment: One does both, you know, to some extent.

DR. CRANE: You could ask NSF to set up a demonstration project in any part of the country and to pay people to go there.

DR. ARONS: Before we try to get more students to take science, I would like to see us clean up the existing act. Students are taking a lot of science now, but it's not very meaningful. That may be a different situation than in the community colleges, though.

DR. HARRISON: The captive ones are taking it, but it's the non-captives I am concerned with.

DR. ARONS: If we learn to teach the courses that we already teach, or change them, students will be attracted to the good ones.

Comment: About 15,000 to 18,000 students a year graduate with a master's degree in the Public Administration Program, although they come in, by and large, with almost no applied science background. That is a big bulk of students!

DR. CRANE: That is an interesting idea: if we do the second one, learning how to teach them, then we have already solved the first one.

DR. HARRISON: We are learning two kinds of things about how to teach them. One may learn in the sense of what certain research tells him or her, but there is also the kind of learning that goes on in endeavoring to use that which is already known; and I would be inclined to take the position that we had better get on with trying to use that which is already known. I don't see any sense in waiting to turn out another generation of scientifically illiterate people in case our skills might get better.

Comment: Could teachers' institutes enable in-place teachers to do a better job of teaching? I think Arnold has taken a position in opposition to the Chautauqua Program--or complementary to it, I suppose--where one could have a greater exposure to an opportunity, to a learning approach; it seems to me that the Foundation could offer such a program to permit proposals for a model demonstration center.

DR. HARRISON: Arnold is addressing a particular group of non-specialists, namely those going into teaching.

Comment: I don't see anything contradictory, for that matter, in what Anna is saying; you should use the resources you have. The fastest way of solving these problems is to have demonstration projects that feed back to individual campuses. We put the people in graduate school and teach them all kinds of substantive material, but we never teach them how to teach. This would provide models for the secondary people sitting in those classes, for they already have examples of how not to teach in many cases. It's no wonder they go out and do such a poor job in the classroom; that is what they have seen for four years.

DR. YOUNG: I feel a sense of urgency about all this: of the utmost importance to our society is that, as quickly as possible, we start preparing people for positions of policy-making. Some basic understanding of science is needed by people going to management and to law so that at least some of them have a competency in the elements of science. Considering the timetable, if we had available right at this moment everything that we could do, we would graduate the first students with a professional degree in seven years. That's 1988, one of the most crucial decades in American history. I have to disagree with the two people that know much more than I do, Rutherford and Borg, on the availability of money. We are soon going to have crash programs to get as many warm bodies doing something with science as possible. A crisis situation is facing us, and to start to talk about waiting until we have learned how to do science teaching better before doing it is just utopia. It is urgent that we try to do as best we can with what we know.

DR. CRANE: And this is a longer-range thing.

DR. HARRISON: Revolutionary.

DR. YOUNG: Then why can't we do it right away? There are models around, and there are persons who teach courses very successfully.

DR. HARRISON: My feeling is to get on with it. One reason I want to have a little help on course development programs is that they enable some people to move on. Some types of institutions may not need it because of the way the institution is structured. Also, I would hate to embark on a course development with 2,000 students in the course. You have to break it into some manageable group for you to cut your teeth on--and that may take a little help in some institutions.

DR. CRANE: I gather that there is general agreement that both of these should be pursued.

DR. MATTHEWS: Doesn't that really tie back to course material development? If you are talking about a certain technique labeled "demonstration project," then it would go back to course development: that whole thing is kind of wrapped up together in my own mind.

DR. CRANE: That's right.

Comment: Arnold was referring to existing curricula, though, saying that those existing curricula had not been taught or implemented properly and that the methodology he is describing would enable proper teaching to occur. Therefore, he is really taking about teaching method, not new materials.

DR. MATTHEWS: Not new materials, but taking older materials and adapting them to his approach.

DR. PETERSON: Bob Karplus and a group of scientists did develop a set of materials called "The Development of Reasoning Workshops" and used extensively throughout the United States. They are designed precisely to hit at what Arnold was talking about, the way that learning processes relate to the various areas of science. Designed for high school teachers, they are very close to the Chautauqua Programs for college teachers.

Comment: These are the materials used in the short course taught by Fuller and Thornton.

DR. CRANE: I think everybody will agree on the next topic, which is being done to some extent already--subsidies for equipment; laboratory equipment, for example, especially computers, could be continued and expanded.

DR. HARRISON: When you address the non-specialist, many possible activities do not require the world's most sophisticated equipment. Now, if you are dealing with people who need to develop certain techniques in reference to professional competence, that's another matter. Quite frankly, if I want to teach people how to measure, I want to use instruments that have rather severe limitations on them, so that we can discuss them.

Comment: In general, this use of simple equipment for the non-specialist is perfectly adequate. However, we ought to listen to what Jim Rutherford was saying: if you are going to recommend things, you need to have some order or priority. For the non-science majors, subsidies for equipment would have a lower priority than some other things discussed here.

Comment: On the other hand, certain kinds of equipment are enormously motivational to non-science students. If you have a couple of laser canes, for example, and the students, blindfolded, can look at the different frequency characteristics (the man/machine characteristics which are achieved by different frequencies and the problems associated with navigation), this is an enormously motivational experiment for kids.

But I think we can get industry to participate in this equipment problem and indeed in the whole problem. I would hope it would be a government/industry partnership because industry has as much at stake as (and really more than) the government has in the success of this venture. This is an area where you could say to industry, "All right, we want you to match, dollar for dollar, anything the government puts in."

DR. CRANE: Are we favorable to this? How many think so? Okay, I see enough hands.

Somebody suggested that the federal government support more research in science education. That's out of my area of understanding; I don't have any opinion about that, but it was suggested.

DR. PETERSON: We have to clarify one aspect. I directed the research for the National Science Foundation's Research in Science Education Program; and basically, what the program does is to support those scientists who wish to do research on how scientists work and talk. Most of our million-dollar budget goes for understanding the thinking processes that take place when one is in the act of learning science concepts.

Question: Do the ability proposals you receive exceed, by a large amount, the amount of money you have; or is there a real need for more?

DR. PETERSON: We have about enough budget to handle the proposals coming in. We have no wide communication within the system and are not shaking the trees for proposals but have a steady client flow and research flow.

Question: Do you include evaluation studies of demonstration or other projects in that?

DR. PETERSON: Because of the size of the budget right now, we do not generally support that unless it leads to the development or the testing of some theory or notion about the way that science is learned.

Comment: In the area of science education, I would like to introduce another kind of research. We have noted the need for a multidisciplinary approach, and there have been comments about the need for probability in education as well as the need for various kinds of technological knowledge for people in journalism. What kinds of science and technology should people study to be managers in the area of business? What is the the interface between science and technology and law today?

There is a great need to identify the types of science and technology education that the various professional groups and industry identify in their day-to-day activities as needed for expansion in areas of undergraduate education. A lot of this discussion seems to be taking place in terms of the traditional categories and perhaps needs to be reexamined.

DR. CRANE: Jim Rutherford told me that he sees a trend coming for money going in block grants to states to let them try to improve education in their own areas. That will mean, then, a job of educating the people in the states as to how to best use the money. We can wait to see what happens.

DR. GRAY: I want to thank you all. This has been a most constructive meeting, and several of the committee members have expressed to me their gratitude. They have gained a great deal from it. We thank you for coming.

UNDERSTANDING THE SCIENCE KNOWLEDGE NEEDS
OF THE NON-SCIENCE PROFESSIONS

Proceedings of an Invitational Hearing
on Science and the Professions
National Academy of Sciences
Washington, D.C.
March 20, 1981

Summary

The final invitational meeting conducted by the Committee on a Study of the Federal Role in College Science Education of Non-Specialists asked representatives from selected fields--business and industry, education, journalism, law, politics, and religion and philosophy--to discuss four questions:

- Do professionals need a knowledge and understanding of science to do their jobs?

- How well is the U.S. educational system preparing, especially at the undergraduate level, persons in the non-science professions?

- What types of new knowledge and understanding do people in the professions need in order to cope with the changes taking place in their professions?

- What role should the federal government have in the education of persons in the professions?

In response to the first question, panel representatives from each field noted the necessity of professionals' having a basic familiarity with science. For instance, although politicians, lawyers, and journalists often defer to specialists in science or science policy, they need to understand the strong influence of science and technology on other parts of society in order to do their jobs adequately. Several panelists suggested that this knowledge can be gained by requiring undergraduates to have a general grounding in the humanities, social sciences, biological sciences, and physical sciences. Members of the Panel on Religion and Philosophy and those on the Panel on Education particularly stressed the importance of understanding science to professionals in their respective fields: (1) to facilitate the counseling process, particularly (for the clergy) on medical issues; and (2) to facilitate the development of basic skills of practitioners in reading,

writing, and mathematics. Other panelists, however, felt that instead of emphasizing the need for understanding science and technology per se, the professions should strive for greater communication between their members and scientists and engineers.

Of all the panelists, only one felt that members of his profession have received adequate training in the sciences. The others believe that American colleges are doing a poor job in this area for several reasons:

1. Undergraduates education stresses one's having a solid foundation in a major area of study, decreasing his/her opportunities for study in non-major areas such as science.

2. For whatever reasons, students in other disciplines tend to avoid science courses in general.

3. Scientists and other professionals seem not to understand each other.

4. The standards of liberal education in the United States have been greatly reduced in the past few years.

Another factor that undergraduate institutions have been unable to overcome is the fact that a student's predisposition to one of the professions seems to preclude his/her being interested in science. Panelists noted, too, that inadequate preparation in science begins in the pre-college arena: (1) science is not taught whenever it can be avoided by a teacher, particularly in the elementary school; (2) teachers often do not use modern textbooks, even when they are available; and (3) lack of classroom discipline and teacher burnout detract from instruction. The result of these problems in education, according to one panelist, is "people very skilled in particular, narrow areas but with very little sense of the relationship between technology, the humanities, and psychology and what they are doing."

After expressing such dissatisfaction with the U.S. education system, participants in the hearing were not hesitant to describe what should be included in the undergraduate curriculum for non-scientists. All panels agreed that members of the professions need a general understanding of science and its implications for society at large as well as recognition of the need for interdisciplinary communication. They agreed that this would incorporate a knowledge of the scientific process and the philosophy of science--including the principles of parsimony, indeterminancy, and statistical inference; the concepts of probability and causality; and the primacy of observation. One panelist even urged that undergraduates learn that science "is not a body of certain, immutable, fixed, and precise principles." Specific knowledge was also deemed essential in individual fields:

- Recognition of the social sciences as being as important as the natural and physical sciences (to politicians),

- Understanding of the "cross-influences between law, science, and technology" (law),

- Recognition of educational experiences in the sciences needed by businesspersons (business and industry), and

- Knowledge of genetic engineering, nuclear energy, and environmental issues (religion and philosophy).

To develop this knowledge and understanding, the undergraduate curriculum must be reorganized, so that greater emphasis is given to courses in communication/semantics and the sciences--such as chemistry, computer technology, economics, logic, physics, biology, psychology, and statistics. In summary, the educated citizen should be broadly exposed to science and technology, and the undergraduate curriculum should enable students to develop individual philosophies that will help them to adapt to the rapid changes in our society brought about by scientific and technological developments.

The next issue in the panel discussions was the role of the federal government in the education of non-specialists. Most speakers viewed the government as the catalyst behind all developments in the education of non-specialists, citing funding as the primary federal function. They felt that the government should provide funds for the following:

1. To address the question of improved reporting of science and science-related issues,

2. To promote scientific research, including research about how people learn science and mathematics,

3. To upgrade the scientific, mathematical, and technological competencies of teachers at the precollege level, perhaps implementing the Indiana Model (page 212) throughout the country, and

4. To improve the teaching of science courses by upgrading laboratory apparatus, especially microcomputers and microprocessor-based equipment.

Three other strong recommendations from the panelists were for the federal government (1) to promote innovative curriculum development by supporting pilot programs that deal with the interrelationship of science and society; (2) to develop courses having a cross-disciplinary approach in order to show non-scientists the importance of, need for, and uses of science and technology in the performance of their future professional tasks; and (3) to expand the scope of summer institutes, seminars, and workshops not only to help teachers--and ultimately, their students--to better understand policy decisions, but also to foster communcation between non-specialists and scientists by inviting members of the non-science professions to participate in these meetings. These suggestions were implemented by others dealing with specific professions.

Before concluding the hearing, the committee asked panelists to discuss other aspects of the question of education for non-specialists. One member of the Panel on Politics urged greater communication between scientists and policy makers: ". . . only when our political leaders realize that management in the federal government has little knowledge of the values and mental habits of scientists and [that it unintentionally] frequently leaves scientists off their team will the policy approach be improved." A journalist followed this, noting that scientists have difficulty "in translating their knowledge into English that the reporter can understand." A lawyer expressed concern that some professional schools, such as those of law, don't encourage their students to understand the sciences. Another problem, addressed by an educator, is that the students in the non-science professions opt not to pursue science courses. The committee was encouraged when one businessman said that industry has the responsibility to help academia prepare individuals to cope with our changing society. This sentiment was conveyed by another panelist, who said that such complex issues as the education of non-scientists should not be left just to the federal government: "what this suggests is a very complex partnership involving various elements of society in this very large debate."

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Participants

Panel on Politics

Thomas Mann, American Political Science Association, Washington, D. C.

Judith Sorum, independent consultant, Washington, D. C.

William G. Wells, Head, Public Sector Program, American Association for the Advancement of Science

Panel on Journalism

Christine Harris, Director, Consortium for the Advance of Minorities in Journalism Education, Northwestern University

Malcolm Mallette, American Press Institute, Reston, Virginia

Panel on Law

Harold P. Green, Fried, Frank, Harris, Shriver, and Kampelman, Washington, D. C.

Lee Loevinger, Hogan and Hartson, Washington, D. C.

William A. Thomas, consultant, American Bar Association

Robert B. Yegge, Professor and Dean Emeritus, University of Denver, School of Law

Panel on Business and Industry

Jerrier A. Haddad, Vice President for Technical Personnel, IBM Corporation, White Plains, New York

Robert P. Stambaugh, Director, University Relations, Union Carbide Corporation, New York, New York

Panel on Religion and Philosophy
The Reverend Michael P. Hamilton, Canon, Washington Cathedral, Washington, D. C.
David Smith, Chairman, Department of Religious Studies, Indiana University
LeRoy Walters, Center for Bioethics, Kennedy Institute, Georgetown University

Panel on Education
Hans Andersen, School of Education, Indiana University
David Lockard, Science Teaching Center, University of Maryland
Herbert Striner, Dean, School of Business Administration, The American University

Invited Observers
Joel Aronson, National Science Foundation
William Kelly, National Research Council

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Introduction

Dr. Gray introduced the Committee and staff members and then explained the purpose of the hearing--to assess how professionals feel about their fields. What kinds of needs do persons in law, at the head of business and industry, and in journalism have in the area of science education? How often must they come to grips with questions pertaining to science and technology? What kind of understanding and background do those public opinion leaders need to make intelligent decisions concerning issues that involve science and technology?

Panel on Politics

DR. GRAY: We will begin with a discussion of politics. William Wells formerly was staff director of the U.S. House of Representatives' Committee on Science and Technology and in that capacity had wide exposure to civil servants. Interestingly enough, he has training in science at the master's level at Purdue, but his doctorate is in international relations.

DR. WELLS: Let me just address the questions as presented by your committee. First, do individuals working in the field of politics need a knowledge and understanding of science to do their jobs? The answer is "Yes," not so much with the details of any particular science or any particular technology as with the implications, the impact, the effects, and the interrelationships with other facets of our society. Unfortunately, some staff members and some politicians have fallen into the trap of trying to become too expert in some narrow field of science or technology or some program that catches their fancy. There was nothing worse, in my judgment, than the having Congress try to design a space system on the House floor during debate, but unfortunately, occasionally this sort of thing happens. Horrible mistakes have been made when political decision-makers lacked the fundamental comprehension of the nature of science and technology and the nuances involved in the role of science in society. These mistakes evolve from the blind faith that any problem can somehow be solved if we only put enough bucks or enough scientists or engineers to work on it. Examples of these kinds of mistakes are all over the spectrum; for example, in the early 1970s President Nixon's war on cancer led to the marshalling of such vast resources in the Cancer Institute at NIH that the allocation of research dollars was completely distorted in the whole health/biomedical area. The feeling was "Now if we can land a man on the moon, then somehow we can conquer cancer." This notion of war on cancer grew from misperceptions and misunderstandings of what the role of science was, what science can produce, and really what the whole state of science was at that particular point.

A current example of misunderstanding what science is all about is the systematic elimination of social science research by the Reagan administration, as revealed by the current budget reviews ranging from the National Science Foundation to NIH, to the Department of Energy. There is almost a vendetta under way to somehow eliminate this whole field of science from federal support. Somehow it is understood by those leading this particular attack that the needs and values of the social and behavioral sciences have changed and that scientists should quit monkeying around with people's lives.

Second, how well is the U.S. educational system preparing, especially at the undergraduate level, professionals in politics? Again, understanding of science in this particular context is, in a word, terrible. Somehow we have lost touch with the realization that the educated, literate citizen should be broadly exposed to science and technology. It is interesting, on an historical note, to recognize that in the 17th, 18th, and 19th centuries, the great discoveries in science did not always come from someone in the professional sciences but instead from people in the other professions where science actually was an adaptation. The consensus that the study of science was part of one's broad education was greather then than it is today. This educated, literate citizen could be defined as one being exposed not only to the great ideas of art, the humanities, and music that are aspects of culture but also to broad elements of science and technology. I would look at this in an analogous situation: just as the scientist and the engineer should also be exposed to the arts and the humanities, non-specialists should be exposed to the sciences.

I forever am grateful to a professor of mathematics who grabbed me as an untutored 19-year-old whose sole idea was to take only physics, chemistry, and mathematics and who believed everything else was a complete waste of time. During the couple of years that I was exposed to this very wise man, he introduced me and my fellow scientists and engineers to music and art, gradually inculcating in us the sense that because we were part of a very large culture, it was a mistake to become narrowly focused on just our engineering and science.

However, why is it important for us to have science and technology broadly based? Well, all citizens have to be involved in the great debates of our society that increasingly involve science and technology in some manifestations. For example, today we are in the middle of a virtually nationwide debate on the whole subject of creationism versus evolution. An issue that is not going to go away, it resurfaced in the mid-1970s with attacks on the National Science Foundation and its social science education programs. This is not a debate solely for the biologists or the anthropologists, but rather one for all of us because it does affect the fundamental basis, nature, and understanding of what science is about; the role that science plays; the ways of scientific thinking; and the meaning of scientific evidence. All of the issues are important to everyone, not just scientists and engineers. Also, we need further consideration of the ethical issues in science. We increasingly involve the citizenry in medical issues, research subjects, and we should not leave to Viktor Burkas and Jascha Yul the full debate on the future of technological civilization. We do have great problems but not as bad as shown by their very pessimistic views.

Third, what types of new knowledge and understanding do people in politics need in order to cope with the changes taking place in the profession? Change wrought by science and technology is affecting all of society--law, medicine, economics, business, and so on. It is not so much the details of any particular science or any particular technology as it is the implications, the impact, the effects of these areas on other facets of our society. Radical institutional changes have been under way--and are under way--with respect to the whole structure of society as it has evolved in the western world over the past 300 years. Many of them have taken place because of scientific and technological advances that we need to understand far better. We need a long view of what they are going to mean for the future of our society. They are bringing into collision a number of fundamental political premises and ethical premises upon which a different society was based, those of 18th-century European philosophers. We need a broader understanding of the particular debates that will arise as we consider the kind of society we want to construct for the future.

Fourth, what should the federal government do about this? Determining the federal government's role is very difficult, but basically there is no single responsibility that I see for the broad, stimulating, continuing examination of our educational system. We need, certainly, to look carefully at what should be centralized at the federal level without disrupting the decentralized nature of our educational system. It is a mistake, for example, for the federal government to pull totally out of curriculum development, as is the current trend. There is a federal role in innovative curriculum development dealing with the interrelationship of science and society, for no one state, one school district, or one university is able to marshal the resources required for these rather broad changes.

In general, we need to look at the federal level as well as at the state and local levels, at the whole relationship between secondary, primary, and university systems. What should be taught in science, for example, at the elementary level? There is a role for the federal government to help in these analyses and research. What is the burgeoning impact of information technology on our educational system at all levels? We are going about this willy-nilly with little attention to what is happening right under our noses, a major revolution of technology, but very little attention is being given to the implications of that technology, either at the elementary or the university level. For instance, engineering school faculty are basically looking at the computer as the replacement for the slide rule, but that is a very narrow and shortsighted kind of view of the computer and technology.

Finally, what other considerations should be made? These complex issues cannot be disposed of in a brief, 10-minute review like this; but I would remind you of H. L. Mencken's words, "For every complex problem, there is always a simple solution and it is always wrong." That bothers me about much current thought on this topic: the Reagan administration seemingly feels that every one of these complex problems that we have been wrestling with and will continue to wrestle with can somehow be solved by a simple equation.

We have to guard against that in your particular deliberations. To restructure and reexamine the fundamentals of the entire education system is not a simple task. Education is far too important to be left just to professional educators or to the state and local governments, let alone to the federal government. What this suggests is a very complex partnership involving various elements of society in this very large debate.

DR. SORUM: When I talk about the importance of science education to my profession, I am talking about people serving in the executive branch of the federal government in managerial roles. At the Department of Labor, I had responsibility for race relations, consumer affairs, and a strange melange of issues. I found that piecemeal we were not putting together a team with diverse enough intellectual tools for solving the problems we were reviewing.

Out of all this comes a variety of considerations concerning the exposure of people such as career bureaucrats to the kind of scientific knowledge and undergraduate education needed for a good job foundation. First, people in important positions must understand the value of having a good mind and being sensitive to the scientific process. Second, in high-level management there really are specialists who understand the value of those concepts of education and are able to use them effectively. The government should increase the level of training and responsibilities of individuals so that we don't continue to find students with managerial backgrounds but more and more narrow educations. I have a fine background which had had no science and math for a long time. Yet one of the things that I am responsible for in the front office is solving major computer problems in, for instance, the employservice computer system. Not wanting to step into the problem-solving area, I came prepared with only a crash course that partially summarized the debuggery of a computer program. I saw that most of the federal managers were so illiterate in any use of computers that they were not able to manage their own staff who had some computer background. Therefore, they needed to rely almost entirely upon the translating skills of the consultant firm to tell what was needed for them to deal with their own people. The main questions when using the computer used to concern who was going to do the programming and how that should be arranged. I found that the managers so lacked such knowledge and interest that they were unable to cope with their own staff.

Although today everyone thinks of the economy in terms of what kind of quantitative bilge can be brought to bear on the problem, I found very few scientists and policy-makers talking to each other. The lawyers continually talk to the economists, but not the scientists. The managers--having little grounding in math, the biological sciences, or the physical sciences--have grown inordinately reliant on the economists to translate the difficult truths that are involved. We need to increase the skill of federal managers in understanding the habits of scientists and the particular weight which they put on problemsolving, the basic form of good research and research questions from the perspective of those disciplines as well as from the social sciences.

The scope of managerial skills is narrow. However, only when our political leaders realize that management in the federal government has little knowledge of the values and mental habits of scientists and frequently leaves scientists off their teams will the policy approach be improved.

An increasing error comes when students lack the technical backgrounds for doing their jobs. What type of new knowledge and understanding do they need? I think it is much less specialist-oriented.

What role can the federal government play? There needs to be some attention given to understanding our science people and computer technology. Where possible, there must be a way to provide people with a solid grounding in the sciences and to consider for management positions people who are clear-thinking and intelligent scientists.

DR. MANN: Politics as a profession is an interesting conception. When Pam called me, I kept asking more and more questions: What do you mean? Are you really interested in political science? Politics, what is that? After all, how large a profession is it? Are we talking about active politics or about appointed executives who manage science programs and other programs with a clear science content? I think what we are really talking about is elected politics at all levels--local, state, and national. It may be civil service as well, although those of us who work with fellowship programs on the Hill have a sort of natural tendency to focus on Congress and things about it, finding the politics in some ways so much more interesting.

Let me just make two points. First, in many respects, the decision-making process has not changed all that much in the last decade or two with regard to science. While overall specialization has really broken down in legislative bodies and we have begun to recruit a new type of politician who fancies himself or herself as being an expert across the board, we now have House members who act like Senators: they have positions on a range of policy areas. Politicians are merged in the media world and live in it and therefore tend not to focus on a particular policy.

In science, the old way works much more. My experience is that colleagues defer to specialists in science policy; and therefore, on science matters one can have an impact by affecting the quality of the

Congressional staffs that work with committee members on science matters and with the handful of members caring directly about science. There is no way of educating all politicians in science or any need to do so. The best one can hope for is a sort of benign attitude towards science that it is mysterious but, in general, does something useful and good.

At best, maybe a little bit of literacy will be gleaned from watching "Cosmos" or something like that, but it is unrealistic to expect more or necessarily to want it. In some ways, a little knowledge is a dangerous thing, as we find out in other policy areas where people feel more comfortable speaking out. In a sense, we have been helped by maintaining the legislature's specialized system of decision-making on science matters. It has improved because we have brought to the Hill people who have science backgrounds and who have learned the art of politics, and the two are a wonderful combination scarcely seen in the past.

When I say science, I am really talking about the physical and natural sciences, although social science is a part of your mandate as broadly conceived, because politicians perceive social science in an entirely different manner than they do other science. All politicians believe that they are natural social scientists and that social science at its best is basically practical understanding, real-world knowledge, everyday life. As a consequence, the attitude today social science per se--with its pretensions about scientific method and the like--is very negative; most politicians have a blind side toward social science and its utilities. For example, they use demography, but they do not think of it as a tool developed from decades of work in the social sciences. They look at the results of evaluations research but have no conception of how its techniques were developed over a period of years in social science disciplines. This general problem reflects how citizens and students feel about social science.

Political science is a smorgasbord of public affairs and what one sees in the newspapers. There is no sense of sequencing or building knowledge over time. There is no real sense of counter-intuitive findings, the nature of discovery, or the tools used to build up a body of knowledge over time and to ask questions that would not otherwise be asked. The whole sense of excitement in the scientific method that actually comes through in a specific class--for example, a chemistry class--simply is not present in most social science classes; instead, we get everything that is topical.

The social science curriculum in the high schools is just dreadful. It sends out all the wrong signals about social science as a science, and it leads to the public belief that social science is social engineering and nothing more: it is simply substituting your values for my values; there is no analysis involved. I have a bias because I work with special kinds of associations. I am trained as a social scientist and believe that many of our problems involve human organization or perception, cognition, and the like. To expand one's thoughts on the social sciences, the whole climate about new knowledge in the social sciences has to change. That seems to be a challenge for science education.

Question: Those who had spoken before you came in had discounted the necessity of much in-depth knowledge of the particular sciences. They had been inclined to talk more about understanding thought processes and methodologies characteristic of the sciences. Despite this view, you attributed to the politicians a hostility towards the social sciences, saying that we need an understanding of scientific methodology --how scientists proceed to develop hypotheses and systems, how they quantitate methodologies. Could these be developed from not only a natural science background but a social science background?

Response: That is absolutely what I am saying. What is needed is a change of attitude, which comes only from an understanding of the scientific method in the context of social science. I would not push for better general and more in-depth understanding of sociology and substantive findings in sociology at all, but I would focus very much on methods and analytic tools in the context of questions about social organizations.

DR. WELLS: Increasingly, concepts which are mounted in risk assessment and risk analysis are fundamental to understanding what works and how one makes decisions. Somehow, we need to inculcate into the education system better grounding and experience in those areas, to involve these interfaces with these particular capabilities in order to understand how we can use these particular insights; that is fundamental to the decision-making process. Very intelligent politicians otherwise won't understand the nature of the trade-off except in a very broad political context; and they now have such difficulty in anticipating how trade-offs come out of conditions in which you cannot give the unequivocal answer that they expect.

Question: Do you mean that because we have done a poor job of educating politicians in the sciences, they tend to think that scientists have the ultimate answer whereas the social scientists do not?

Response: Yes, absolutely. It is a caricature on both sides because they know they have this sort of physical, natural side but fear digging in; they feel a loss and, therefore, defer to their colleagues.

DR. SORUM: There is a tendency to see something mystical about science. Teenagers don't understand and don't have a grounding in it, but that is probably not relevant to most of the vague questions involving science problems like OSHA and safety. Yet we have a tendency in an agency like Labor to assume that things in certified research operations must be reported, and then we turn to the social sciences to determine services and operations. It is a problem from that perspective. Just having an inordinate respect for the usefulness of the social sciences and the involvement of scientists at that level would lead to greater interactions of managers who better understand the value and implementations of science.

Response: That is very interesting. There really is a difference between those elected by the legislation and, in this case, those working in their agencies. The agencies have to work closely with social scientists; they carry out formative social experiments and understand the work of social scientists through the agency manager.

Question: I don't really think that the Congress is unaware of this problem or that they deal with it in any different way than people in the executive branch. After all, the Congress decided that the National Science Foundation should specifically conduct work in the social sciences. The Congress determined and supported the establishment of science fellowships. The Congress decided that the president ought to have an Office of Science and Technology Policy. You can debate how people look at each other, and obviously this whole matter of communication is very difficult; but that is only what we are talking about. How do we get a better way for people in different disciplines to communicate? Why is it that social science courses are so terrible in the secondary schools?

Comment: We could ask the same question in reference to college work.

Response: Yes, although it is somewhat less of a problem because there at least a number of people begin to specialize in particular social sciences so that we begin to see an accumulation of knowledge and an understanding of method and its usefulness in a range of fields. However, it is really quite possible to pick up a general undergraduate education in the social sciences and not learn very much.

This results from a combination of things that are subject to tremendously pluralistic disciplines. Political science has a strong element of practical political philosophy based on institutional analysis and antagonism for the scientific method; and in parts, one can go off on a stream that offers little exposure to those methods, particularly in the pre-college. First of all, various disciplines own the turf in high school and elementary school. For example, state legislatures mandate certain kinds of instruction, and some people have fought for that turf. And then teachers seeking to embellish the offerings have attempted to delineate the topics covered, often developing a course for whatever is up at the moment politically with no sense of its underlying structure or knowledge of method. Mainly, a course like current events is offered, so that students think there is nothing there that they can't get by reading the newspaper and Time magazine.

Question: Does that happen on the college level, too? Are there similar topics or research areas which agencies will fund so that courses somewhat tend to reflect those areas?

Response: College courses aren't nearly as much influenced by large-scale curriculum development projects and other courses. Colleges now are seeking fees and therefore search for courses that would be attractive to lots of undergraduates. The tendency is not to offer the esoteric, specialized courses; in fact, those are fading, being replaced by popular ones that appeal to a large number of students. There really is a sort of a shopping in colleges now, just because of the economic crunch within the system and the universities.

<u>Question</u>: You have spoken about the awareness or sensitivity that is needed and the deficiencies in the current system. What role <u>must</u> the federal government play if, in fact, the perceived need is going to be addressed effectively? The tendency is to decentralize and to make concessions to the private sector. If the committee is going to have an impact, probably it is going to be because of the abilities displayed. Whether or not that will happen is unclear, but there is an indispensable federal role.

<u>DR. WELLS</u>: One way is the continuation and expansion of summer institutes for educators. This program is one of the items within the current Reagan budget to be eliminated. But the need is to expand that kind of approach beyond its earlier focus, acquainting teachers with research in their respective areas. The federal role for expanding them would include the policies, the issues, and the decision-making problems so that educators then can convey to their students a sense of what is involved in some of these very large areas. An example is the debate between the National Academy of Sciences' Food and Nutrition Board (FNB) and the Congress and the Department of Agriculture concerning some older misperceptions about the role of scientific evidence. The FNB has reported that we cannot at this point conclude that salt, sugar, and fibers are dangerous elements in one's diet. This board says, "No, our scientific judgment is that the evidence is not in yet, and we will only make a judgment about these things when the evidence is conclusive." On the other hand, those in the Department of Agriculture and some of the Congress have insisted that evidence of the danger was unequivocal. So we have this collision of what people want to perceive about the evidence and what the scientific community says. This is fundamental to understanding the nature of scientific rules and scientific evidence and goes right to the core of most national issues raised by the board. We need not only to reach the students but also to inculcate teachers with a better understanding of these kinds of decisions.

<u>Question</u>: Have you touched on curriculum development?

<u>DR. WELLS</u>: It is a dreadful mistake for the federal government to move out of curriculum development solely as the result of the major fight in the mid-1970s over one social science course--Man, A Course of Study --because it presented a perceived conflict of values. That course taught fifth and sixth graders that different cultures have different sets of values. The case in question discussed an Eskimo culture in which the elders were traditionally placed on ice floes when they became no longer productive. Another tradition was that one whose brother had been killed would be responsible for the care of his wife, taking two wives in some cases. This course led to major controversy that nearly wrecked the National Science Foundation because of this imposition of an alien sense of values on the American heritage. That

sort of debate led to the National Science Foundation's withdrawal from curriculum development, in civics or anything else; and that was a major mistake.

Comment: There is a concept that if we all understand the same technology, we will arrive at the same decisions about what ought to be done, but this seems to me absolutely not true. For example, at the time of the Three-Mile Island incident, even those well-informed on scientific and technical knowledge were exactly opposed in taking up the decision of how to handle Three-Mile Island. This brings on a concept of quality of life, quality of the environment. Their positions were not coming from their scientific values, but from other values that science has nothing to do with whatsoever. I think we would not want it any other way. But I have become awfully nervous because of people who discuss with students what seem to be value judgments having nothing to do with science itself; what they are doing is projecting their value judgments onto people unable to defend themselves. This makes it extremely difficult to talk about the kinds of things one might have done in the educational system, for many actions required a rather high level of participation and maturity.

You have several times used the phrase, "values and habits of mind of scientists," but as a scientist, I don't know what you are saying.

DR. SORUM: Let me clarify that. Thinking of values, I rely on evaluating data concepts and data context as well as the rigor of response, the reliability. In fact, flight into science is blind. Science is so exciting; yet the public community accepts what goes on. So many people give their lives to trying to find some new variant on old science, and that perhaps is one of the things that hinder us, even if it is otherwise meeting needs and helping people to understand.

Comment: I have worried a lot about this question of values. As far as I can see, in science per se there is nothing that gives a scientist any advantage over a non-scientist for making the same decisions dealing with the quality of life and the environment. Now, there are values within science itself--how you design an experiment and carry out scientific work, what you do with data, how you assess the data, what conclusions you draw. That is, science has to do with that which is fact and can be checked.

DR. WELLS: A good point that probably needs to be explicit is the disentanglement of one's personal values from one's professional arguments. It is reprehensible that Linus Pauling is using his Nobel Laureate to push Vitamin C; he has absolutely, totally misused a power by following a thesis that has nothing to do with scientific evidence. That kind of untangling is what people need the equipment to do.

Comment: The mysticism associated with scientists leads to the transfer of all kinds of authority to other areas in which they really are not an authority.

Comment: And also, you really do not expect scientists to speak out on public affairs. They may not be wrong, but part of this comes down to the old argument that having in the Congress a science committee composed completely of scientists leads to anticipated problems.

Question: People, especially in elected offices, treat social science as not-science; and at the same time, the government generally spends much more on social science than on natural science. The question of why that is the case and the implications of that for curriculum development seem to be very important. Does the Mickey Mouse and non-scientific nature of social science courses that most individuals in political life are exposed to, in fact, lead to this dependence on social science knowledge to the exclusion of its interrelationship with natural science? If we improved the social science curriculum and made it more scientific, would that then distance social science from the political process in the same way that natural science is now distanced from the social science process?

I am in some ways confused. If I look at areas of natural science --such as chemistry, physics, or the biological sciences--economics as an ideology, a profession, and a scientific endeavor seems no less complex in its intricacy than these sciences. Yet, at the same time, we have this enormous dependence in the political process on professional economists and their expertise in the making of public policy but not such dependence on physicists or chemists even in areas where their expertise is quite relevant. The question is "What are the social mechanisms that produce such dependence, and how does that relate to the educational system, especially at the post-secondary level?"

This committee ought to be quite concerned about relevant instructional goals in the sciences for non-scientists at the college level. I am still very much confused about what "relevant goals of instruction" are. We have had a lot of discussion about respect for scientific inquiry as a mode of human activity. We have had a devaluing of specific scientific knowledge implicitly because, for public policy purposes, there is so much of it that no one can become expert in it. How would an undergraduate curriculum for non-scientists be designed in order to produce any relevance, knowledge, skill, and attitudes which would improve public debate and decision-making about relevant public issues?

DR. WELLS: I would like to teach a course at the undergraduate level on the greater issues of today, selecting about 10 issues that have a high scientific and technological content but not talking about them as science and technology today. One issue brought up here is risk and probability as an underlying concept in some decision-making. We are talking about 18-, 19-, and 20-year-olds who will be in positions of political authority in 25 to 30 years. It seems to be totally stupid to think that we are going to give undergraduates specific kinds of knowledge that will be useful in their political decision-making 30 years from now.

Question: I am not talking about specific knowledge. I am talking about ways of thinking, ways of analyzing, ways of challenging them. Although I don't know what the definition of "ways of thinking" is, we do have a mythology of commonality about scientific method, which at some level means "intelligence and systematic procedural ways of perceiving information." Beyond that, we have considerable variation in the way in which we proceed. The question is "Is there any commonality that one can communicate other than to tell people to be intelligent?"

DR. MANN: Duality occurs less because of a social mechanism in the education system and more because of the situation the decision-makers find themselves in--having to make decisions about macroeconomics and, in the agencies, having to make decisions about tinkering with modes of implementing. It so happens that in those settings, social scientists doing that research speak directly to the issues and thus rely on them.

Question: We understand your agreement that neither the natural science attainment of students nor the social science attainment is adequate. The natural sciences are to a large degree now experienced by the student at the college level, and my impression is that the social sciences are rather extensively experienced. We think we have a problem because some people don't have any experience, and then we have a problem because they do have experience. Now, what can you offer?

DR. WELLS: Well, in social sciences I think we argued that it was content, structure, and approach rather than the fact versus the abstract. People can go through the whole college system without ever having been exposed to political science or ideas on science and technology.

Question: If it doesn't work in social sciences, why would it work in natural science?

DR. WELLS: There is a difference between this and what I am talking about. Last year I went to an American Psychological Association speech on the issues of the social sciences and politics; that attracted only 40 to 50 people. Down the hall 2,000 people filled the auditorium where the topic discussed was sexual responses in the male.

DR. GREGG: One question has to do with the minimum federal role and what we are trying to deal with. When I was at the Sloan Foundation, its major concern was literacy; and it seems to me that whether you are in the business world or in the federal government, you are facing three unavoidable major forces that the citizens will have to be involved in, although they can abrogate their responsibility if they would like. One is that the level of investment required to deal with the scientific and technological problems of today is extremely high. Second, it requires a considerable amount of lead time. Third, if you are wrong, you are really wrong; the consequences of failure are enormous.

I listened to economists talk with great ease about their good notions of the supply side versus some other side. If we follow with a sense of devotion the theoretical bases that some of these schools now believe are going to solve our problems, we won't find out if they work for 10 or 15 years, and then we will have to go through a major retrenchment, losing generations in the meantime.

One of the major concerns that the federal government ought to have is determining the acceptable level of public literacy necessary for them to participate in the debate and have some kind of input. The consensus here may be that if you are not trying to transmit some understanding, then you are probably adding to the likelihood of having a mistake.

The second point is "Can you deal with science and not deal with values?" Kids have challenged us, saying that they want to get into solving real problems. We face that every day in the medical field. There is no drug without a risk or some side effects. Scientists can decide that they want to deal with only the pure aspect of the drug; but when business has to decide if the risk is acceptable, scientists must decide whether to sit in on that discussion. And if a scientist does participate, he must bring to it some values as to what is a reasonable level of risks. The major dilemma that we have to face is whether the efficacious nature of a new drug overweighs or overshadows the risk effect. The scientist, if he wants to go from theory into the real world, has to somehow deal with values, and his values are a part of it.

The issue I wanted to raise--and it takes me back about 15 years when I with some trepidation appeared before Congressman Daddario's committee to talk about the cost of graduate education--is that if you leave college education to a free market system, any administrator who wants to control costs will cut the science program to as low a level as possible, allowing the other parts of the program that do not require heavy investment to then be the leading forces. To what extent is cost going to be a part? I know the problem of the topical aspects of political science, but they are probably very low-cost courses to put together. The cost of building the pitch-scale notion of additive understanding of scientific nature is extremely common. How much is economics a factor? And should the federal government be able to rectify that imbalance so that the marketplace does not skew implications of the direction for lower-cost education?

<u>DR. WELLS</u>: Sure, absolutely. That is the reason that I am so opposed to the termination of the United States Science Education Program, where the dollar cost was relatively small but where the national agency played a very large catalytic role in its dollars and programs.

<u>DR. MANN</u>: It comes in, not just through the science education budget but more directly. The University of Michigan, one of the best institutions for engaging in social science research, has its impressive survey research center, the Institute for Social Research. But the federal government's actions on social science research have led to the departure of four major social scientists so that I expect to see that institution weakened. Quite apart from the dollars that specifically go into science education, the whole apparatus has to be maintained, but what is the federal role in this?

Attitude and legitimacy are a problem, making basic research the key to science education activity. Then, the problem is the quality of the people in research. Many institutions have turned to disincentives; and therefore, without pre- and postdoctoral fellowships, the quality of social science research will decline so that what we have to say may not be worth transmitting through science education programs. That is as great a problem as curriculum development and inservice training programs.

Question: You have all talked about the importance of economists' communicating with scientists and lawyers and having a better way to talk to each other and understand each other's language. Should we, at an early age, continue to have courses which would separate the scientists from others and obviously affect communications later?

DR. WELLS: I am reluctant to separate children too early, however early the indications are. At some point, we must begin to reach children with some aptitude (and not necessarily just science, either); but we ought to be cautious about those kinds of endeavors too early.

Question: Are you concerned about mixing non-specialists with medical students in college chemistry courses?

DR. WELLS: We can mix these people if we remember our earlier discussion. You can't foresee what is to develop from those kinds of discussions and debates that are precursors of real-world debates between lawyers, businessmen, and economists.

MR. DADDARIO: When we were talking about this whole business of education, the question of what government must do arose. This goes back to our Congressional hearings of some time ago. A. Hunter Dupree at that time, when there was a little bit more money for science than there is now, said, "Education must take account of the humanities and the social sciences as well as the physical and biological sciences. The fields outside the conventional definition of science must be included in and partake of the same rationale as made government-supported science possible. Therefore, the government must come to see strong and effective intellectual activity regardless of field as a national necessity."

Panel on Journalism

MS. HARRIS: I asked 12 journalists and journalism educators the questions that you had put before me. The questions were whether generalists need a knowledge of science to do their jobs, whether the higher education system is doing an adequate job of preparing journalists to master the science meanings in their work, and what role the federal government can play in providing necessary educational opportunities for journalists to do a better job.

I would like to give you a little bit of background about the schools involved in the Consortium for the Advancement of Minorities in Journalism Education. First of all, 102 historically black colleges in the nation still have a predominantly black student enrollment, and six of those schools have a total of 1,428 students studying for careers in journalism or another area of communication. While many of these schools are more than 100 years old, their journalism programs are fairly young--a consequence of the fact that, by and large, blacks were excluded from journalism until the urban riots erupted in the 1960s. The oldest communications program is at Hampton Institute in Virginia. Although Hampton, which is 112 years old, did not have a department of mass media arts until 1967, today there are 284 students in that program. Howard University, here in Washington, has a School of Communications, in which 216 students are preparing for careers in journalism. There are 534 students in the mass communications program at Clark College in Atlanta, and the other three programs are at Florida A&M University in Tallahassee (which has 119 journalism majors); North Carolina A&T University in Greensboro (with 150 students); and Norfolk State University in Virginia (with 125 students).

I interviewed key people at these institutions: Dr. William Carney, chairman, department of mass media, Hampton; Dr. Gloria Walker, director, mass communications program, Clark; Professor Robert Ruckels, director, department of journalism, Florida A&M; Dr. Richard Moore, director, program of mass communications, North Carolina A&T; and Dr. Pam Johnson, associate professor of journalism, Norfolk State. I also interviewed Dr. Lawrence Cobb, director, journalism program at Howard University, and Dr. Wallace Terry, who is on the faculty at Howard.

In addition, I interviewed five other persons: Charles Gene McDaniel, director of the journalism program at Roosevelt University in Chicago (Professor McDaniel was a science writer, by the way, for the Associated Press for a number of years and remains a free-lance science writer); Derek Blakely, a correspondent for CBS television network news; Claudia Richie, an energy and environment reporter for the <u>Chicago Sun-Times</u>; Jacqueline Thomas, an urban affairs reporter for the <u>Sun-Times</u>; and Roger Witherspoon, a health and science writer and a columnist for the Atlanta <u>Constitution</u> for the past two years. Of these last four, the only person with a science background is Claudia Richie, who has an undergraduate degree in biology.

All of the persons I interviewed did agree that an understanding of science is imperative for journalists today. There are just too many science-related issues--including pollution, energy, nuclear and chemical wastes, space exploration, the environment, public health and medicine, and controversial research and experimentation--that journalists must cover today.

There was disagreement, however, on just how much and what type of science education journalism students and journalists need. There was general agreement that the best education a journalist can have is a solid and broad liberal arts education that includes science and math courses. None of the persons I interviewed advocated that journalism majors must have a second major in a science, but two educators expressed concern that students should receive more science than they currently do. Professor Terry thought students should be required to take more math and three or four science courses. One person felt not only that students should take more science but that more should be counseled to minor in science. He said, if students have taken only one biology course, "I have a hard time seeing them cover medical stories."

Dr. Carney put it this way: "A good reporter must go beyond the who, what, where, when and why to put a story together. If somebody mentions something that is in the physiological world or the biological world, it should not hit the journalist as totally strange."

On the other hand, Dr. Moore thinks the educational system is already good and adds, "Even if he doesn't get enough science at the undergraduate level, I don't think he would be handicapped for the rest of his life."

So, to sum up the responses to the question of how much science education journalists should receive at the undergraduate level, most agree that while there could be a few more course requirements and while more students might be encouraged to minor in a science or to use more electives of science courses, in general, the key is a broad liberal arts education that includes science and math.

Next, we considered what sort of science courses students should take, and this gets to the heart of many of the comments made this morning. Some of the persons criticized what is currently taught. This could help to explain a statement I have heard over and over again, not just by the persons I interviewed but in general: many journalism students shy away from studying science and math, as do many people in general. They are afraid of it and intimidated by it. Every one of the educators I talked with noted that many students take as little math and science as they have to to get out of college; and this, of course, has terrible consequences for journalists, for journalism in general, and consequently for the public at large.

Dr. Cogwell, for instance, feels that students who avoid science and math will later avoid many science-related articles in magazines and newspapers and will therefore not be informed journalists. Dr. Johnson noted that students who become journalists might avoid covering science-related stories; and while there may be other reporters around who will cover those stories, journalism as a whole can only suffer if journalists who are afraid of science become editors who then decide what the newspapers and the television stations will and will not cover.

The person most critical of what is currently taught is Gene McDaniel, who called the situation "lousy." For people who are not going to be scientists, McDaniel feels there should be a different science course that involves what he described as a humanistic liberal arts approach to understanding science--as opposed to the current situation where, "Journalism students take the same chemistry courses as the chemistry majors and the same biology courses as the biology majors, and it doesn't mean a thing in the end because they don't have the broad picture of what science is and what it is about." Bob Ruckels was equally critical: "If scientists would help us develop some issue-oriented courses that have good, solid content along with coverage of the issues, that would help us to interest students to take more science."

Finally, I asked the persons I interviewed for other suggestions for improvement and what role the government should play in funding those improvements in order to better prepare journalists to do their job. Professor Ruckels suggested that the government put up money to encourage colleges to begin to address the question of improved reporting of science and science-related issues and developments. He also pointed out that government experts would be extremely useful in helping colleges to project what courses ought to be developed so that programs won't be out of date before they are off the ground.

Claudia Ritchie thinks there should be more internship programs for journalists. The example she gives is of a reporter who might cover the Center for Disease Control in Atlanta. She thinks maybe a month or two spent on-site at the Center and then in Washington, talking to people at NIH and other agencies that give out grants, might let journalists see where the money comes from and what the policies behind receiving it are. She would also like to see basic biology required of journalism majors and more weekend seminars, workshops, and short courses for working journalists who can't get away for these internships.

Two suggestions from Professor Terry were week-long science seminars for journalists on college campuses during the summer and the creation of prestigious fellowship programs to allow journalists to study the sciences for a semester.

A fifth suggestion comes from Dr. Walker, who felt high school programs should not only give students a better understanding of how and why the sciences are important but also should show them how to take that knowledge and use it in journalism--how to better cover science stories and why it is important for them to understand science as journalists.

In addition, Dr. Cobb would like to see workshops designed and sponsored by agencies such as the National Academy of Sciences for college juniors and seniors majoring in journalism. He said they should be held on weekends and during school breaks to augment what the students are getting in college or to give them what they are not getting.

Finally, Gene McDaniels feels non-science majors should be taking courses that will increase their overall understanding of the sciences. However, he suggested that issues such as social and economic impact of the sciences or ethical considerations should be covered in separate courses having a cross-disciplinary approach. For example, there could be courses offered jointly by the science and sociology departments to look at the social impact of the sciences, or courses with the economics department to explore the economic impact of science, or still other courses in cooperation with the philosophy department to explore ethical considerations in science. He says that government perhaps could provide money to encourage universities to make such offerings.

I agree with the suggestions that were made. There are many areas for improvement. I think, though, that higher education should not be too hasty in doing away with the requirement that journalism students do take some traditional science and math courses. There is no question that society at large does need to know more--no matter where they learn it or how they learn it--to understand the world in which we live and, more importantly, to understand how science shapes that world.

Question: How many minority students are guided by just wanting to pursue a career that would be exciting without respect to race; and how many of them represent those guided by the possibility of impacting the functional literacy of the underprivileged, who seem to face very serious problems of scientific literacy? The increase in awareness of birth control is one example; but at the same time, we also have a commensurate increase in illegitimacy, a very serious dilemma that many underprivileged people are facing today. Scientific knowledge may be at the heart of some of those complaints.

MS. HARRIS: You see to a large extent the same patterns with minority students that you see with other students. Here I have to split off my mind's responses between those students going into broadcasting and those going into newspapering. Many students, black and white, are interested in broadcasting because they want to make a lot of money. On the other hand, many students go into journalism because they like to write and want to be writers. Many students, including minority students, are turned off to the sciences and math and would tend to shy away from stories unless really pushed. A number of minority students might have a particular concern about the issues that you raised, but to get at those social issues, they have to go through the sciences in some cases and tend to back away from that. Of course, as they get older and stay in the business longer, they build up journalistic skills and aren't afraid to tackle anything; but initially at least, they want to avoid those hard stories. They might be inclined to say, "I don't want to be a hard-nosed reporter. I would like to be a features writer or a soft-nose." You hear that an awful lot.

MR. MALLETTE: In preparing for this appearance, I consulted with my six professional colleagues at API, who along with me represent 140 years of newspaper experience and have been both reporters and newspaper executives. I also consulted two very highly-regarded and experienced working editors and a director of research for a major newspaper group.

First, Elwood M. Wardlow, an associate director of API and former managing editor of the Buffalo Evening News, said, "In directing reporters and other editors, I found that they usually had a limited scientific knowledge but that it sufficed most of the time. The greatest difficulty for newspeople is in gaining the trust of scientists, not in comprehending what they have to say. Technical people distrust most others, doubting that we either understand or appreciate. Often, when they permit coverage, they want to do it on their own terms. If we increase the scientific understanding of newspeople, we might also orient scientists in the ways of communication." He does not see a need for more undergraduate science education for journalists, but he would like to see much more post-college opportunity for adding scientific knowledge.

Lawrence S. Hale, an associate director at API and former editor of the Evening Press in Binghamton, New York, says, "A good reporter is a good reporter is a good reporter. A major problem in reporting developments in science is the difficulty scientists have in translating their knowledge into English that the reporter can understand. Consequently, it is incumbent upon a science reporter to learn as much about the sciences as possible. A person seeking to specialize in science journalism ought to have taken college courses in chemistry and physics; with a sound grounding in those two courses, they can usually understand other scientific fields."

Another associate director is Donald E. Lippincott, the former associate editor and managing editor of the Trenton (New Jersey) Times. He said, "I don't think the average journalist today has enough background in science. Whatever he has won't be good enough tomorrow. Only the extraordinary reporter is able to play catch-up on a science without sufficient background from formal education. The average medium-size newspaper is going to need a staff who has more than a nodding acquaintance with science, as well as one or two reporters with a stronger foundation in science."

Paul Forman, editor of the Akron Beacon Journal and a former managing editor of the Detroit News, said, "The range of science is so broad that I have never found the ideal science writer. He would need an affinity for science and a background in physics, chemistry, mechanics, and so forth. Newspapers have a problem. In nuclear coverage, for example, I had an interview with two scientists, both of whom were lying and defending a position of their employers. We therefore fall back on attribution and quote the other side, et cetera. We take the middle stance, but the truth is not necessarily a middle stance." Paul Forman was making a specific reference to the Three-Mile Island Nuclear Power Plant episode as an example of difficulties that newspaper reporters often have in arriving at the truth.

Joseph Ungaro, executive editor of the Westchester-Rockland Newspapers in White Plains, New York, noted, "In the future, every good newspaper will have to have scientists and medical specialists together with other specialists. I have not had good luck trying to hire specialists out of college. They lack the basics of reporting and writing. This is true in science and medicine, arts, business, and so forth. I have had success in taking good generalist reporters and creating specialists by sending them to college courses and buying them books."

The other person I turned to was Tom Curley, director of research for the Gannett Company, the largest of the newspaper groups. He spends most of his time trying to ascertain what readers want and need in their daily newspapers, concluding, "Our research tells us that we have been almost negligent in all markets in not providing the volume of science news for which there is an appetite. Health is the base, but this extends into other areas. Where we have improved science coverage, reader response has been excellent." He told of being on an airplane not long ago with the February 24 issue of the New York Times, which contained one six-column headline story, "The Science of Dieting, a Fight Against Mind and Metabolism," and a lead article by Jane Brody. Other passengers, seeing this headline, asked to borrow the paper; and the flight was long enough that at least four other passengers read the article. Tom says, "I bet I could have sold ten articles for $5 apiece had I had them."

I agree with the consensus that newspaper reporters must first become good generalists. They must have command of the basics, which are reporting and writing. Attaining that command is not easy--often leading young reporters (strong in specialties like science) to fail because in acquiring the special knowledge, they have not learned the basics of journalism. They are very much like football players who have not learned to block and tackle. Journalism schools are struggling to squeeze the basis of journalism into the class hours available, and yet they are under heavy pressure to add even more courses. They face an immense problem in teaching writing skills.

Any journalist needs a grounding in history, political science, economics, and sociology (among other subjects). That is why journalism courses are limited to 25 percent of the undergraduate curriculum. But with all those needs, I still hope that all journalism students will take undergraduate courses in math, chemistry, and physics. They will then be better prepared as generalists and in a position to take specialty training in science if they wish something additional after the bachelor's degree.

I also believe that American newspapers must improve the coverage of science. At present, most newspapers simply don't have sufficient expertise. The defensive stance of scientists in speaking with reporters may reflect not only their own exactitude but also embarrassment over past reportage. As someone associated with mid-career educational journalism, I was greatly heartened by Peter Drucker's article in the Wall Street Journal on March 3. Drucker wrote that the biggest infrastructure challenge in the next decade is the American school system, including postgraduate education of adults: "In continuing education, we face an all but insatiable demand for advanced professional education in journalism among several other professions." I myself certainly hope that much of that advanced education for journalists will be in science.

Question: You talked a lot about science content and science courses but not about the attitude of evidence orientation needed by journalists, the whole notion of the use of evidence in the reasoning process. The other question concerns this problem of continuing education. Has there been any significant impact in journalism as a consequence of National Science Foundation programs for science writers, one of the programs being cut by the Reagan administration?

MS. HARRIS: A little bit of experience in science might be transferred over to the process of reporting, but you can also go too far and get too involved with that in some cases, sometimes over-researching an issue. On the other hand, surveying is more of what you do in journalism: you survey the different points of view and whatever information is available and try to pull all of that together. I would not carry reporting so far as to use the detailed scientific gathering that you are talking about.

Comment: I am not talking about a lot of heavy science but rather things like misuse of analogies and drawing conclusions by induction from a few cases because of not understanding the nature of them.

MR. MALLETTE: Your point is well-taken. I think science would be valuable. I would add that in any good journalism school, the importance of getting at the facts is drummed at the student day upon day upon day; and when he gets to a newspaper, it is drummed at him there, also. If the city editors forget to do it, the readers soon bring it to their attention. But it is oftentimes more difficult to get at the facts in a reporting situation than in a laboratory situation. This is the kind of thing that Paul Forman was addressing: a conscientious, skilled reporter at Three-Mile Island was at the mercy of official spokesmen unless he could don some special clothing and enter the compartments themselves, taking his own measures.

Question: The second question has to do with the very important issue of continuing education. You seem to feel that science education needs which were skill-oriented--that is, knowledge-oriented toward particular issues--could be met by in-service, post-college training activity and that there wasn't much need for any great modification in the collegiate science education for journalists. The questions seem to be "How much of the science education needs of reporters has to do with specific knowledge and skills?" and "How much of those needs has to do with a somewhat more general understanding of the process of science, the notion of what scientists do and the inquiry process?"

MR. MALLETTE: Let me now say what I think I said. An undergraduate journalist should strive to take some mathematics, chemistry, and physics--which is a good base. Biology would be fine, too, if journalism schools can add it, but I am also much aware of the difficulties that the schools are having in taking a poorly-educated high school graduate and, in four years, making him a good liberal arts graduate as well as a good technician or craftsman in the journalistic skills. A recurring experience is that if students do not have those journalism skills, the other things just do not work. Someone could come out with a good degree in chemistry but be unable to handle the other aspects of the journalist's work. I hope journalism students will gain this background to be good generalists and also to go on to further inservice learning.

As to the scientific method versus inquiry, we are talking about the ability to understand a nuclear scientist who comes out in front of Three-Mile Island and talks about those rods being overheated, to have some understanding of the nuclear process, as one example. In science and medicine, certainly we need to know something about nutrition, and reporters have to take so many directions that a flat answer is difficult to give to you. The consensus seems to be that we should get a good generalist and then try to take him further. If we don't get the good generalist, then the other things do not work in most cases.

And we are also seeing that newspapers are not doing a good job filling the need and the appetite for more scientific reporting that the average reader can understand.

Question: A number of the people whom you talked to raised the issue that any good, urban newspaper is going to have a specialist or a set of specialists in scientific activity, presumably perhaps subdivided so that we might have a physical science and technology specialist and a health and biology specialist. But that specialization is, I assume, a relatively new mode of journalism--that is, 25 years ago I presume that the extent of specialization was less than it is now and occurred in different areas. Are the post-secondary education needs of specialists different from those of general journalists?

MR. MALLETTE: Yes, if newspapers are going to fill this need. We simply are not prepared to do it; and any question of this nature has to be considered in the overall context. Just preparing a journalist to get to the entry level is difficult, and then the level of turnover in this profession is massive. Most of the people on Congressional staffs here are former journalists, showing that we have to have a continual churning process of creating new people.

Question: Are you saying that when you have someone who is really an expert, of the calibre you would want, someone else hires him or her away?

MR. MALLETTE: Oh, this happens all the time. Piracy is rampant.

Comment: Once one develops a name in journalism, then the newspaper is probably very vulnerable because others who tend to pay more pick the talent off to do more specialized writing.

MS. HARRIS: For a journalist, having those journalistic skills first and foremost is extremely important; you then have the ability to comprehend the subject matter of the story you are covering, whether it is politics or science or something else. And you know how and where to get the background information. And then you have the ability to translate it into interesting terms that a layman can understand. Specialization can come later. You probably will not want to start sending journalists to postgraduate courses until they have been in the business for a year or two and have done some of that basic jumbled-assignment reporting, have polished their interviewing techniques, and are experienced at getting to the heart of the information, knowing how to work sources and contacts a little bit better. Then a newspaper can start to put them on a specialized beat.

On the other hand, the people I interviewed had mixed feelings about whether there should be postgraduate education courses and seminars. Some people said that they would be helpful; but Roger Witherspoon, in particular, did not especially like the idea, feeling that he himself could do a better job in gaining this background information than a seminar could provide. He said that often seminars represented only one or two points of view, whereas when he did his own backgrounding, he would make sure that he got more points of view in order to have a better picture of the situation.

DR. GREGG: Changes have happened recently in areas of public awareness and public interest. What particularly comes to mind is the evolution of the New York Times Science Section. Is that an indication of the trend? Also, the Wall Street Journal seems to have become very much science- and technology-oriented. For instance, during a policy meeting at Bristol-Myers Company, executives referred to some new phenomenon in the pharmaceutical industry, saying, "Well, I read about it last week in the Wall Street Journal." That paper seems to have become more interested in the business aspects of what is going on in science.

During my previous activities in public television, it seemed as though every time we helped to fund a science program, we had very good audience reception. In the history of public broadcasting, the highest rating of any show was received by "The Incredible Machine," a Nova series funded in part by Gulf. But even CTW, the "Sesame Street" people, has moved in the direction of science. Certainly Nova is a good program, as well as the well-received "Cosmos" series. Public interest and appetite seems to be there.

The second point, and what has happened to change it, is the role of the federal government.

MR. MALLETTE: I don't feel very strong in telling you what the federal government should do. I feel better telling you what the situation is and then letting you folks address that question.

It is recognized that most newspapers present information in a very general, confused fashion which is perceived by the reader as jumbled and confused. In fact, related stories will often appear in different sections of a newspaper. However, within the past few years, there has been a latter-day development related to technology and production problems that we could not previously solve: "packaging for reader convenience." Newspapers are now compartmentalized and departmentalized in the way of Time magazine so that readers have a better chance of finding given information in a given location day after day. This was not true in the past on most newspapers.

I am not sure whether the New York Times is presenting more science information now than it ever has. It is preparing it in "Science Tuesday," conditioning readers to know where to look and giving the impression that they may have been getting more than in the past simply because they could not find some of it before. The New York Times, for example, employed Walter Sullivan, one of the foremost science writers, for years. If he were here today, he would probably get better "play," or more prominent presentation.

The Wall Street Journal editors are very alert to sociological developments, and the emergence of all these technological terms has forced them to give more coverage to that. We certainly see much more about the Silicon Valley, miniaturization, micro-lithography, and so forth. Therefore, the presentation of scientific material is part of reader awareness.

You mentioned the Nova series and Carl Sagan, whom Chris and I heard during a meeting of Associated Press managing editors. What Sagan has done is to popularize some things that a lot of us did not understand very well. He has a great capacity for presenting things in understandable, dramatic terms that many reporters lack.

Question: Are you at all familiar with the work of NSF's science writers on a program that provides seminars for professional science writers?

MR. MALLETTE: It is a salutary development but a positive movement.

MS. HARRIS: That would pretty much be my response, too, although I am not too familiar with it.

Question: Does it really have a significant impact? Is it affecting a significant majority?

MR. MALLETTE: I fall back on what I said earlier: there are 17,060 daily newspapers in this country, and we have approximately 400,000 people employed on newspapers. Every year about 15 percent of the 70,000 journalism graduates go to newspapers. This may improve something in Kiokuk, Iowa, or Minneapolis, Minnesota, but how would I know? My instincts are that it helps, but I cannot give you an accurate answer.

MS. HARRIS: Often those sessions are for leading science writers, but the information does not filter down necessarily to general assignment reporters or to reporters covering other beats.

Response: That is an accurate assessment. It has been a tremendous advancement for science writers, who appear much more knowledgeable! They know sources better, understand concepts better, know where to seek evidence and how to evaluate it better. But it is for the science writers, a specialized group with their own communications systems. It has no impact on city editors, managing editors, news editors, or general reporters. That is unfortunate because they--particularly the editors--are the ones making the decisions about where an article is going to be placed, how money is going to be spent on covering an issue, and what topics they are going to send people on for more dense work.

MR. MALLETTE: Where I was leading, of course, is how that specific role in the federal government should change.

Comment: Work needs to be done for editors. The government needs to extend workshops to the decision-makers, who are on the day-to-day, month-to-month, and year-to-year basis of coming up with allocated budgets, directing staffs, and making determinations about the packaging (including not just how much is covered but how it is illustrated, the topics that are used, the headlines, and placement, and so forth) that can call public attention to the variety of issues.

MR. MALLETTE: The information and training needs of the newspaper profession are so voracious in so many fields that there can be a salutary and beneficial program, but to measure the results overall is difficult. For example, right now a number of programs to increase the knowledge of economics are emerging. Newspapers are gaining a latter-day recognition that they have not paid sufficient attention to the business community, where a lot of progress has been made. There have been programs at the Wharton School of Pennsylvania, at Princeton, and I think at Stanford as well as some shorter seminars around the country by individuals, universities, and colleges within the past five years to improve our coverage, to make it more intelligent, more interesting, and helpful. A lot of things have been done. Newspapers have been dismal in covering something like the monetary standards; this is improving the situation, but to measure it is extremely difficult.

In arts and leisure, a middle-sized newspaper--the average one having a circulation of 35,000--simply does not find enough people capable of reporting dance, film, theatre, art, and so forth. This is the kind of need that all of us are struggling to fill, and science falls very much into that group.

Comment: Scientists and journalists have to confront the communication problem. The relationship between these two groups must be improved. I would hold workshops for headline artists, copy desk people, because often the headline is weird; and that is what upsets a lot of scientists and misleads the public.

Question: When I was the fund-raiser for Northwestern on the governmental side, they got the money to start a science writing course. Now, we can point to the journalists and say, "You know, we don't quite understand this, and we really ought to understand this better."

I also remember that during the missile-space era, if a group of scientists were having a convention or a conference, the last thing they wanted was to have the press in attendance. They wanted to find some remote place where they could talk to themselves. But then, when they found out that their needs were getting far ahead of the public's ability and willingness to support their activities, they suddenly wanted to turn around and say, "You let us down because you did not continue to support us," when in actual fact, the scientists themselves had been too busy to expend the time and emotional energy needed to notify the public of whatever they were doing.

Fortunately, the Congress, the government, had the adrenalin in the 1960s to keep science very much in the forefront of public awareness. However, scientists really were not much a part of that hey-day, and we did not need to spend time and extra energy trying to translate into lay language what we were trying to accomplish. As a result, science writers had a time trying to get access to information that might ultimately lead to the right headlines because a gap had occurred. To some extent, the problem was a lot of success early in the game. Do you have any better access now to scientists than you had 10 or 15 years ago?

MR. MALLETTE: I would guess so, but I would say that newspapermen are not without their own measure of arrogance: we have in our profession a few who hold their own.

MS. HARRIS: We probably should keep in mind that we are talking about two different categories--the general-assignment reporter and the beat reporter--who often have very different needs.

Roger Witherspoon gave me an example in a New Jersey newspaper for which he covered the energy beat. Even before he started that beat, one of the things he did was to visit two nuclear power plants, one that was completed and operating and another that was under construction so that he could see how it was put together. He talked to engineers and to scientists to get an understanding of nuclear energy. He did all of that before he even started his beat in order to be prepared with a basic understanding of the subject matter.

A general assignment reporter, on the other hand, doesn't necessarily have that advantage. For example, with Three-Mile Island, people were called in to cover the story while having never done a story involving nuclear energy.

Comment: I have been trying to see what we in science departments can do for journalists, which brings up the old question of whether it is better to give a survey course or for the student to take one course in almost anything but in such depth that he learns a little analytical ability. You spoke of generalists many times. I do not believe that you think a survey course makes a generalist out of anyone. It seems to me he learns many of the words in a lot of different areas, gaining a very thin acquaintance with those things. Personally, I would guess that learning some analytical skills through only one course would be better to build upon than a superficial, service-type course. But I don't mean to say that by taking one of the standard courses in physics and chemistry, students will gain an analytical ability. In too many cases, the student sits between pre-meds and other students who are learning just the basic laws of physics or some other science and does not learn to consider trade-offs.

MR. MALLETTE: I could only answer your question in a very convoluted way. In 1968, when the environmental movement was a-borning, we held our first seminar for environmental writers; and I thought it would be the first of a series. But it was the first and the last because the environmental movement became so broad that almost everybody on the newspaper had to cover some facet of it and were hard-pushed to keep track of the technical developments involved on pollution and so forth. They just did not have the scientific base. I cannot tell you what they took in college, but they were ill-prepared.

Panel on Law

MR. GREEN: I had my undergraduate education at the University of Chicago during the Robert Maynard Hutchins era. The core of that education consisted of four general survey courses: humanities, social sciences, biological sciences, and physical sciences. I have always thought that was a splendid kind of general education before one got into academic specializations. It is my view, as a true Hutchins disciple, that a college should provide every student--whatever the discipline, profession, or vocation to which he or she is bound--with that broad, general education. Subject to that overriding principle, no particular science education is required for lawyers.

I have done a great deal of work with questions of science and technology, both as a law teacher and legal scholar, over the past 30 years or so; and it is my opinion that lawyers, even when they work on matters that involve scientific questions, do not require a previous knowledge or understanding to do their work. A lawyer who has had a good legal education is perhaps the most consummate generalist in our society, being able to work today on a tax problem, tomorrow on a whiplash injury, the next day on a tariff matter, and the next day on a nuclear power case, Clean Air Act case, chemical food additives case, or new drug applications case. A lawyer with a good legal background can very rapidly pick up whatever scientific information he or she requires to do that job. I have never yet seen a situation in which that was not the case.

In my experience, it is disadvantageous (from the standpoint of getting the job done) when the lawyer brings to his task a substantial previous knowledge of the science involved in that problem. First of all, the lawyer with background in the science area in which he is working tends to be too knowledgeable, tends to be too much tied to the science that he knows, tends to have less flexibility to pursue doubts, to pursue exceptions or nuances to the questions of scientific fact that are involved or alternatives. Secondly, such a lawyer is less able to communicate in the ordinary language in which lawyers and politicians do their discoursing. He tends to be too eager to use the mumbo-jumbo of science rather than the kinds of language ordinarily used. I tend to reject the Renaissance Man theory. I tend to be skeptical, really, from the lawyer's standpoint whether somebody who is a science Ph.D. and also a lawyer really has added very much to his legal skills by having a Ph.D. in an area of science. What is more important than all these skills or knowledge wrapped up in a single person is for the lawyer to be able to communicate effectively on a scientific matter with the scientists involved. In my experience, a far greater barrier to lawyers' doing their thing is the inability of scientists, because of the limitations in education that most of them have had, to understand some fundamental principles of the ways our society operates, the way the political process operates, and the way public policy decisions are made. That is a much greater barrier than are difficulties the lawyers may have in understanding science. The bottom line is that the undergraduate educational system today is producing good law students who become good lawyers, quite able to deal with scientific questions although I do hope everybody, including scientists, would have a broad general undergraduate education.

<u>MR. THOMAS</u>: I had a punk undergraduate education, almost a trade school education in science from one of the Big Ten universities, and I have regretted it ever since I realized what I really had.

First, we might want to clarify possible semantic confusion. There is an old Latin maxim that says, "Law is the science of what is just," and there is a long string of scholarly articles that say, "Law is science, science is law." Consequently, there is a growing sentiment among young law professors to refer to themselves as social scientists.

Do lawyers need knowledge or understanding of science? If you include appreciation and awareness of science, then my answer is an emphatic "Yes." Whether they need to be able to answer the quizzes in the back of scientific journals, the answer is "No." A well-trained lawyer is a consummate generalist. But to be a generalist, if one gets into science policy, then he has to understand the philosophy of science; and all too many people in science policy simply do not. Science is an impetus for change within the legal system itself, and law responds to science at least as frequently as science responds to law. Lawyers often need to understand scientific facts in handling a specific regulatory proposal in a specific case for a specific client, but what I am referring to here is science philosophy or something a little more broad than "facts."

Second, you asked how well the United States educational system is performing in this regard. In a word, "poorly"--not only with respect to pre-law education but also (as we certainly know from recent studies in the press) with respect to almost any other endeavor. There seem to be two causes. First is self-selection: people with a predisposition toward law do not have a predisposition towards science; if they did, they would be in science curricula and, of course, they have to keep those grade point averages up, which taking some science courses does not help. This is coupled with the reduction in the standard of liberal education in the United States. The core curriculum and the academic discipline is shrinking, and as a result, the definition of "educated" loses its meaning. Too many law graduates from too many schools, including some of the better ones, simply are not well-educated; and I include science as part of that education.

Then I was asked, "What types of new knowledge and understanding are needed to handle things?" and that is hard to answer. Keeping up with current events usually suffices, but keeping up with current events will suffice only if the person doing so understands the cross-influences between law, science, and technology; and too many lawyers just do not understand them. Also, the legal journals do not do nearly as good a job of educating lawyers about science developments as do the science journals with regard to law.

You then asked your hardest question of all, "What is the proper role of the federal government?" That is a timely question, indeed. The influence seems to come from two directions. There is what you scientists love to call a "trickle-down effect" from having lawyers serve on multidisciplinary panels. For example, OSHA, DoE, DoD, and NRC all have multidisciplinary panels; and assuming that they are used correctly--which they are not always--there is, indeed, a trickle-down effect in which science helps to educate lawyers. But that is not the proper role, although it is a big one. The effectiveness of every lawyer dedicated to promoting what the federal government should be promoting will be enhanced if the individual understands science policy in the first place, rather than being thrown into the fray to help work on science policy matters. I certainly expect no sweeping reforms, thanks to federal assistance to science education, but I do hope we do not wait for another Sputnik before deciding to act.

Then you asked the most intriguing question of all, "Other considerations." There are 125,000 law students in the United States right now, and there will be another 42,000 starting this autumn. Three months ago, the American Bar Associations special committee on legal education published a report, "Law Schools in Professional Education," which considered why kids go to law school in the first place, how they like it, why they chose where they went, and so forth. And believe it or not, they do want Hal Green's Renaissance Men and Women. After noting that law is a social science and getting off to the wrong start, I read on, discovering two paragraphs about science and engineering in the pre-law curriculum:

> Most law classes include a number of students who have concentrated in college on the sciences and engineering. The traditional rigor of the training provided and the precision demanded in these fields guarantee that some students, then, will have engaged in critical thinking before arrival at law school. This education also promotes the kind of fact consciousness that should be part of every lawyer's make-up. Furthermore, this training often puts the lawyer in touch with computer technology, which is becoming more important to the understanding and solution of many legal and social problems. There is, however, a risk. When concentration upon science has preempted entirely the student's attention in college, he or she may be deficient in skills of communication and in exposure to the general culture.
>
> The increased technology of modern society is such that legal issues often involve complex scientific and engineering questions. Knowledge of physical and biological science as well as engineering increases the lawyer's ability to deal with important questions. Thus, those with an understanding of law, of science, and of engineering often are in demand in patent law and in environmental law.

Now, two things there really strike me as being short-sighted. First, it refers to computer technology when most lawyers work with computers only in a word processing center--if, indeed, they do that. Second, it refers to the traditional areas of patent law and specific environmental litigation, which is very fact-specific and requires no real background in science and engineering.

Nonetheless, this is quite a break with the past. Until five years ago, one of the better-known law schools in the United States said on the front page of its catalog, "Students with backgrounds in science and engineering are not encouraged to attend this law school." That was taken out with a change of deans. Law schools do respond to society's need, but they follow rather than lead. There is very little peer support among the law school students to take anything related to law and science except that if they know they are going to a law firm that deals with discrimination cases, they will take a two-hour cram course in statistics, just because no one else in the firm understands it. In addition, there is no faculty support: faculty career development in law follows rather traditional disciplinary lines; and of course, in many law schools, the curriculum is geared toward passing the bar exam, and not toward knowing what society and educators do.

Finally, we cannot rely upon institutional diversity. It does not suffice in public and private agencies for the scientist to say, "Sure we can handle that. We have a General Counsel's office." Nor does it suffice for lawyers to say, "Sure we can handle that. We have a corps of retained expert witnesses." There is just no substitute for personal understanding.

Question: Would you recommend law schools to change the kind of advice they give students about prelegal education? Have we reached the stage where we ought to alter tradition and say something about education in the physical and biological sciences and mathematics?

Comment: Students should not be made to feel ill at ease because they have science, technology, and engineering backgrounds, as they are in many schools right now.

Response: Your remarks about that surprise me. I am not suggesting it is not true; but when I was on the faculty of the University of Michigan, students expected to do well in law school, as a group, were those coming from good institutions of engineering and science departments.

MR. LOEVINGER: One of the points, perhaps, that would give me any cachet with the scientific members here is that I am an earned member of Sigma Psi, a fate that has just occurred. Let me say that answering basic questions about the relationship of law and science in 10 minutes is a little bit like trying to summarize the development of modern culture and explain the Einstein theory in the same length of time. It is impossible--at least for me.

Let me, however, attempt a few simple, categorical answers here to your questions. First, lawyers can do their jobs without much knowledge or understanding of science as demonstrated by the fact that the overwhelming majority of lawyers are functioning without such knowledge or understanding. I do not agree, however, that this means that they are preeminent generalists. In my experience, certainly in my firm and in most of the great firms of the United States with whom I have been associated, lawyers are inevitably divided into de facto specialists; and they do not try successively one case after another of the categories that Mr. Green mentioned.

In my firm, a young lawyer who is at the top of his class in the finest law school and who has been a Phi Beta undergraduate is hired as the result of a selective review of 4,000 resumes a year. The 15 whom we hire spend two years before even selecting a field, and they are just then getting the significant postgraduate education that doctors get as young residents. But there is a very high degree of specialization among competent lawyers today; and even those who advertise themselves as generalists are not, in fact, generalists but specialists in certain limited fields that appeal to the man on the street. The generalists in big New York and Washington firms tend to be specialists who appeal to particular categories of clients more widely scattered throughout the nation and perhaps throughout the world. However, saying that lawyers do not need knowledge and understanding of science in order to practice their profession is not particularly remarkable. A great many who earn their living laboring in various fields of science have relatively little knowledge or understanding of science as a general discipline. Most of those working in various fields of science appear to be highly trained and very skilled technicians rather than scientists in any philosophical sense.

On the other hand, both lawyers and scientists, as well as legislators and other professional intellectual workers, need a knowledge and understanding of scientific principles--the philosophy of science, if you like--in order to perform at a completely competent and adequate level. What are these principles? First and foremost, for example, is the principle of parsimony, Occam's razor, which requires an economy of concepts, not of money. Imagine the revolution in government, if you will, that would occur if this principle were understood and respected by the personnel laboring in Washington. Next perhaps, is the pervasive principle of indeterminancy in all measurements. Heisenberg's principle of indeterminancy at the sub-atomic level is well-known, even to many laymen. It is far less well understood that all measurements, scientific and otherwise, are approximate at best and indeterminate to some degree.

Correspondingly, contrary to popular impressions, science is not a body of certain, immutable, fixed and precise principles. Rather, it is--as I am sure you all know--a body of probability statements. Indeed, the whole concept of probability is at once one of the most fundamental and most elusive concepts in the fields of both science and law. Both legal and scientific conclusions are never certainties but only probability propositions. Yet the concept of probability, except in its most popular and intuitive sense, is studied and understood by very few in law. The discipline of statistics, as a mode of dealing with uncertainty and quantifying probability, is not much better known among lawyers. Measures of central tendency, dispersion, and correlation as well as criteria of significant variations are usually well-known to scientific workers but not to lawyers. I myself have impeached purported expert witnesses because they did not know some of the elementary principles of these matters, and I don't know that much. The related matters of survey research, counting, sampling, and securing a reliable data base are obviously of importance to the law as current litigation over the United States' Census attests. These matters are in no curriculum that I have heard of, and apparently judges and lawyers generally are not comfortable with questions relating to them.

The primacy of observation as a source of data needs no emphasis for this audience. The most numerous types of lawsuits in our courts are those involving collisions between vehicles, usually automobiles. Each of these accidents is the result of the operation of certain fairly simple laws of physics, mainly conservation laws. Yet every practicing lawyer and judge whom I have ever talked to thinks that conservation laws refer to the protection of forests and rivers.

Both the terms and the concept of causality are employed in law and science. In most cases where the circumstances are not too complicated, this will suffice. However, increasingly complex cases are being presented to the legal system, and there is little scientific sophistication available to guide lawyers and judges.

The elements of psychology are of obvious importance for law in many aspects. Although there is a vast body of data and a moderately large number of articles and books on the unreliability of eyewitness testimony, that is still the preferred source of evidence in most courts and is generally accepted in legal proceedings without much skepticism as to its validity. According to the latest issue of the Key Reporter, Harvard Press has just issued a compendious volume on this subject that has gotten a very good review. Cross-examination is still regarded as the best test of truth in modern trials. However, there are virtually no empirical data validating the technique, and it is today accepted mainly as the equivalent of a medieval ordeal.

Rationally, the study of semantics should be as basic to the study of law as mathematics is to science. Actually very few law schools even address it, and in fewer is anything very competent said about it. Reed Dickerson at the University of Indiana Law School is one of the few law professors in the United States who seems to understand the subject. Lawyers professionally engaged in the manipulation of language seldom self-consciously study the structure or the mechanism of language.

Similarly, logic, which is ostensibly a basic tool of thought, is conceived by most lawyers and judges to consist of the forms of syllogism postulated by Aristotle. Some lawyers and judges--precious few--have heard of symbolic logic and Boolean algebra, and a few brave and adventurous souls are trying to instruct students in these still-arcane subjects. But it is still an understatement to say that these are not popular in the legal sphere.

The concept of operational definitions (which has been employed so successfully and described so lucidly by physical scientists like P. W. Bridgman) are virtually unknown in legal law, although a few brilliant minds like the late Justice Oliver Wendell Holmes have used similar ideas. The profound insights of scientific philosophers and logicians like Kirk Godell have yet to penetrate very far into either one of C. P. Snow's two cultures. I have serious doubt that it is very important for lawyers to know much about the second law of thermodynamics, as Snow suggested. However, an appreciation of entropy theory and its analog is.

From what has been said, the inference can clearly be drawn that judges, lawyers, and legislators need to know a great deal that seems to lie in the field of science and which most of them today do not know. Equally obvious is that the educational system is not providing much teaching of these matters to anybody but a few specialists, and most of them seem to go on to teach other teachers.

On the other hand, science is not a path to salvation that will solve all or most of our problems as soon as a sufficient number are properly instructed in the creed. The landscape seems to be filled with shouting Messiahs peddling a gospel of social salvation in the name of science, nearly all of whom I regard as charlatans. At one time there was a notion, widely circulated among scientists, that they were better than others because something in the grain of science compelled truth, integrity, and certain other virtues. The disclosure in recent years of some notable scientific frauds should have put that myth to rest.

Science has much to contribute to our ability to think rationally and so does law. Data, popularly called facts, are certainly proliferating, but they can be handled by such modern mechanisms as computers. We do not yet have, and I think never will have, devices that will contain or process wisdom for us. The disciplined human mind is the only source that can create, the only vessel that can contain wisdom. This is our only hope of progress or social salvation, and for this we need to have minds that know and understand some of the principles I have mentioned, as well as many others which can be gleaned from the fields of both science and law.

MR. YEGGE: Almost all human activity is transferred into law, one way or another. When there is a dispute--a question of effective allocation of resources--science and its practical counterpart, technology, play a very important part in human activities; and it is growing in importance. Thus, necessarily, lawyers must respond to science and technology and must know something about them.

Probably the only science necessary at the undergraduate level is a good distributive knowledge of science. Beyond that, I guess I would raise the question, "What lawyers are you talking about?" Lawyers are not monolithic. Lawyers do quite different things, and some may need far more scientific knowledge than others. Some may best not know any science lest they abuse it. The notion of being a generalist in law today is really sort of nonsense. I suppose you can find some generalists in Durango, Colorado, but that is about the extent of it, I would say. If there are generalists in law, they may be diagnosticians, who in turn would not think of handling a certain problem but would refer it to an expert. That happens often in the legal profession.

Lawyers of almost every kind, still thinking they are omniscient, perpetuate the notion of the general practitioner, despite the facts. Lawyers do think they can try an antitrust case one week and move into a murder defense the next and then do a products liability the third week. They cannot. To say that simply because you have a legal education you are an omniscient creature is, of course, nonsense. That folklore is one of the greatest problems lawyers have in interacting with science and technology: since they assume that they have more knowledge than they do, they do not frequently enough call on experts who have the knowledge that really needs to be gained. One of the things that I hope a budding lawyer might learn at the undergraduate level is a bit of humility and the ability, notwithstanding his legal education, to call on experts when he needs them. This is going to be difficult for lawyers to learn but nevertheless is, with the increasingly complex ramifications of science and technology, necessary.

A third problem of lawyers is the nonsensicalness of the notion that law is science. It clearly is not. As a matter of fact, reference has already been made to C. P. Snow. Law and science are quite antithetical. One is a deductive system and the other is an inductive system. The lawyer, being a pragmatist with the need to solve a problem rather rapidly, does not have the luxury of experimenting, redoing the hypotheses, and experimenting again. Indeed, his clients are not paying him to do that, but rather to reach a preordained conclusion; and that is hardly science.

We see this difference between the mindset of the scientist and the lawyer not only in the procedural aspects of lawyers' work, but also in the substantive law. The best examples are the insanity defenses. When lawyers and medical people talk about insanity, they simply are not talking about the same subject. One is in terms of the traditional common law notion of being crazy, if you will. The other, a concept or medical question for the psychiatrists, is not using even the same kind of language as is the lawyer. I am not sure that an increase in knowledge of science is going to ever bridge that gap. Probably there will be change in the laws, and in the insanity defense specifically, but it is going to take time. Maybe some additional science knowledge on the part of the lawyer who is sitting as judge or legislator will assist in redefining that defense, and maybe not. It is hard to know.

You specifically questioned, "Do individuals working in the field of law need a knowledge and understanding of science?" Of course they do--maybe not in depth for some kinds of lawyers but maybe in great depth for others.

"How well is the United States educational system preparing lawyers to master the type of science they need in the conduct of their work?" The educational system may not have a problem, but it has a problematical job. Perhaps the choices that the students make in that educational system are the problem--the avoidance of a range of courses that will better serve them as lawyers rather than the lack of sufficient courses.

"What kinds of new knowledge and understanding do they need to cope with the changes that are taking place in tne profession?" Lawyers--because in most fields they are going to be touched by these problems--should know something about the electronic revolution, not just data processing machines but also biotechnology because those matters are going to affect greatly the work of lawyers in the future. Lawyers are going to have to face those problems.

Finally, "What role can the federal government play?" That is the tough one. Last year, the National Association of Attorneys General asked me to perform a study under an NSF grant on science and technology in the offices of Attorneys General in the United States. The answer to the question--"What role does science and technology play in the offices of the state attorneys general?"--is "virtually none." That is really a very frightening conclusion. The attorney general is a lawyer in the lawyerly sense; but because the attorney general is also a policy-maker, it is somewhat frightening to see how little attorneys general recognize the importance of and the need for science and technology in the performance of their tasks. Part of the problem may well be the political nature of the office and the frequent turnover of incumbents to the position, but the study is somewhat reflective of the general practice of law. Quilled pens and leather-bound books, rather than the modern kinds of technologies that science has developed and made clearly available to us, continue to be used tenaciously.

The results are not all in yet. At least there is some movement. Thus, maybe that is one of the strategies: get to organizations such as attorneys general or the American Bar in its discrete components. And take a hard look at where science and technology is within those subcomponents of kinds of lawyers. Make them aware of the possibilities for using science and technology, and maybe there will be the kind of movement toward better understanding of science and technology that I suspect the panel is looking to.

Question: You said that lawyers feel omniscient, and you hope that they might learn at the undergraduate level a little humility. But how do they get it unless they can communicate with each other--not only on a professional level but during the stages of education through which they go?

Response: A funny thing happens to students when they leave a nice liberal arts undergraduate education. Relatively fresh and clean intellectually, they march off to law school, where we promptly ruin them by making them forget a good share of what they learned in undergraduate school and train them in a new method of thinking which they probably have not ever looked at before, a system of appellate cases and of looking into the past for solutions to all the problems. The socialization process at the law school level may be so strong that nothing at the undergraduate level would do any good.

It may, however, be that--if undergraduates were exposed to the kind of analysis and thinking that goes on in law school and integrated that with all of the other studies they are doing--possibly the problem would be slightly alleviated. It is interesting that, except in the case of constitutional law, rarely is a student exposed to the Socratic case study method at the undergraduate level. Maybe putting that in the undergraduate level in a more significant way and showing how it connects with other disciplines being studied concurrently would be of assistance.

Comment: I have been involved with the implementation of the Toxic Substances Control Act, an issue where scientists and lawyers certainly come head to head. My impression is that the role of the lawyer is to resolve existing conflict and perhaps anticipate and avoid potential conflict within the boundaries of the existing law.

Response: The traditional role of the lawyer is one of solving problems already created, but I suspect that the role of the lawyer has changed somewhat. Certainly there are lawyers where this role is totally changed: some clients tell the lawyer, "Help me solve the problem of not getting in trouble." But that is a relatively new idea except, let us say, in estate planning. I am always intrigued with the difference in the role of the Washington lawyer and the lawyer out in the hinterlands. What Washington lawyers do I find fascinating because it is not very closely connected with any of the traditional roles that one thinks of lawyers doing: because of the buttons they can touch, they are doing some quite different things than traditional lawyers. For instance, a lot of the things that happen in Washington law firms are frequently called "government relations" and use either nontraditional (from a legal point of view) mechanisms for solving problems or try to avert a problem by making certain that the legals agree.

Comment: Most of the good law firms in Washington do not lobby. They don't do it any more than law firms in the state capitols or anywhere else. On rare occasions, an old client says, "Look, I have some stuff pending before Congress. Would you send somebody down to explain to the staff of the Congressman what my position is?" and we will occasionally do it. But most firms known and respected in Washington are not lobbying firms. We practice, by and large, traditional law with the single exception that we are more concentrated on federal law than on state or local law.

As far as being in the hinterlands, fortunately, both for my own comfort and for my rapport with my wife and family, I spend a very large part of my time in the hinterlands because that is where my clients are.

Now, in fact, the practice of law does involve a very large element of counseling. However, there have been some surveys by popular journals as well as books in recent years as to the functions of lawyers. Society has become much more litigious so that much of what previously involved counseling has now become litigation. All of the Washington law firms are becoming of necessity more involved in litigation than they have previously, a development which is lucrative but nonetheless lamentable and not socially profitable. It is a waste of everybody's time: we are thrusting policy issues into courts not equipped to solve them.

Comment: There seemed to be shared agreement within this group that at least some segment of the legal profession have some measure of familiarity with science--if not in terms of detailed data in a particular field, then in terms of principles and methods of philosophy. The historical position of the American law school has been based on this idealization of the generalist, abjuring any kind of focused advice about what one should do in the prelegal years if one were going on to law school.

Comment: Our admissions committees are looking at solid, scientific backgrounds, but we should be a little more vocal about strongly urging it. As I was going to be a physician, I spent the first two years at Princeton taking all of the basic chemistry, biology, and physics. Then I decided that that really was not for me at all, and I wanted to get into history, sociology, and political science; and I was very pleased that that happened. Being a pre-med for two years and then being a liberal arts student for two years was excellent background for going to law school.

Response: I would agree and my answer to your question would be unequivocally, "Yes." When leaving government in 1968, I spent a fair amount of time thinking seriously about becoming dean of a law school. I considered requiring some scientific background, either prerequisite to admission or after admission.

Comment: Perhaps you are aware of the reaction to the AALS' recommendations by the Claire Committee in New York. In response to the complaint of Chief Justice Burger and others as to the incompetence of lawyers in trial courts, a group of federal courts set up a committee to study it. They recommended that certain courses--federal practice, procedure, and evidence--be required as prerequisites for graduation from law school.

The AALS immediately responded, "This is an infringement of our academic freedom. You are telling us what to teach. You can't do that." Even trying to tell lawyers that a couple of basic law courses are relevant seems to affront them so that I would not have very much hope for this kind of recommendation. We interview literally hundreds of law school graduates every year, and those students who come with a sound academic record and background in some of the harder disciplines --in physics or chemistry--or with a degree from M.I.T. rather than from the West Podunk Liberal Arts College seem to be much more tough-minded and able to handle the difficult problems of intellectual discipline that they will confront in actual practice.

Comment: I am not holding up Harvard Law School as a paradigm or an example. When teaching law, I still encounter far too many students who--when they learn I have a Ph.D.--ask for advice and wonder why they end up in law school with a science background. The answer is that faculty members would say, "Oh, you want to be a patent attorney. Well, you'll be taking Professor Soandso's course your third year." It has a chilling effect.

Question: If the law profession or the law schools should decide to build science into their programs, do the appropriate courses exist in the undergraduate colleges, or would they require some new development?

Comment: It is a matter of the students making choices among the traditional fare. They might be avoiding science courses because they want to keep their grade averages up. In other words, they are not waiting for federal subsidy of grades.

Comment: If a student figures out, halfway through undergraduate school, that law school is in the future, he or she is going to find out what the law schools are looking for by the way of pre-law education. If the law school that they are looking toward says, "We like folks with some science and engineering background," then all of a sudden those students will start to take science and engineering.

Comment: You have to look at the curriculum. My two children recently graduated from college and are practicing physicians. Incidentally, the young woman was constantly met with the expectation, "Oh, so you are a nurse." And the idea that she has taken tough scientific courses and gone through medical school is still somewhat of a surprise to an unfortunately large number of people on campus.

Question: We have been talking about existing courses, where the law is a profession. There is also the possibility of something being available for students in the upper-class years, by which time their progress into law would be fairly severe. And my experience in teaching is that there are more detailed, less philosophical things that you can treat at the beginning stages as compared to what you can do at the later years. Would you care to comment on the value?

Comment: As far as I am aware, your observations are correct: you could do this in law school if you wanted to and if you had the teachers. This goes back to the earlier question as to whether it would be more useful to teach a survey course or an intensive course in the philosophy of science. Those are empirical questions to be answered by examining what is being done and their results and perhaps by establishing some experimental courses.

Comment: As far as I know, many of the physics and chemistry courses are really not very helpful and, as a matter of fact, may be counterproductive if that is what you want people to learn.

Panel on Business and Industry

MR. HADDAD: First, I am going to broaden the definition of science to include all of R&D, emphasizing that knowledge of science or engineering is really not as necessary in business people as is knowledge of scientists and of engineers--with respect to their goals, their ambitions, their rewards, their frustrations, their methods, their practices, their lines of reasoning, their self-images, if you will--and the very subtle differences between scientists and engineers and between science on the one hand and engineering on the other. There should be knowledge of these distinctions and of what the work requirements are for each type of person, what the optimum environment ought to be, and what the relationships can and should be between them and other functions of the business and especially with other professions within the business. One needs enough knowledge to be aware and to appreciate the effects that science and technology have on the business community.

But certainly, business students do not need to be facile in engineering or deeply studied in science. I knew a fellow once who used to say, "Protect me from the don't-know squared's: If I have a guy and he don't know and he knows he don't know, that's okay. But if he don't know he don't know, then we got trouble." I am suggesting that even though a little too much knowledge might be a dangerous thing, no knowledge at all is equivalent to the don't-know squared: he don't know that he don't know, and he can be a danger in business and in industry. Some knowledge is necessary but certainly not the kind given a beginning scientist or a beginning engineer because that is the beginning training to make people facile with respect to a discipline. And a businessman does not need that; he needs more understanding than he needs facility.

One element is that non-scientific or non-engineering students are often made to abhor science and technology courses because these courses are designed to make them chemists, physicists, or mathematicians; and they clearly do not want to be chemists, physicists, or mathematicians. They have no aptitude and no interest in this. Our undergraduate system really does not attack this set of elements. Certainly, some courses in math or science are necessary, but they are not sufficient, and more courses than math and science are certainly not appropriate. The sociology of science and engineering is acquired by these non-technical students either as a set of pre-conceived notions, or by observation (movies, TV, and novels; role models such as the professors, relatives or friends who may be scientists or engineers), or by serious study such as reading history of science or history of technology. But this is very unstructured, very haphazard, and more likely misinformed; and unexpert informers, like science fiction novels, can do more harm than good.

Now, the cure is not necessarily a special course in the sociology of science and technology. Look at the rest of the faculty: professors in non-scientific or non-technology disciplines probably are also misinformed, and they probably also do not care very much. They could be helpful if they did know and cared, by weaving into the fabric of whatever discipline they are teaching the appreciation that they might otherwise have; but more often than not, my experience is that they don't know and they don't care.

Most importantly in this high technology society and culture, people in walks of life other than science and engineering had really better understand scientists and engineers and their motivations, and they had better appreciate science and technology--just to be able to live as a whole human being. I do not know how we can say that a person has received a liberal education without this kind of appreciation; that is somewhat of a mystery. An academic discipline should have emerged by now to fill this type of vacuum. Probably the worst offenders in this regard are in fact the business schools themselves, who treat the various non-business, non-science-of-management disciplines as though they were almost secondary in importance to the so-called "management sciences."

Lastly, I'll point out that the role of the federal government certainly can be that of a sugar daddy, but federal dollars means federal control. Other sources of money (foundations, universities, endowments, and even business people) are available--and this kind of thrust does not require any big money and dependence on the federal government for it--that would more properly and more enthusiastically donate with a lot less control.

<u>MR. STAMBAUGH</u>: We have a problem of defining the profession of business and industry because it really is not a profession. I have chosen to

look at the professionals who are scientists and sought-after decision-makers but different from the managers who have to understand these things. My remarks will contain a certain amount of personal bias and do not represent a policy position of my company. I believe, however, that my answers to the five questions posed by the committee represent a fair consensus of my colleagues in the chemical and related manufacturing industries.

"Do individuals working in industry need a knowledge or understanding of science to do their job?" The response of business and industry to the value of scientific education is quite predictable and very favorable. In fact, in the high-technology companies a scientific or engineering background approaches a prerequisite for entering the organization. The hiring of recent college graduates is a highly decentralized process in most companies. Furthermore, since most entry-level positions are in an area of technical operations and the hiring manager is usually a scientist or engineer, the candidate with the best technical credentials nearly always gets the job. The depth of scientific knowledge needed varies with the assignment, the deepest usually being in research and development. But--even in staff positions such as finance, public relations, or law--an appreciation of scientific principles is highly desirable, if not an absolute requirement. The premium placed on scientific competence is most clearly illustrated by the keen competition of employers for undergraduate engineers. These 21- and 22-year-olds are regularly offered starting salaries higher than the professors who taught them.

"How well is the U.S. education system doing--especially at the undergraduate level--to prepare professionals in industry to master the type of science they need to conduct their work?" Most industrial employers would probably agree that new graduates in science and education have really excellent technical training, including summer intern or co-op experience in a related field, which make them productive practically from the first day. But while there are few complaints about the quality, there are real problems with the quantity, particularly of engineers.

A distinction must be made between the physical sciences and civil engineering, on the one hand, and most other branches of engineering and computer science on the other. In the first case, the balance between supply and demand is reasonably good, although there are predictions of a shortage of doctorates in the foreseeable future. For the latter disciplines, the problem is here <u>now</u>: nearly every graduating engineer in these fields can collect as many job offers as he or she cares to, simply by accepting more job interviews. The demand for undergraduate and master's-level engineers is so great and the salaries they command so high that doctorates in engineering are falling behind needs at an alarming rate. There are today at least 3,000 open positions for engineering Ph.D.s in industry. Perhaps even worse, over 1,800 (or almost 10% of all engineering professorships) are vacant, and the situation is going to get worse before it gets better. The questions, of course, are "Where will the innovation come from in our industrial laboratories?" and "Who will teach the large numbers of students now competing to get into engineering schools and so important to the nation's future?" Fortunately, this matter has recently gotten the attention of school administrations and of industry, and some cooperative initiatives are getting under way to turn this problem around.

"What types of new knowledge and understanding do professionals in industry need to cope with the changes that are taking place there?" There are important needs in two areas. The first deals with the so-called "computer revolution." Industry is rapidly turning to computerized process control for reasons of productivity and quality control and is generally ahead of the universities in this area. Training in this complex technology will have to be incorporated into an already overburdened curriculum, and the equipment required will add significantly to the already high cost of an engineering education. The second and more basic need to prepare professionals in industry to cope with their jobs involves the curriculum itself. So many technical courses must be crammed into the four years of the undergraduate program that there can be only limited exposure to economics and social and human relations, let alone to basic writing and communicating skills which come mostly from continuing education programs or on-the-job training and are generally insufficient. It may be time for reviving the idea of making the master's degree the first professional degree in engineering with a prerequisite undergraduate degree similar to pre-law or pre-med.

"What role can the federal government play in providing the necessary educational opportunities, given changing knowledge needs?" The federal government can and should play an important role both in increasing the production of Ph.D.s and in providing the tools required for a quality education in science and engineering. In testimony given earlier this month to a subcommittee of the House Committee on Science and Technology, Dr. Robert Frosch, president of the American Association of Engineering Societies (the umbrella organization of 38 U.S. engineering societies representing over a million students and professionals in engineering), made three proposals:

- The National Science Foundation and the agencies supporting mission-oriented research could play an important role by providing incentives and by catalyzing arrangements between universities, government, and industry to increase the level of industrial support. This support could be in the form of industrial funding to assist engineering schools, the provision of equipment, and the use of industrial equipment by students and faculty with engineers.

- A private foundation could be established to channel industrial and private funds to support engineering education. NSF could usefully cooperate with such an initiative, providing catalytic support of research in the universities. The combination of university research interests and the practical requirements of industry seeking new products and new ideas is likely to be healthy for both, but it appears that some kind of "marriage broker" is required in many cases. This seems a sensible and not overly expensive government role. Using public capabilities as a stimulus to improving the nation's ability to compete seems far more sensible than direct government support.

- Finally, the federal government, probably through the National Science Foundation, could undertake basic research. That makes technological sense but is not covered by mission requirements of government agencies and is not otherwise stimulated by the short-term market forces in industrial research.

The fifth and final question invites additional comments on the issue of science education. Most leaders of business and industry are greatly concerned about the technical illiteracy of many college graduates and of the general public. In a recent talk, Edward G. Jefferson, the newly elected chairman of Dupont, related the following anecdote:

> John Kemeny captured the essence of the technical community's doubts about the body politic. He said that while he was chairing the presidential commission investigating Three Mile Island, he had a nightmare. He dreamed that after minimal debate, the House of Representatives, by a vote of 215 to 197, had repealed Newton's Law of Gravitation. Maybe the ghost behind that dream was the state legislator--atypical to be sure--who once urged that the value of Pi be set at 3.0, so it would be easier to handle in calculations.

Lack of understanding leads to a general distrust of technology and an emotional, rather than a reasonable, view of the critical issues before us such as energy, the environment, and the supply of natural resources. The danger is not that it's bad for business but that uninformed public opinion will lead to bad decisions for which future generations will not forgive us. Though the burden of providing a balanced education for living clearly falls to the academic community, the rest of us must surely help. Industry has an important duty to involve the educational establishment more directly in our operations. There now seems to be a renewal of the traditional ties between industry and education which deteriorated when the government became a major partner through grants and research contracts. This is good and will grow. An essential step is to put the tremendous prestige of the President and the executive branch behind the need for understanding technology. To this end, we are anxious that the post of science advisor to the President be filled carefully and soon. And finally, this committee is to be commended for its efforts to get a handle on this slippery problem and chart a course to help our people live with and use science instead of fearing and rejecting it.

Question: Would you expand on the ideas of the first degree in engineering being the master's degree and of a more liberal, general education process in the earlier part of an engineer's education? How strong is the movement for that among engineers in business?

Response: It is an underground movement at the present time. Not too long ago a commission came to the brink of making such a proposal, but the rest of the engineering academics really voted it out. But this shortage of doctorates and the danger for the total teaching of engineering is such that they are talking about doing some things that would not have even been considered earlier, such as tenure of engineering professors and accreditation of business people to teach. The situation, in their view, is so desperate that some of these things that were not possible before are now being discussed. But the impetus comes from the shortage of personnel rather than from any educational process.

Comment: The problem comes from the great number of opportunities in industry.

Question: Is there any movement for some of the bigger corporations to take the matter into their own hands and provide engineering courses?

Response: That is happening now. A number of them, such as the telephone company, hire hundreds of electrical engineers at the bachelor's level; and while they don't educate them themselves in-house as an employee, they send them back to get a master's degree as employees of the Bell System.

Comment: That does not solve the problem of the shortage of engineering teachers in the colleges, though. It just throws them back onto the college.

Response: It does to the extent that there are 3,000 vacancies in industry for which the salary is higher. We have to fill up the whole pipeline. You can't fill 1,800 in the schools and still leave 3,000 vacancies in industry because the incentives to leave schools and come into industry would still be there.

Question: What is going to ultimately happen to industry if it takes all the professors away from the schools of engineering?

Response: We're going to die.

Question: Where is the talent?

Response: That is the problem, and that is why industry will eventually in enlightened self-interest--when we see our source of basic, undergraduate engineers drying up--make money available.

It is self-destructive, and that is why this group has been formed. There will be at least 100 more graduate students at the Ph.D. level this fall as a result of the beginning we have made. The goal is to get 1,000 more American Ph.D. candidates (almost 40 percent of the 2,850 Ph.D.s granted in engineering in 1980 were non-citizens, making the problem much worse).

Question: How many years in the future are you predicting the glut of engineers? This pendulum will overswing, surely, and engineers will be driving taxis at one point.

Response: One of the heads of engineering that we have talked with said that when faced with this question of what will happen when engineers are a dime a dozen, probably the best thing to happen would be a glut that would send engineers into journalism and the other professions. Now there is no incentive at all to do that because they make so damn much money when they go right into industry, but it might not be a bad idea.

Comment: You have to be careful. If you look at the placement of engineering college graduates, a high percentage (around 30 percent) go into other professions--law, journalism, medicine, whatever. Business administration is a very heavy draw, 30 or 40 percent. Engineering deans decry this, and I decry their decrying because I point out to them that if this movement from engineering into other professions did occur, they would be bemoaning the fact that the other professions were devoid of people having technical backgrounds. A good number of them do, in fact, go.

I would like to point out one other thing. When a student goes to college in order to study science, the chances that that student has his or her eye on an academic career are not much higher than the chances that an engineering student has his or her eye on an engineering faculty career. It comes as a result of expecting that a certain percentage of all college students are going to be motivated to go into academic careers, but I don't believe there is any such thing. Especially in engineering, kids entering the field are motivated to design, build, and produce something that hits the marketplace and that affects society in a very direct way. A lot of them are capable of doing science, just as most scientists are perfectly capable of doing engineering. But being capable of doing is described as the inner motivation. I have asked graduating seniors going into industry, "Why haven't you considered studying for a graduate degree?" They respond, "The thought never came to me."

For that matter, I look at the faculty and say, "And where have you been? Business comes on your campus to tell students what a great place industry is, particularly their company. They proselyte like crazy. You have these kids for four years. How come you have not proselyted them?"

I sit on a Board of Trustees and review faculty salaries. The comparisons are with competitive universities; and when I am through, I say to them, "Now, that is fine, but show me your real competition." They are kind of surprised when I say, "Your real competition is not other universities, but industry. Why are you not comparing your salaries against industry's?"

There are a lot of problems with this; on the other hand, you have to get to the base motivation of the people involved, and I don't think a kid flips a coin in his senior year and says, "Shall I study for a master's degree or shall I go into industry?" Instead, that is a mindset acquired over a considerable period of time, making changing his or her mind difficult.

Question: Mr. Haddad, have you any of these impressionistic figures that might be comparable to Mr. Stambaugh's top 100? How would your company spread the top 100 as to technical backgrounds?

Response: It would probably be reversed and a little heavier in the other direction; out of maybe 40 company officers, perhaps 10 or 15 have technical backgrounds.

Question: Are there any more or less stable patterns to the undergraduate educational experience of those in this leadership group who do not come out of scientific or technical backgrounds?

Response: Not so much with respect to undergraduates, but there is a very distinct pattern. For example, the corporation counsel is always a lawyer; but beyond that, the pattern would seem to be at the master's level, where the MBA is perhaps significant. A great number of MBAs, by the way, have engineering undergraduate degrees, but I did not count them when I said non-technical. Our chief financial officer has a physics background, but he has an MBA.

Question: With respect to those top leadership people who lack technical backgrounds, either as an undergraduate or at some later time, do they have sufficient ability to understand and to develop a satisfactory rapport with either the personnel or the problems produced by the scientific and the technological areas?

Response: It is a tough learning process. I would rather not make broad observations but talk from my personal experience. I worked as a subordinate to one of those generally educated business people who obtained a liberal arts degree and then went into business, working through sales. We were very good friends and could communicate very well. I was in charge of the largest research and development division in the company.

He remarked on many occasions that he was learning a lot with regard to the development function. Now, certainly he had to gauge the marketplace. He had to operate from a businesslike point of view, but I was impressed by the little nuggets of knowledge that he had learned as a result of his experience with me and with the operation. It was as much of an education on my part as it was on his.

Into your own major development program, you have put hundreds of thousands of dollars. One fine Monday morning, somebody comes in and says, "We have a real problem," and it looks as though the whole program is gone because of a technical problem. What do you do? You solve the problem. The first time this happened, he was completely shattered; and a week later he said to me, "You know, I'll never cease to be amazed. It was as though you expected that problem." And I said, "Good God, no. If I had expected it, it would never have happened. But I expected that there would be a problem that I did not expect. And that is the nature of engineering." He had the funny notion that engineering was just simply one step after another--logical, preplanned, preordained--and that lack of understanding in the educational process caused him to learn the hard way.

Comment: If you interviewed all 100 of these top people, you could not identify those who did not have a scientific background, . They have had to learn to understand their business and the scientists that they deal with. Also, because the former scientists have become obsolete in their science by the time they reach the top, they are indistinguishable in their understanding and their way of relating to the scientists below them. For instance, our chairman is a financial man, but you would not know this if you talked to him. He knows quite a bit about what is going on. He has had to learn.

Question: Recently, an article in the New York Times (and it has appeared in other places) said that one of the reasons--and maybe the main reason--that industry in Japan, Germany, and the European countries has been doing very well compared to the American industries is that their business leaders are technically trained whereas the people running our businesses are MBAs without that technical training. The article purports that a technical training gives one a long-range view whereas MBA training gives one a shorter-range view. How do you feel about that?

Response: I don't believe that. The guy that led my company through its greatest expansion and technical flowering was not a scientist or a technician. As a matter of fact, he had a terrible inferiority complex with respect to technology, but he had a better instinct for these kinds of things than he thought he did. Just having an MBA does not mean that one necessarily lacks this understanding or intuition, although the way business administration is taught in a great many places, that intuition is perhaps beat out of them.

Question: Mr. Stambaugh, do recruiters for your company accurately project to the academic institutions the kind of educational experience that top management would like to have? This has bothered me very much because sometimes I am on the same program as recruiters from industry, sometimes even the same companies where I know top management people. Often the advice that recruiters give to students conflicts with that of management, and I find it rather horrifying.

Response: No, I don't think that they do. You are exactly right, and

I don't think we can change this. It is a characteristic of pressing the decision-making down to the lowest possible level, a good management practice that makes the hiring process highly decentralized. However, if both a senior manager and a person who normally recruits were simultaneously hiring people, they would probably select different people.

We are hiring for the short term and hoping that the cream will rise to the top. An indication of this is that when the engineers all come here, some of them realize that their set of tools for being an engineer is not enough to be a manager and that another set of tools normally identified with the MBA is necessary. If we take slices of our organizational pyramid and look at the number of MBAs present, the percentage of MBAs goes up as you go up until you get to the very top, where almost all are MBAs. Most of them went to Columbia, N.Y.U., or some business school rather than going away for two years; but they found that this was necessary to supplement the education they got as undergraduates.

Comment: What worries me is that in this process some people remove themselves from the technical part as a profession because they imagine industry wants a very able but very narrowly-defined technician. Because they do not get into that in the first place, there is a great loss.

Response: That is right.

Panel on Religion and Philosophy

REV. HAMILTON: I would like to begin with a quote: "I am appalled, listening to sermons, how ignorant of science some ministers are! Nearly all of the priests are badly prepared to understand new scientific truth. Ministers are intimidated by scientific topics; hence, they tend not to touch it. As a result, our culture is missing an enormous resource in relation to scientific research and technological development."

I asked scientists, seminary educators, clergy bureaucrats, religious journalists, and others whether they thought ordained clergy were sufficiently conversant of scientific matters to do their job adequately. The answers, like those just quoted, were negative in all cases but one. It must be recognized that if I had asked the same people whether they believed clergy were adequately prepared in their knowledge of the humanities and English grammar, the answer would probably have been the same! But in our age, while a split infinitive may be stylistically offensive, a misunderstanding of the nature of the shortage of natural resources or the possibilities for genetic manipulation is a much more serious deficiency.

The problem in mutual understanding between scientists and theologians has existed for a long, long time. We church people need to make frequent, public, and sincere confessions that many of our leaders have been seriously wrong when they persecuted such scientific prophets of truth as Copernicus, Darwin, and Freud. All too often we Christians misunderstand our own religious experience and the nature of God's revelation as it came to us in tradition. We Christians should always be open to new truth--whether it emerges from scientific disciplines or from Biblical scriptures.

On the other hand, plenty of scientists--who do not know the limitations of scientific knowledge and extrapolating from legitimate, scientific conclusions--have preached their own brand of philosophic and social nonsense. When both parties to a conflict are confused, little creativity and mutual understanding emerge. All too often the contestants, bruised by the encounters, draw apart and come to believe that the other is both unreasonable and immoral.

While occasionally seminary courses on ethics include material on medical technology, ecological issues, and energy dilemmas, there are not enough of them and relatively few continuing-education courses for clergy. When one reflects on the influence of technology in our century and remembers that scientific knowledge, once discovered, can never be forgotten and that politicial and social realities change as often as governments and fashion, it is deplorable that more attention is not paid to the study of science.

The very success of scientific research and development has led scientists to realize that they do not have within their disciplines information which will guide them in the use of their new powers. Physicists and medical investigators are especially open to rapprochement with theologians. Facts never have contained values. Science and its technologies have always been dependent upon non-scientific sources of inspiration to guide how their discoveries can best be used for the welfare of human society. I have some suggestions to make:

1. Departments of science at universities should have required courses on the history of their discipline. Such courses should be taught so that the cultural context which contributed to the support of research becomes clear.

2. Scientific departments at large universities should offer survey courses of contemporary scientific knowledge for non-scientist students.

3. In seminaries, law schools, and other graduate departments, courses should be offered on the relation of their subject to scientific developments.

4. Interdisciplinary conferences, sponsored both by scientific and non-scientific organizations, should take place when new, important discoveries are made. We need to share wisdom, not react in fear to one another.

Hence, I support not simply the teaching of more science, but also the teaching of science in relation to other disciplines. I hope that such ventures will prove intellectually stimulating and meet some important needs in our society.

DR. WALTERS: The history of the relationship between science and Western religion has not been an entirely happy one. Major milestones in that history include the humiliation of Galileo for his cosmological views and church opposition to Lyell's geological studies and to Darwin's research on biological evolution. Medical discoveries concerning causes of disease also tended to challenge traditional theological beliefs about the role of sin in human suffering. Given this series of encounters, it is no accident that the major work on the history of science and religion, written at the end of the nineteenth century, was A. D. White's book entitled A History of the Warfare of Science with Theology in Christendom. Happily, the twentieth century has witnessed a greater accommodation between science and religion, although tensions periodically recur, as in the current debate about the teaching of evolutionary theory in the public schools.

The relationship between science and philosophy has been much more peaceful since its inception in the nineteenth century. John Stuart Mill was one of the pioneering figures in developing the philosophy of science as a distinct subspecialty within the field of epistemology. Since 1850 many other philosophers of science have sought to understand how hypotheses are formulated and confirmed, what the significance of laws in science is, and how scientific theories are formulated or abandoned.

Any discussion of the relationship between science and religion must take account of at least two professions: the clergy and the teachers of religion in universities or seminaries. The major points of contact between the clergy and science would seem to occur at two levels: (1) theoretical and (2) practical. At the theoretical level members of the clergy try to relate the faith--whether it be Christian, Jewish, or other--to the scientific approach to reality or to particular findings in science. On a more practical level, members of the clergy counsel members of their congregations on crises of life which often have a rather direct relationship to scientific research or, more especially, its applications in a field like medicine. For example, the clergy may need to know about genetic counseling centers in the vicinity of their churches or synagogues to refer members of their congregation for expert technical advice. Similarly, members of the clergy may need to have a basic understanding of diseases or probable outcomes of particular illnesses in counseling with the parents of seriously handicapped newborn infants or the adult sons and daughters of seriously or terminally ill parents.

The work of theologians, including theological ethicists, proceeds on two analogous levels. On a more theoretical and speculative level, theology has--since the advent of modern science--always had to come to terms in some way with the scientific method and the positive findings of science. In a more applied vein, theological ethicists have devoted significant attention to problems raised by science and its technological applications--for example, problems of nuclear warfare, a broad spectrum of issues in biological research, and the delivery of health care.

Philosophers of science have continued to develop their field, broadening its sphere of attention from an original focus primarily on problems of physics to include those of biology and, more recently, technology and medicine. However, the impact of science has spilled over into other branches of philosophy as well. For example, twentieth-century research in neuro-physiology has profound implications for the philosophic relationship between the mind and the brain and for person theory generally. Thus, these topics in metaphysics can also be illuminated by scientific research.

Especially in the 1970s, ethics has turned significant attention to problems of science, particularly to those of biology and medicine. The 1970s witnessed the emergence of significant interdisciplinary discussion between biology and medicine on the one hand and philosophy and religion on the other. Evidence that the interdisciplinary field of bioethics has taken off includes the following. There are currently 2,000 documents published per year in English alone on bioethical topics. Between 1976 and 1981 no fewer than 10 anthologies of readings in biomedical ethics were produced and have, in turn, been used in approximately 1,000 U.S. undergraduate courses per year on such topics as "Issues in Bioethics," "Ethics and the Biological Revolution," and "Medicine and Human Values." A four-volume _Encyclopedia of Biothethics_ has sold over 8,000 copies in the two years since its publication. And the leading journal in the field, _The Hastings Center Report_, has a subscription list of almost 10,000 institutions and individuals.

Philosophers and theologians have been actively engaged in research and teaching in the bioethics field. Undergraduate majors in philosophy and religion, graduate students in both fields, and seminarians have all been heavily involved in this new hybrid variety of science education. Through their involvement both faculty and students have had to learn a significant amount of science and to confront specific ethical and conceptual problems raised by biology and medicine. Future scientists and health professionals have also gained enriched education through exposure to philosophical and religious ethics while studying questions of profound importance to their careers. The teachers of these students in biology departments and medical schools have also become involved, often in team-taught courses.

The primary need in the relationship of science to philosophy or religion is for continued and augmented _interdisciplinary communication_. Unless quite deliberate efforts are made to foster such communication, the incentive systems within each discipline or department will simply choke it oft. Team-taught courses create particular problems for department chairpersons and university accountants, since such courses may seem to involve only half the time and effort required for an individually-taught course. Interdisciplinary faculty seminars and courses, released time for interdisciplinary course development, and flexibility in course-load computation are thus essential prerequisites for the success of such interdisciplinary efforts.

The federal government--and particularly the National Endowment for the Humanities and the National Science Foundation--has played a significant role in fostering interdisciplinary study in science and philosophy or religion. One hopes that, even in an era of budgetary austerity, federal encouragement of these creative interdisciplinary efforts will continue.

DR. SMITH: My special interest is applied ethics, in particular Christian ethics and moral theology--medical ethics to be most specific. In addition to leading many seminars, short courses and conferences for religious professionals in the Midwest, I have taught courses in biomedical ethics to hundreds of undergraduates. Thus I think I have a pretty good sense of the weaknesses, needs, interests, and abilities of the religious leadership of the country, which is a very important segment of the population because it can influence public opinion and behavior. By affecting the way people think, religious leaders can open or foreclose policy options. Very few people in society have a captive audience of the sort a rabbi, priest, or minister does; even fewer are more likely to be sought out in time of trouble. Of course, not everyone is or should be religious; we have a vested interest in having a well-educated leadership in all of our religious communities. The religious leadership in the United States is deplorably ignorant about modern science. They know that there is such a thing as relativity theory, but they have no idea of what it may mean. They have heard of genetic engineering but immediately associate it with a range of developments similar to science fiction. They are concerned about nuclear energy without much sense of the odds that something disastrous could happen. Environmental issues are on their minds, but they tend to be insufficiently aware that ecological improvements are only bought at financial costs. The intersection between human environmental ideas, economics, and concern for the poor is seldom discussed. Thus, they are not well-informed either about the intellectual frontiers of science or about advancing technology in energy, engineering, or medicine.

On the other hand, they are better informed than most people and, most importantly, realize that they are not well-informed. Thus, they are eager to learn; continuing education programs that will help them cope with the world (as science is changing it) are popular with them, and they are articulate participants. For the most part, our religious leaders are no more stupid than our academic leaders. Their greatest problem--and it is not unique to them--is that they can be intimidated by scientific jargon and by the tangible success of engineers, social scientists, and physicians. References to chi squared, environmental impact statements, and pseudopsychobromides tend to leave them glassy-eyed, abashed, and unable to mount a sufficiently critical, informed analysis. They are left with a vague sense that they are ignorant. The resultant anxiety leads to putting the head in the sand or thoughtless responses. My own experience indicates that the issue is worse with biology, where recent theoretical and technological breakthroughs have been remarkable, and with the related field of ecological studies. It is also serious in the social sciences--notably economics, about which most religious leaders are positively illiterate.

What is to be done about this problem? I have several suggestions. First, we need better, <u>not more</u>, teaching of science. Although most colleges and universities require some course work in science, undergraduates are unexposed to the subject: they see the trees but no forest and are left without any sense of mastery or competence. Furthermore, in many large universities teaching has a very low priority among the scientific faculty. Incentives to change this should come into existence; in the long run research may be more secure if more people learn to appreciate what scientists do. Moreover, few scientists can write well or speak effectively about their research to a lay audience. If religious leaders are to be better informed, the scientific community must be better equipped in the communication skills. Again, it's not a matter of more science, but of a different allocation of priorities within the scientific community.

Second, popular vehicles for the communication of scientific work --journalistic and media coverage of theoretical and applied science-- need to be expanded and improved. Some of the "facts" as we now know them and our possibilities for altering ourselves and our world will change. Higher education should train people to expect this, and our communications services should learn how to cover science in a balanced, accurate, yet attractive way.

Finally, life in a changing world means that people are constantly having to learn to cope. Courses dealing with the human, the value, the moral consequences or implications of scientific change should be introduced. That many people feel religion to be threatened by modern science stands as a terrible indictment of our educational system, which has irrationally excluded the study of religion and ethics from its disciplined purview. The increasing number of courses in biomedical ethics on college and university campuses represent only the beginning of what can and should be done.

What does this imply for the role of the federal government? Basically, it calls for very adroit maneuvering with a precious carrot. The National Science Foundation, the National Institutes of Health, and other scientific funding agencies should make the teaching of college science a high priority and should take steps to make work in the communication and policy arts (i.e., ethics, political science, and law) an attractive option for scientists. Really there are two components to this proposal: (1) that scientists be helped to do a better job of teaching science and (2) that programs to train science faculty in writing, ethics, political science, and law be developed.

In addition, increased funding should be available so that higher education can develop programs dealing with the ethical, economic, and political--broadly, the cultural--implications of science. These kinds of courses are vital for our future religious leaders, as they are for all of us. They can help people develop principles and a vision of the world that will help them to live with change. A step in this direction exists in the so-called EVIST program [Ethics and Values in Science and Technology] jointly funded by NSF and NEH, and both foundations have funded some short courses and seminars for college teachers. But this is just a small assault on a major problem.

Finally, higher education should be encouraged to develop programs for alumni--programs in continuing education about science and its implications. The old joke has it that education is too important to be wasted on the young, and nowhere is that more true than in our area. Some shifting of university resources toward post-baccalaureate education (degree-oriented or not) is in order; unusually active and important among the audiences for such programs will be our religious leaders.

Question: Is most of a typical clergyman's training in graduate study in the theological schools?

Response: That is my impression. The American Association of Theological Schools does not recommend a particular concentration. Indeed, it used to discourage undergraduate work in religion and archaeology and encouraged work of some other sorts.

Comment: Many evangelicals in our country would take an undergraduate degree in religion; go to the same small college to get a preparation for ordination; and, by our standards, would be woefully inadequate.

Response: At least 50 percent of the people who climb into the pulpits in this country are inadequately educated in contemporary scholarship in regard to Biblical scriptures or in relation to current science. They have very narrow exposure to what higher education is.

Question: Are you aware of any data, or have you any impressions, as to the extent to which the people going on to seminaries have some significant investment in science instruction as undergraduates? When people think they are going on to seminary, may they not be attracted to the sciences as part of their undergraduate work?

Response: Sometimes they do. But I have seen the Lord put His finger on the most unusual people, including even engineers who haven't the faintest notion they were going to end up in the ministry; and many of us--like Peter the fisherman and Matthew the tax collector--did not either. You really don't know; we are a very mixed bag, and that probably is a strength, not a weakness.

Question: Isn't it probably going to be a function of the baccalaureate degree requirements, rather than of entrance requirements to the theological seminaries? A major way around it, of course, will be in those denominations in which the baccalaureate degree is not required for the ministry.

Response: Also a lot of people in their middle age now enter the ministry, having a second career, which means they have had extensive experience in another discipline. Trying to educate them in the skills of pastoral counseling and a number of other things is not as easy as it is when you are preaching to young, malleable persons in their early twenties; rear admirals still will be rear admirals, whether they are parishioners or clergy.

Question: Rev. Hamilton, you mentioned the importance of interdisciplinary conferences sponsored by both scientific and non-scientific organizations on important new discoveries so that people can share wisdom and not react in fear to one another. It seems to me that we need a better educated community from the standpoint of science not so much to get them together under those conditions but to get them together after those inventions have become such a pervasive part of our society that the negative side effects cause people to be at each other's throats. Do you foresee the development of courses that would promote a better understanding so that we can meet the problems of that kind?

Response: One relevant function of undergraduate education is to help a young person develop an individual philosophy of life that will help him or her adapt and which is oriented to the fact of a rapidly changing world. I see the long-range contribution as very important. Teaching about things other than science makes a very fundamental contribution to the on-going health of scientific research. I would have social scientists, to a point, and humanists do it. I would certainly capitalize on the development of renaissance in the study of ethics in the past decade, which does tend to involve people primarily in departments of philosophy and religious studies--and I would make sure that was done well. There are also possibilities of dealing with literary discussions and analogies as well as ethical. I would help young people figure out where they are, as they say, and try to suggest to them that philosophies of life, all ways of interpreting the universe, are not just wiped out by some scientific events.

Question: Dr. Smith, some departments have distribution requirements, supplemental to general institution requirements. Has your department's distribution requirements in science led people concentrating on the study of religion to do something scientific?

Response: They have not. At least at Indiana, the whole concept of the minor--that is to say, a requirement outside that major area of concentration--has very much fallen into disuse. Two specific points about that are that (1) in our department of religious studies, only a small fraction (10% at the outside) of students are going to be religious leaders, so that what we require for our majors and training for the clergy are distinguished; and (2) our department has made in its small way a contribution to bioethics development. Courses in that area are very popular interdisciplinary activities of undergraduates, and the interaction (between pre-medical student, students in religious studies, and students in journalism) that goes on in that classroom is salutary and, as some earlier panelist remarked, a nice precursor for what is going to happen down the road.

Your mention of distribution requirements calls to mind one more idea that goes back to a religious analogy. The separation of church and state is required by our Constitution, but the states retained establishments of religion for some time after that. The church was disestablished in Connecticut in 1818; and 10 years later, in the midst of a tremendous religious renaissance, Lyman Beecher referred to it as "the best thing that ever happened in the State of Connecticut." For the most part, non-science courses that bear on the sciences are, if you will, disestablished. That is to say, they have to play in the Free Market; and one result is that they have got to be well-taught, as distinguished from being easy, if they are going to survive.

Question: Could I conclude that one of the best things for the improvement of the teaching of science to non-specialists is to stop requiring any science at all and make courses compete in the marketplace?

Response: It is very healthy for science departments to compete against each other. I would not want to remove all distribution requirements, but that is exactly the direction in which I was going. In fact, the teaching of science on our campus has improved in the past decade as a response to such pressure.

Comment: In most academic institutions now, the departments do compete with each other.

Comment: There is also the problem that the leading people in those departments would naturally prefer to work closely with majors who plan to devote their careers to, say, biology or physics than they would to a group of non-scientists. Also, if there is any correlation between excellence in research and publication and excellence in teaching, then that already skews matters against the non-science majors.

Comment: Some of the comments about competition among science departments for students is precisely what we heard during the recent discussion of the deterioration of quality in science education and may in fact be related to it. When you suggest that these captive classes are of less quality, I am not all that sure it is true. They may not be nearly so popular because they may require a little bit of effort, work, analytical reasoning that we are unwilling or unprepared to do.

Response: I would tend to trust the judgments of my faculty peers (who will, of course, talk about each other) and judgments of very high-quality students. That is one way I would judge it.

Secondly, in the particular science department I am thinking of, I don't think the quality of science teaching has dropped in the past decade. I actually think it has gone up. But more competition would help as would other incentive changes within the institution encouraged by outside funding.

Comment: It is interesting that we have had more specific suggestions for the federal role from persons speaking within the other groups. I thought all three of you made several suggestions that the federal government could do certain things to improve the situation.

DR. SMITH: The separation has always been a limitation on the government but not a limitation on the church presently.

Comment: Maybe I was confused because I heard differently. Dr. Smith, for example, felt the need to improve the quality of teaching with "better teaching, not necessarily more courses." This has troubled some of us on the committee: as the data emerge, they look like rather abstract body counts; and one doesn't really know what educational impact lies behind those body counts by number of courses and percentages of students who take common courses. It strikes me that increasingly there is a kind of Pirandello aspect to this committee. Our mandate has to do with undergradute education and with the federal role, and we are sort of in search of that. I just did not hear this group talking about predominant federal roles these days in undergraduate education.

Comment: Maybe I misunderstood. I thought David Smith was talking about federal funding for experimental courses on ethics, economics, politics and science, and other cross-disciplinary issues and workshops for alumni as well as funding to increase the work of the National Science Foundation and NEH and their seminar/workshop program. Or did I misunderstand you?

Comment: That is what I meant. I work with the assumption that this is an "era of austerity."

Comment: But the small carrot reference was for federal funds to improve teaching of communications skills to scientists and to do better teaching.

Question: We can talk about the desired role; and certainly one role in achieving the desired role of the federal government is to play what someone earlier referred to as the "sugar daddy" role. If we are going to be persuasive in the short term, at least--and I am speaking with respect to the current administration--it may be because we have identified a role vis-a-vis science education and the undergraduate nonspecialist which has some unique features that almost have to be played at the national level.

Now, have any of the suggestions you have made zeroed in on something so distinctively a national need that you think only the federal government could do this--as opposed to private foundations, increased state support for university budgets, or some other part of the private sector?

DR. WALTERS: Never having been afraid of shooting from the hip, I'd say, "Yes, the federal government is the greatest funder of research so that I would have thought it possible to relate in some way funding programs for improved teaching to funding of research."

Comment: More research seems to be funded by industry.

Comment: Federal funding of research, at least in the biological sciences, is still 60 percent.

Comment: For those suggestions you made, you don't care whether the impetus comes from government or whatever?

DR. WALTERS: No, I have to say that that was where the money came from. In fact, if it doesn't come from the federal government, some private money is certainly available. Some foundations will help. The Washington Cathedral was done with private money, and some of the things we have done in Indiana have used private money. The Lilly Foundation has been very active.

Comment: The history of the last 10 years in the biomedical fields and ethics reveals that the major impetus has come from the National Endowment for the Humanities much more than from the National Science Foundation and NIH put together and, I think, much more than from private foundations. Whether that was necessarily so, who can say? The fact was that no one else was doing it, and it is not clear that anyone else will pick it up as the National Endowment's funding is cut.

REV. HAMILTON: Like David, I don't think it matters where the money comes from. However, in order to make an impact on the country as a whole, state funding couldn't do it, and foundation funding is not big enough so that we almost of necessity fall upon our federal funding.

Comment: In many cases, state funding is hopeless. Its foundations are on the federal level.

Question: Through the day I have been hearing about course needs for non-science students in science, but the identified needs seem to deal with survey kinds of courses rather than specific disciplinary courses. In that context, the reward structure within university academic departments tends not to support such courses, and faculty members tend not to get rewards for teaching survey courses; the norms within the field tend to discourage people from engaging in those activities sometimes on a voluntary basis.

More specific information in this emergent field of bioethics could determine whether it is feasible to create a respectable, separate group of individuals whose primary identity is attached to interdisciplinary, cross-disciplinary survey approaches to giving scientific information to undergraduates. Is the bioethical field emerging in that way? Do people now get Ph.D.s in bioethics and write articles for bioethical journals? Is there now a separate subfield that is neither biology nor philosophy but something else that has its own identity, its own meetings and international congresses, and so forth?

DR. WALTERS: Within the field of philosophical and religious ethics is a clear trend toward specialization so that one simply can't help but cover the waterfront of applied ethics. There is a subgroup whose business is to keep up with the general science journals and the best medical journals as they are published weekly and monthly and then try to relate those developments in biology and medicine to the traditional categories of philosophy. Also, it is possible now to get a Ph.D. in philosophy with a special concentration in medical ethics, for example, so that one could enter either a philosophy department or a medical school's department of humanities. Much of the work initially is that survey kind. I would hope that would not rule out more specialized types of courses where, for instance, a biologist and a philosopher might collaborate on the mind/brain problems and recent developments in neurophysiology. After the survey course was finished, I would hope a more detailed type of course along the lines of the traditional reward system in either philosophy or biology, for example, would be possible.

Question: Dr. Smith, who would take the responsibility for course development at an interface like science and ethics? Are you teaching the bioethics course out of the Department of Religious Studies?

Response: That is correct. There was a great deal of support within the science department, particularly in biology, for the development of such a course; and I began team teaching it, as LeRoy suggested. A good introductory course in an area has to have a distinctive disciplinary or departmental identity. If nothing else, it is necessary pedagogically. Certainly, many students in biology are pre-medical majors; and in fact, the last time I taught the course, 90 of the 160 students were pre-meds.

In no way does it address all of the issues that this committee is concerned with. It does take a step in the direction of helping young persons to incorporate a changing world into the philosophy of life they are working out for themselves. In the interests of a healthy scientific community over the years, that is something that science has a very great interest in.

In addition, retraining programs are needed for scientists. In a good introductory course in any science, some questions of ethics, politics, and economics will be raised, and there may be a tendency for some scientists to assume that they can easily pontificate about such matters. And I think that they can speak on ethics no more than I can about biology. Thus, for NSF to put its prestige behind some retraining programs of that sort might accomplish a great deal.

Comment: In my university we have a "university professors' program," supposedly the parent of these innovative, cross-disciplinary offerings. My experience in that has been very disquieting indeed because the courses emerge to the student as essentially free-floating electives, and here again the reward system comes into play. My students were not giving to the courses enough time to make them interesting for me and fruitful for them because the reward system called on them to give their primary emphasis to their own departmental concentration; and since these courses were simply floating around out there in the blue somewhere, they took second or third place. If these are to be developed, they must be given a home in a department where they can be fitted into a concentration.

Question: Would the seminaries put more science into their programs if the undergraduate colleges offered courses which they considered more appropriate? Or are appropriate courses already in existence but just not incorporated into the program?

Response: In a few seminaries it is now possible to take biomedical ethics, and once in a while, there is an amorphous course called "science and religion"; but a great part of the problem has to do with the perception by seminary administrators of the clergy's future needs, which have little to do with science or technology. Another part of it is the two-culture phenomenon at the undergraduate level, where pre-seminary students are more likely to take a major in the humanities or the social sciences than they would in the natural sciences.

REV. HAMILTON: It calls for both. It is a social problem that is everybody's responsibility. For instance, after the atomic bomb physicists and atomic scientists began to worry, wanting some discussion of political and ethical issues. Now as Dr. Walters knows and said, the biologists are scared stiff as to what they are going to do with their new knowledge, and they are really asking for information and dialogue.

Comment: We have listened to lawyers, businessmen, and various people; but not one of them has come out clearly and said that if you develop appropriate courses, we will put them into our programs.

Response: If you mean fund them on a seminary level, I am sure they would get in. If the federal government provided grants to major seminaries in this country for pilot programs to offer first-class teaching in science and some scientific disciplines (among them, ethics), certainly the professors and presidents would be delighted to have them, and students would attend.

Comment: But there might be a Constitutional problem with federal funding of seminary courses.

Comment: It has historically always been true that the federal government creates a program because there are always going to be people to take advantage of it. The question is "Is there a need that ought to be filled that way?" and not whether people will take the money that is available. People will always take money if it is available.

Comment: Not every religious leader is a rabbi or a clergyman. If the federal government funds postgraduate aid for all these continuing education seminars, will religious leaders, clergy and lay, attend? At least in the state of Indiana, the answer is easy: "Yes, they certainly will develop themselves." If better undergraduate science courses are offered, will more people take them? The answer to that is easy, too: "Yes, they will." However, whether there is a structure that will require those things is unknown.

Question: If good courses were offered, would the professions build them into their requirements or at least advise their students about them?

REV. HAMILTON: You are really restating the problem because the problem of so many of the scientists is that they are politically uneducated. Doctors, in general, are terribly uneducated and so busy with their own thing. But if you just take a subscription to the New York Times for a couple of months, you can see that the massive worldwide problems are ecological and all involve contemporary technology as an essential part of their solution. Whether the engineers will take advantage of something that is offered is known only by the engineers, not us; we need a lot of help and expertise.

Comment: Not to act like the economists as they thrash in the supply side of economics and such, but I think we have an issue of supply and demand. On the one hand, we can make courses available; but if there is not some kind of incentive to encourage people to pursue this kind of information, people will automatically go into it because of interest--for example, the scientific literacy of lawyers, the scientific literacy of business managers, or the scientific literacy of other non-science professions. Both forces have to be at work. One is incentive to have better teaching for people who are non-scientists, but the other is a demand situation; otherwise, you will only have a small group that will tend to do it.

Universities now are not unwilling to come to grips with that kind of rationale. The Harvard change in approach to core curriculum is an example of that: they are not willing to let it be just a totally optional kind of an experience; certain items will be considered prerequisite. A certain level of competence--whether it is in communications, of an analytical type, or of some content nature--will be prerequisite for completing the program. However, whatever we are trying to do, we are trying to bail the lake with a teaspoon unless the professions themselves are willing to call to the attention of those wanting to pursue the professions the need for preparatory training at the undergraduate level in order to matriculate to that professional training program.

Question: Isn't it fair to say that most of the groups we talked about today generally require a liberal arts degree for entering into the professions?

REV. HAMILTON: Even for the mainline traditions, an engineering degree is a perfectly good prerequisite for a master's degree.

Comment: Law prefers a person with a liberal arts degree.

Question: How much factual biology is in a course like bioethics? Is there a prerequisite of biology?

DR. SMITH: I in no way regard it as a substitute for a course in biology. Most students come to the course with a basic knowledge. I seldom have to explain basic things; I really deal with conceptual issues and technical problems in ethics, illustrating with biological facts and problems.

Question: So we scientists can't push our problems of educating students in that kind of biology-offered course?

DR. SMITH: Oh, absolutely not. It is very different, but it is quite relevant. But for me to try to teach a course in popular biology would be a scandal.

Panel on Education

DR. STRINER: To lend a little bit of credibility to what you might take to be brash statements coming from a dean of a business college and an economist, let me first state that I was an undergraduate in biology at Rutgers University but after the war decided to change to economics.

However, because of my background, I was still intrigued with relationships between economics and the social and the physical sciences. My dissertation in 1950 on the economics of developing a synthetic liquid fuel industry based on coal led to my job in the Department of the Interior, which decided by 1953 that this was an exotic venture.

I left to join a fledgling institution also interested in the relationships between economic growth and R&D; that was the National Science Foundation. As an economist, I started their series of surveys in R&D, since at that time we didn't have the faintest idea of how much R&D was being done in the United States; and without that basic information, we really were ill-prepared to determine what relationship existed between R&D and the economy. Meanwhile, I have remained in touch with my colleagues in the physical sciences as well as the humanities, since I have had great doubts throughout my life that many problems occurred in nature by discipline.

Although I had never stepped into a business school until I became dean, I soon learned that business education in the United States is, in a word, terrible for a number of reasons. For example, regardless of which school of education you examine in the United States, when you step into a class at 10:00 a.m. on Tuesday, you usually find the same course being taught in much the same way because we have an accrediting association. Accreditation for business schools--unlike the schools of law and medicine--is voluntary, however. But they all more or less adhere to the structure of the curriculum as designed and as revealed by the American Association of Colleges of Business. The basic assumption is that in the first two years, students take humanities and social sciences and become rid of them; and then they pursue what is really serious education in finance, accounting and management, operations analysis, and so on.

I find this horrendous, revealing a gross ignorance of educational theory on the part of the business faculty and deans. If one mentions Dewey to them, they think of Thomas Dewey rather than John Dewey; and there is very little understanding of education, learning readiness, and the relationship between areas such as psychology, biology, botany, and areas of business interest. The result is people very skilled in particular, narrow areas but with very little sense of the relationship between technology, the humanities, and psychology and what they are doing. What the Japanese are doing in industry to handle problems of productivity, for example, is in many instances related to what Maslov has done in terms of a hierarchy of wants and needs. In the United States there is very little understanding of the relationship between Maslov's pioneering work in psychology and its implications for the quality of work in life and decisions which management makes. In addition, it is difficult to learn to conceptualize in many business areas because we have not had the benefit, for example, of understanding the implications of the Linnaean system or taxonomy for the learning process itself.

As a result, we tend to turn out very highly-trained individuals in very narrow areas. In contrast, a student should have an in-depth course rather than a survey course--an intense experience in any one of the physical sciences (chemistry, or physics, or biology--it does not much matter)--and be forced for a year or two to confront a rigorous sense of discipline and the relationships between areas of knowledge. He or she is much better equipped to deal with the necessity of understanding business relationships and the components that affect management decisions. Without that, I suspect we turn out semi-literate people unable to question intelligently and to open to concepts and ideas outside of his or her previous realm of experience.

Nonetheless, short of converting every baccalaureate into a doctoral program, very little can be done in one sense. In another sense, one thing that can be done by the federal government is to look seriously at the imprimatur put on various mechanisms for accrediting accrediting associations. It is devilishly difficult for a dean of a business school--if he or she doesn't wish to pioneer in terms of new approaches to education and environment. There are a tremendous number of penalties imposed on such a school and such an individual, and I speak to this because I happen to be one.

A number of good schools in the United States--for example, Georgetown Unversity--have not chosen to be accredited for business. Yale's excellent School of Management has not chosen to go the accrediting route. On the other hand, Harvard has; and I might say that some of the great schools like Harvard and Chicago tend to ignore some criteria of the accrediting organizations, which are not overly quick to drop them because of their obvious concern of not having the first-rate, prestigious institutions accredited.

To deal with this problem, about three years ago we redesigned the curriculum to include the physical sciences and to break the lockstep of the first two years being completely social science and humanities. We redid our curriculum to reflect what we now understand in terms of learning readiness: for example, we feel that a student can take a great deal of accounting the first two years but a course like psychology as a junior or senior--after the individual has been away from home, been with different people, lived in a different environment, and acquired a greater degree of sensitivity to the world around him or her.

We also, contrary to what AACSB [American Assembly of Collegiate Schools of Business] would accredit, have a mixed discipline so that classes dealing with industrial relationships are team-taught: someone with a background in industrial psychology can offer insights about anxiety situations and conflict situations to supplement the insights of the professional individual whose background is industrial relations, which basically is based on concepts growing out of a major body of psychology.

Although it is difficult to do, we have done this. We had no access to federal funds to do this; but I finally was able to convince a few small organizations like IBM and AMOCO that business graduates had a great deal to learn. By the way, from the point of view of serious social scientists, the only way to do this is to run two tracks, so that you have a control situation with random sampling of entering students and, over a period of six years, with specific targets that you would measure for performance. An outside firm is evaluating this so that we can't be accused of building in the possibility of the higher, rather than the lower, probability of success.

In conclusion then, an effective individual trained in the area of management must have courses which deal with the physical sciences as well as the social sciences. Secondly, these areas should be taught in depth in terms of a specific regular course, not a survey course. Thirdly, these areas should be blended in some instances with the substantive area. (By the way, we also teach business law with a team effort: a professor of philosophy whose background has been in ethics and social values works with a law professor so that the student gains insights into the changing nature of law and of the ethical constraints and values of society as reflected by law--which is a living, growing, dynamic mirror of the image of the society in which we live.) Finally, the role of the federal government is not to become a part of the gatekeeper activity that makes experimenting with alternative approaches to accreditation difficult. I am not opposed to accreditation, but it has to be based on a series of criteria perspectives that are conducive to learning, to experiment, and to enlarging rather than curtailing the intellectual environment in which we educate people in the humanities.

Funds are always welcome. Business schools right now do not seem to be short of funds. In a way, that is unfortunate because good people who would rather become chemists or educators are forced to enter business schools so that they can acquire jobs.

Question: You mentioned the federal role in accrediting and the accrediting organizations, but I am not sure what that role is or whether that is a chink in the armor that we need to look at more carefully. What is the federal role in that accrediting organization?

Response: There are two organizations. There is an organization representing the professional societies which has been in existence for a long, long time; and now there is a new group in the Office of Education that emphasizes affirmative action, requires schools to have a public interest member for accreditation, and plays a key role in passing accreditation organizations by virtue of reviewing their processes and criteria and supporting them as legitimate organizations. The government's recommendation does not have the effect of the law in the sense that a school is penalized by virtue of not receiving accrediting funds necessarily, but many foundations will not give money to schools of business unless they are accredited. Thus, even though accreditation is voluntary, it is very difficult not to seek accreditation, for business firms and foundations are leery if they really don't know much about the criteria and the curriculum, believing that if you are accredited, you are better than if you are not.

Comment: But the federal group would not say that this accrediting organization is no good because it does not require something.

Comment: Yes, they could deny accreditation.

Response: It is a very unhappy and sort of idiotic situation. By the way, the American Assembly of Collegiate Schools of Business has for years been subject to criticism by business schools themselves, many of whom are accredited. Most of the state university systems or state legislators themselves don't really know what accreditation is about but assume that it must be good; ergo, you must be accredited. I know that any number of deans of state systems--for example, the dean of the School of Business of the University of Tennessee--feel very strongly, as I do, about these criteria; but because the state system must be accredited, he has to go along with it, although he has spoken out against what the accreditation process does to education. You are caught in a Catch-22 situation.

Private schools are in a somewhat different position; but then if they are seeking funds and are not going to buck the system, they follow the accreditation route.

Changing your curriculum is very difficult. The problem is building in more of the physical sciences and social sciences and putting them into a curriculum in a much more imaginative fashion. The difficulty is that at some point you soon encounter the problem of the accreditation criteria.

Comment: Your accrediting agency is perhaps one of the leaders in erratic and irrational conduct; but I have never understood why the constituent schools don't simply try some internal reforms.

Response: Oh, you would almost have to have a background in abnormal psychology because basically, most people don't want to upset the system; it is easier to go along.

Comment: It is also self-perpetuating after a while. An executive director and a group of officers get wedded to it, and they tend to move it along.

Comment: But you also must remember these accrediting associations and accrediting various kinds of institutions; and typically, the accrediting body would be controlled by the main bulk of the institutions rather than the elite. You would have an elite institution and a mismatch between the criteria imposed on the curriculum and the contraints imposed by the accrediting agency.

Comment: The more you accredit, the more that becomes true. At the meetings--for example, of AEA--I have always been intrigued to find very few papers presented by faculty or deans from prestigious universities. Largely, they are from schools not terribly innovative in terms of the faculty publications and research; and it is a self-perpetuating system.

Also, in accreditation, you can go from Harvard to East Carolina State. They are both accredited.

DR. ANDERSEN: I want to point out to you that you can always look to Indiana for a lot of light. After all, it was a Posey County, Indiana, physician who proved that pi was equal to three, which he subsequently patented and volunteered to give to the state of Indiana to use free. That was the first that came out of Indiana, and the light continues to be bent in that same direction.

I am going to talk about the elementary teacher because he or she is the non-specialist that I deal with. I am not going to try to talk about the inherent value of science as a study itself, though I certainly come from that particular orientation.

First, do elementary teachers need to understand science? Children viewing the scientific, technological world around them frequently will ask their teachers questions about science, ask for scientific explanations. And the science textbook or science curriculum may involve children in making scientific decisions they will share with peers and their teachers. The fact that the elementary school child and the teacher cannot escape ever-present science supports the argument that elementary teachers need to understand science.

However, that is only a small part of the story because science has more than itself to offer the elementary teacher. Good process or activity-oriented science instruction provides a means for developing basic skills needed in both language arts and mathematics. Several studies (see bibliography, p. 223) support this. For example, Rowe (1970) discovered that the amount of student-initiated content-relevant speech in 10 Harlem classrooms was 200 to 500% higher during science classes than during language arts classes. Similarly, Ayres and Mason (1969), Hoff and Languis (1973), and Renner and Coulter (1976) all have found that young children involved in process/activity-oriented science courses make considerable language gains. In yet another study, Quinn and Kessler (1976) found that when children are given practice in formulating hypotheses, their language becomes syntactically more complex. And finally, Newman (1975) suggests, "You don't have time <u>not</u> to teach science." Children initially unsuccessful in reading and writing are frequently successful in process/activity-oriented science, and this success motivates them to pursue their other school work with more vigor. Hence, the elementary teacher needs to understand science not only because it is a valued study in its own right, but also because it facilitates the learning of reading, writing, and mathematics.

The second question is "How well is the U.S. system doing?" A visit to an elementary school most often will reveal that science was taught last semester or will be taught next semester. Sometimes teachers honestly will admit not having enough time to teach science--probably because most elementary teachers simply do not understand science, particularly the science in the elementary curriculum. They did not have science in the elementary school; the only science they had in high school was biology; and the general education science courses they took in college may have prepared them for a second college science course but did not help them to understand the process/activity-oriented, modern-education science curriculum.

General education science courses are more frequently a rhetoric of conclusions than an exciting experience that reveals the nature of science. First-year courses are more frequently dues one must pay, for faculty as well as students, to get to the excitement of science. When one recalls that the elementary education majors typically take only these dreary first-year courses, it is easy to conclude that they will learn little from these courses of value to elementary teachers. How well is the U.S. system preparing elementary teachers in science for their roles as elementary teachers? In my humble opinion, if we planned carefully, we <u>could</u> make it worse.

Third, what types of knowledge are needed? To be a really successful elementary science teacher today the teacher should (1) understand the process/activity-oriented science commonly found in elementary science curriculum materials; (2) understand enough modern science to be able to comprehend the science discussed in the popular media; (3) understand enough science to examine local science phenomena that attract the spontaneous interest of their pupils; and (4) have enough knowledge about, and practice in using, microcomputers that they actually will use them in instructing their pupils. To summarize the elementary teacher's science needs, I shall borrow from a science colleague who stated that the elementary teacher needs professional courses in science specifically designed for elementary teachers (Droste, 1978).

Fourth is a consideration of a role for the federal government. A massive effort is needed. However, if the national mandate to reduce federal expenditures is to be met, we must focus our attention only on problems of high national priority. The president of the National Science Teachers Association, Donald W. McCurdy, in testimony before a subcommittee of the U.S. House of Representatives listed eight high-priority needs for science education. Of the eight he listed, six apply to the problems I addressed:

- Upgrading the scientific, mathematical, and technological competencies of teachers at the precollege level;

- Development of applications-oriented and practical science and mathematics instructional materials for schools and for lower divisions of colleges and universities;

- Helping colleges and universities upgrade laboratory apparatus, including especially microcomputers, micro-processor based equipment, and other apparatus which form the components of high-technology industry;

- Development of instructional materials to inject the use of computers into essentially all science and math courses, as appropriate, at all levels;

- Providing high quality, targeted science programming by TV for children and adults to help reduce the widening gap between what is known by those who are not scientists, but who must work and live in a technological world;

- Continued research on how people learn science and mathematics.

At the present time, it probably is correct to state that typical pre-service elementary teachers do not relate the science they are learning in college to their future roles as elementary teachers. To correct this state of affairs, it probably will be necessary for universities and colleges to design special programs for pre-service teachers. At Indiana University an NSF planning grant led to the development of the Indiana Model for the Science Preparation of the Elementary Teacher (see Figure 1). This and similar program efforts may be necessary if we ever hope to insure that our elementary children re- ceive appropriate instruction in science.

Let me briefly point out what I mean in saying that particular sort of thing. In the state of Indiana, a law enacted in 1962 requires 15 hours of science of all people who are going to be elementary school teachers, meaning that one-eighth of their college preparation is in science. After more than 10 years, we discovered that in spite of teachers' having all of this particular science, science was not being taught in the schools of Indiana. This led to the idea that we call the "Indiana Model": we wanted to see what we could do to make sure that the elementary majors did not hold the science they were learning way out here and their ideas about teaching way over here. We wanted to force a cross-over so that the elementary majors would learn right away that the science they were learning in college was relevant to them as elementary school teachers. Therefore, we planned and put together our two-track model that helps the pre-service teachers to learn some science, immediately puts them into a situation where they talk about teaching that science, and immediately puts them out into the classroom teaching the science to kids. Now that they see this cross-over, science becomes important to how they view their careers.

<u>Question</u>: You have painted such a grim picture of the problems, I'd like to really ask two questions. You said that even with the standard of 15 hours, science wasn't being taught so that you developed the Indiana Model. How is that working? Secondly, unless we cure this at the primary and elementary school level, are we really going to be able to handle it at the college level as a matter of science education?

<u>Response</u>: If you consider teaching children basic thinking skills, the science process skill, that can successfully be done with primary school children. You could move then into a curriculum that would involve intermediate-school children in learning integrated process skills by experimenting and so on, practicing in doing these things all the way through the grades. But what tends to happen is that teachers who are process-oriented and who get kids involved in thinking and doing science are then, all of a sudden, followed by a teacher who believes that the science is content, causing the students to spend a year learning science as a foreign language and to forget many of their process thinking skills. Later, the chemistry teacher says, "These kids can't work with proportions."

There needs to be a lot of work on articulation. We have to see what we can do to keep emphasizing. Years ago, people said drill was bad in schools, and we still say drill is bad: most educators will talk about "appropriate practice," which is really drill that kids enjoy doing and which is an absolutely essential part of any good curriculum. These things could be done, and more federal support could bring some additional romance back into teaching science. Teaching science in secondary school right after Sputnik was exciting and romantic. I could share my problems with college science teachers on Saturdays, and they would help me think about what I was going to do later on.

The second half of the question is "Is the Indiana Model working?" A lot of people, including the older students, are very excited and very happy about it. But the Indiana Model is, frankly speaking, one faculty member deep. If I had someone die tomorrow in biology, physics, earth science, or astronomy, I would have a problem of recruiting another faculty member because they don't get rewards from the department for doing it. Another problem is trying to subtly reorient them to teach the process-oriented kind of science necessary so that the teacher knows the elementary school curriculum. Also, teacher education is an all-university business: science people teach science content, and we want them teaching science content, but also science people come over and go through all of the elementary curriculum. Science people asked, "Hey, what do they do with the elementary team in this concept?" And we copied half a dozen different elementary books on that particular concept. Science people even brought their children to page through the science curricula so that they could determine from their kids what was exciting in science to them and what was not.

It is taking a lot of energy. We have five to six meetings a year, and we really have been meeting long enough that we are bloody obnoxious to each other: "Kids this semester can't do such-and-such." "Who didn't do something about that earlier?" "We needed to do more about that earlier." And as long as we have the energy to maintain a constant fight between science educators and the science people, it will continue to evolve and grow.

We think the Indiana Model is good; but we are very, very much like the old farmer who said, "Don't tell me all those new ideas; I know how to farm a lot better than I already do." You rarely will find a teacher who teaches as well as he really knows how, but we must convince them that they always want to try to do that job as well as they know how.

<u>Question</u>: One of your teachers told me that a major reason for her becoming a primary teacher was that her son reached a point in school where she realized that he was not learning anything about science. She told me that in her department people typically will teach a course for one, two, or three years and then, growing tired of it, want to move to some new experience. But if you have only one biology teacher and one physics teacher, what are you going to do 10 years from now after her son has just graduated from college and she is no longer concerned with his science education?

<u>Response</u>: You deal with it, very frankly, painfully. Right now, I would like to go to the National Science Foundation and say, "Hey, you gave us money to plan this model. We are really the only institution in the whole country that was able to pull off implementing this particular model, one that is full-sized like that across all disciplines. Now we would like some funding."

Figure 1. The Indiana Model

Content/Process Stream	Planning Stream	Practicing Field Experience Stream
Q200 Basic Science Skills Variable Credit 1-3		
Q201 Biological Science for the Elementary Teacher 4 Cr.	Q211 Methods 1 Cr.	Early Experience
Q202 Physical Science for the Elementary School Teacher 4 Cr.	Q212 Methods 1 Cr.	Early Experience
Q203 Earth Science for the Elementary School Teacher 2 Cr.	Q213 Methods 1 Cr.	Early Experience
Q204 Astronomy for the Elementary School Teacher 2 Cr.		Student Teaching Elementary Science

Now, I would like to spend a whole summer with all the science teachers and rework every one of these courses, fight through articulation problems even more, and rewrite the whole works, preparing for trial again. But even though I have great science people working with me, they are very cold to that idea because even though they give up a lot of time during the academic year to work with me, they cannot afford to spend the summer. They have to take their summer for research.

The same thing is true with elementary school teachers. When I was a secondary school teacher, it was not economically feasible for me to go to Summer Institute. Teachers can't afford it; they have to work in the summer. Unless NSF puts money back into that particular program so that it is economically rewarding or economically feasible for these people to attend, teachers will not pursue summer programs of this type.

But teachers really do work hard, and they are really getting burned out at the end of five years, resorting to one year of teaching 20 times. The number of people that have taught 20 years and really have had 20 full years of teaching are few.

DR. LOCKARD: While Dr. Andersen was talking about elementary science teaching, I am going to be talking more about the middle school's and the high school's interests, too.

I would like to move right into the question of how well the U.S. education system is doing the job. I work day by day out of the schools, training science teachers and supervising student teachers. Two weeks ago, while in a sixth grade (middle school) classroom with the chairman of the science department, I noticed that he had copies of the fourth edition of Focus on Life Sciences, a middle school, sixth/seventh-grade book that I co-authored. When I asked how he liked it, he said, "Well, fine. But it is too difficult for our students, and here is what we are using," handing me a science workbook with a second-grade reading level. I think that answers part of the question of what is really happening.

All of you here know about the three NSF studies on social studies, science and mathematics. I also was part of a team that, working for NSTA, compiled a summary on the sciences and math, determining that the key to the whole operation was the teacher.

I am concerned presently that we have some serious problems: for example, teacher burn-out and the substitution of discipline in the place of science. Discipline is the name of the game all over the place.

I am concerned about the training, about how to get these teachers trained to go out there and face the situation. I don't think we are doing a very good job; too often we see professors who have not been in the classroom for some period of time involved in training of science teachers.

I have a master's in education because I could not get science courses in the summers at the institution I attended. At an NSF institute, I discovered that plants were living--they weren't pickled, pressed, and preserved. We need some group--the federal government or others, the National Academy itself--to say that teachers need up-to-date science, and I am concerned that what I see out there and what is going on in the university classrooms are two different ball games.

I am concerned that the science faculty members and the education members are not communicating, although some institutions have been trying to solve that problem. Colleges of education and colleges of science must get together. Even some science departments do not communicate. For instance, when I was at Maryland in 1961, the dean of the graduate school, who was also the head of botany, hired me. Sometime in our interview, I said that I could teach more biology in a year course than I could in a semester of botany and a semester of zoology. When I arrived in September, I received a biology book in the campus mail along with a note saying, "Since you are the only idiot interested in biology on this campus, you keep it." I mention this because these faculties--botany and zoology--were not speaking at all. Now at least most departments of biological sciences are trying to work together, but we still have four separate ones at Maryland: microbiology, entomology, botany, and zoology. So the neutral ground for writing a biology course was the Science Teaching Center; and we literally had to have departments come to the Science Teaching Center as separate faculty before we could write it. That poses a serious problem in the sciences that is worse than that between science and education.

I believe in joint appointments. Mine keeps me honest and in my own field so that I teach every day in the science department and try to do some research, too.

The second question was "What types of new knowledge and understanding are needed to cope with the changes that are taking place in education?" They need to have on-going training. We talk about teachers' having 25 years' experience; but many of the teachers I worked with across the state of Pennsylvania for two years as a science teaching consultant showed me that they had one year of experience repeated 24 times. I don't say that facetiously: they are teaching the only way they ever taught. But if you have been in science departments and talked with them, as I have, then you know that isn't the kind of science that is going to turn on kids.

We assume that the kids coming to us in our science classes are interested, and we don't really motivate them the way we have to. We can't do that in public school--or private school--at this point. We need to have on-going institutes that get the science teachers and the science educators up to date. If you think there is a scientific lag, there is a fantastic educational lag that follows that and is much worse.

The best and most exciting parts of science textbooks are the last couple of chapters. Why? Because the largest-selling biology text in the country was written in 1921, and its 1958 edition contains the same words, the same paragraphs, the same old pages. So where is the exciting biology?

One strength of the curriculum development work was the involvement of scientists with writers and educators; they were forced to share their information. We need to work at that: scientists have as great a responsibility here as educators to say, "Yes, we are interested in helping the science teachers in their training." Dr. Andersen has talked about special courses for elementary science. We don't need separate courses for secondary science; but we do need in the science departments faculty members who understand the need to motivate students and to get them excited about the latest thing instead of saving that research for graduate school.

"What role can the federal government play in providing us our educational opportunities?" was the third question. First is to take a positive position that says, "Yes, science teaching is important, and the training of science teachers is important." Government shouldn't just wait. For instance, when I was working with AAAS in the science teaching improvement project, we wrote the Flemming Bill, which became the National Defense Education Act, only because Sputnik went up. Otherwise, the Flemming Bill would still be floating around and never have gotten moved.

And I am really very much concerned about the present political situation. Two years ago, I was asked by the Ministry of Education in the People's Republic of China to take a team of science educators to China. I watched second-grade students in mathematics doing the same mathematics that my daughter was doing in the Washington area in the fifth grade, and I became very much concerned about that. Similarly, students in East Germany are so far ahead, as are those in Japan. We have to wake up before it is too late. We are going down the tube right now, attempting to wipe out science education and the support that some of the people in this room have helped to build.

Scientists must speak up, take a stand, and say, "Yes, we do have important activities for science teachers. I don't think we can sit and talk about it any longer." We must have an interaction between scientists and educators. The scientists must take teaching seriously. The Westinghouse Science Talent Search has shown over the years that people who have come through their program and become actual scientists made their decision at 12.8 years of age, indicating that middle-school science education is crucial if we are interested in having scientists. We must teach them and get them motivated.

Dr. Andersen has talked about the problem of elementary science teachers who are afraid of science. Lots of studies reveal that that is a serious, unresolved problem. A similar problem exists in the middle schools right now, as many teachers are assigned to teach subjects outside their competence. At Maryland we require at least 60 hours of science and mathematics, one of the highest standards in the country. Yet we still feel that students are not adequately prepared --even after a year of chemistry, a year of physics, a year of earth science, a year of math, and 36 hours in biology. They end up not in a life science course where they are qualified, but by teaching physics or a physical science course in the middle school. Things are not very good out there, and I am not very proud of what we have done for the system. We really have to worry about it.

Comment: This committee ought not to become too sunk in the notion of the poverty of science teaching in the public schools without realizing that what is true of science teaching is true of all the other areas. We are in a period where there are a great deal of problems with respect to teaching in general in elementary and secondary schools. For instance, the problem of teacher burn-out is in fact becoming fairly widespread, not restricted to science teachers. Furthermore, the difficulties of teaching tasks and the inadequate preparation that teachers have been given to face those tasks are universal throughout the whole curricular area. We should not just think that this is a problem locused in science teaching. If we feel that way, we might want to treat it quite differently than if we feel that it is a problem of teaching in general at both the elementary and secondary levels.

Comment: We might want to give it emphasis, however, since both Dr. Lockard and Dr. Andersen have indicated that stirring the kids up with science helps all the other areas.

Comment: Very much within the purview of our committee is this concern for teaching non-specialists science. That non-specialist in many cases will be the teacher of elementary science later.

DR. LOCKARD: I did not mean that we were not to take the problem seriously and that we are not to address the problem. We would need to address the problem with somewhat different conceptual equipment, leading perhaps to somewhat different recommendations, if we felt that the problems were endemic to the school system as a whole as opposed to being endemic to the training of science teachers. While I think he is right about the general problem, the science is more severe because of keeping up to date. The problems that occur are terrible. Change is just so much more rapid and exciting.

Under NSF I could hire scientists all the time to teach summer school, which had a reward system built in; but you can't get anybody to teach science at a university in the summer any more because they have to publish, obviously, and can't do that and teach simultaneously. It is serious, and we are way behind.

Question: Could teacher institutes be taught remotely by TV or by sending out kits of apparatus in order to avoid the problem of away-from-home expenses?

DR. ANDERSEN: Yes, but you are not going to get the same pay-off. One of the reasons for the summer institutes' success was the fact that NSF brought science teachers from all over the place, and it was really a deeply rewarding professional experience because we literally talked about teaching science over breakfast, at lunch, at dinner, and in our social get-togethers. It was really an intensive experience that will not be achieved by sending out a cassette or something like that. I am not saying that we shouldn't send out cassettes. That is another action that certainly could be done; mechanisms to exchange software to work on the Apple computers and the microprocessors that are arriving in schools are very, very much needed and quite popular.

Comment: I think that one of you made the point that the teacher was extremely important. I always have trouble with programmed instruction, which seems to me to be so darned impersonal.

Response: I have had quite a bit of experience with that, and I would say that it's the program, which can be exciting and interesting and humorous or dull and drab and boring.

Question: In some places, people will try to use these machines to replace teachers, and that is a mistake, for there are too many things that teachers can do. The only way to humanize education--to give kids the competencies they want because kids do like to be competent--is by using computer-system instruction. But that is not instead of teachers; it is to supplement them.

You referred to your 400 elementary-school teachers. What is your assessment of their intellectual capabilities and their commitment?

Response: I teach the first course in a sequence--the 2200, basic science skills course. We do everything--from very, very simple algebra to observing; classifying to experimenting; mixing variables to destruction of matter--because of the way we have the sequence organized. The typical elementary education major has had only one year of algebra--which has been forgotten because it was taken during the freshman or sophomore year--and biology, their last science course. The NSF report just pointed out that only one-third of our nation's secondary schools require more than one year of science and mathematics.

About a third of them are motivated to be elementary school teachers because they love children, and that third makes me highly nervous. About two-thirds of them are motivated to be elementary school teachers because they love to see children learn. Those kids are really worth every bit of effort that you can give them. Some of them lack these basic skills primarily because there isn't continual practice of them.

Question: What about their inherent ability? Are they some of the better students in the college? What we hear is that people that elect the elementary education major are the least capable people.

Response: It will be an overlapping curve that will not be skewed towards the brighter student. It is skewed toward the student with lesser ability, although we have some super bright.

Question: Yes, but how badly skewed is it? This is one of the problems. I suspect another group is taking a major in elementary education because they did not know what else to do.

DR. LOCKARD: Well, not so much now because there are not so many jobs out there for elementary education.

Comment: And there are lots of other opportunities for women, although what you are saying might have been true several years ago.

Comment: Reports I have been reading contradict that. They say that is the common opinion, but actually there are jobs in high school.

Comment: In the physical sciences in high school, it is true that we are placing about 75-80 percent of about 300 students who finished this year.

Comment: That is pretty high placement. What happened to the others?

Comment: Some got married and don't want to teach.

Comment: They don't want to teach, or they go into their father's business.

Comment: Some can't find jobs.

DR. ANDERSEN: Now, by the way, one of the things that the Indiana Model does is to eliminate many students who discover very early that elementary teaching is not the role for them.

DR. STRINER: Concerning the use of programmed instruction, the argument on the subject usually winds up with the fallacy of the excluded middle, the basic assumption being that you have to go either this route or that route. In the real world what happens, of course, is that the programmed instructional approach is quite often security to a large number of individuals teaching in that area. I saw an excellent example of that in the early 1960s when I was on the Review Panel of the President's Committee on Juvenile Delinquency: one of the problems we encountered was functional illiteracy, which we overcame by taking individuals who had been tossed aside as untrainable and using the talking typewriter and software development highly effectively in dealing with these young people and adults.

It was fought by a number of individuals in the educational establishment who took the position that, after all, the humanizers and master teachers could do a good job. I asked one individual, "How many master educators do you have in your public school system? And are they really capable, in terms of their numbers, of dealing with the problem of functional illiteracy in the City of Chicago?" When the answer was "No," I asked, "Don't you think they might want to use this alternative route?"

What happened was that the choice was made unconsciously to continue the high level of functional illiterates in the City of Chicago. This is repeated in New York, Washington, Philadelphia, and you name it. The defense which often arises very quickly is usually that humanizing should exist; and of course probably the most humanizing aspect of the whole process is the large numbers of people who were cast aside on the scrap heap and remain not only functionally illiterate but unemployable.

Question: You described graphically what I suspect many of us intuit about the current situation in secondary schools, not only in science but in other fields as well. Do you attribute the severity of the problem to the programs that are available or not available in undergraduate institutions? I raise the question again because of the mandate to the committee. Are you suggesting that something could be done that is not being done, specifically within the context of the baccalaureate program, to ameliorate the circumstances that you describe?

DR. LOCKARD: You have raised a crucial question, but I don't know the immediate answer. Dr. Andersen talked about teaching science as a process, but a real serious situation in the science departments is that we are still teaching science as a body of knowledge. We talked about experimenting, and AAAS did the science-process approach; but we don't have students develop hypotheses in order to grasp their courses. The science stuff is in the graduate school. I am really bothered by the fact that there are more new terms in biology than in a new French course for a student.

Question: But wouldn't it be true that whatever is done during their four-year period in the undergraduate school is going to become, in some significant measure, obsolete very quickly after they leave so that you will simply replicate in some measure the problems you have already described? Needs exist for updating educational experiences and support mechanisms for them; but if you focus specifically on the undergraduate, are you suggesting that the deficiencies in science education really do grow in significant measure out of the undergraduate opportunities to study science?

Response: My point is that for too long we have taught science as a body of knowledge--and I for one taught chromosomes and units of tissue. But science changes too fast. We have to teach it as process, to learn to take information and work with it logically, but we are not doing that in most of the undergraduate courses.

Question: Labs are exercises, not experiments. Suppose at Maryland you had a student who took 36 credits of chemistry as a major. Would that student be prepared to teach chemistry in high school?

Response: He would know a lot of content.

Question: But do they know the right content? You see, I am so thoroughly convinced that in many academic programs in chemistry--and the more prestigious the institution the more probable it is--a chemistry major can be absolutely unprepared to teach at the high school level.

DR. LOCKARD: We tried to change that by working on science teaching methods, but it can't be done in one semester.

Comment: I have been looking for a course that is more appropriate for the general student. Now, if you can develop a course that is appropriate for the general student--namely, the person who is not going to become a professional scientist--my guess is that that course would also be appropriate for those people that might teach. Thus, it is possible to approach both of those problems.

Response: In fact, the scientists did say, "We will teach a different kind of course." They are willing to go to elementary, but they are not willing to go to secondary. I don't want to segregate that; we would have to change the nature of science courses.

I am concerned about the science educator--the training, updating, and interactions with science of the science educator. The curriculum didn't work across the country because the science educators were not exposed to it. There is one area on which we could concentrate the undergraduate program: giving science educators their training and putting them into joint appointments where they have to know the science as well as the education and then getting them out into the schools to see what is happening. That is really going to upset them, but it will challenge the deans to have their faculty really go into schools.

I was told five years ago that I could go out and supervise student teachers but that I was too expensive, that full professors cost too much. I said, "I will not teach any more science teaching methods" --and I didn't. This year I finally forced the issue, just to see what is out there: I went back and substitute taught. The principal could not believe it and said, "This is the first time an education professor has ever volunteered to substitute in this school in the three years I have been here."

So we have a real problem. It is serious and needs to be moved on.

APPENDIX A

INVITATIONAL HEARING ON SCIENCE AND THE PROFESSIONS

March 20, 1981
Washington, D. C.

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