ADDRESS AND CONTRIBUTED PAPERS

TECHNOLOGIZING SCIENCE

Alice S. Bennett

I am pleased to have the honor to address the members of the Indiana Academy of Science at a time when we are looking forward to celebrating our centennial year. The Indiana Academy of Science has functioned effectively for almost one hundred years as an organization whose principal objectives are to promote scientific research and the diffusion of scientific information; to encourage communication and cooperation among scientists . . . and to improve education in the sciences" (1). I believe that the members of this Academy will continue to assume important leadership roles in promoting science in the state of Indiana during the coming year and the following hundred years. I also believe that if we are to assume leadership during this period of the computer revolution, the crisis in science and mathematics education, and the loss of international superiority in advances in science and technology, we, ourselves, must clearly understand the nature of science. We must understand the definition of science. This is not an exercise in semantics because the way we define science has a profound impact on how we do science.

It is not the intent of this presentation to make value judgments as to the relative importance of either science or technology. Technology is dependent on the findings of science and the furthering of scientific investigations is dependent on the tools created through technology. However, I would contend that it is imperative that we, as scientists, understand the meaning of science and distinguish between 'research and development' and 'science and technology' and place each in its rightful position of priority, if we are going to be able to define the relationship of science to society, and to face the challenges of the 1980s.

Tonight, as we are looking forward, I would like to take a brief look backward as well, in an effort to put the present into some perspective. The advancement of science during the last hundred years has been fast and overwhelming. A look at the "100 years ago" section of recent issues of Scientific American reminds us that at the time the Indiana Academy of Science was chartered the existence of sub-atomic particles was unknown, chromosomes were unknown, enzymes, nature's catalysts, were still a mystery, and radioactivity had not yet been discovered. Indeed, it was only about 50 years ago that the first protein was isolated and shown to have enzymatic activity, and that the quantum atom was described.

The accomplishments of science and technology during the last three decades have been increasing logarithmically and are too numerous to even begin to list. The explosion in science and technology in the past decade has been, at best, unbelievable. This explosion is not only pushing forward the frontiers of knowledge, it is also affecting the lives of citizens in a way that is without precedent, and has created an upsurge of interest in science, science education, and technology. How to deal with this revolution will be a prime concern during the first years of our second hundred years.

The upsurge of interest in science, technology, and science education is not new. Many of us can remember the reaction of the country to the launching of Sputnik by the Russians. I remember October 4, 1957 very well, but it had a different significance for me since that was the day our first son was born. Some years later he was quite impressed to realize that he was born at the beginning of the space age. At that time the response of the country and the scientific community was to support new approaches to science education, to increase the budget for scientific research, and to expand our technological and space efforts. These actions gave birth to the golden age of science. Researchers had almost unlimited freedom to pursue studies which were truly basic science. It was largely upon this foundation that the rapid advances in applied science and technology in the 70s and 80s were based. However, by the early 1970s science was under severe attack. This led to calls for a moratorium on science and the now-famous "Golden Fleece Awards" which went to any research that did not show immediate results.

A number of writers have suggested that the anti-science attitude of this period was really a dissillusionment with the apparent failure of technology to solve all of our problems and the realization that technology actually created many expensive

At the dinner meeting Alice S. Bennett delivers her Presidential Address, "Technologizing Science."

problems. This represents an obvious confusion of technology and science. Now, 10 years later the interest in science and technology has been rekindled. We hear that it is an important, indeed, a prime objective of the nation and the state of Indiana to develop a scientifically literate population and to educate young scientists. As a scientist it is gratifying to see this rekindled interest in science, technology and science education, but it also causes me to have some grave concerns. At this time I would like to share some of these concerns with you.

In discussing these concerns I will:

1. Discuss the factors that contribute to the misuse of the of the term science.
2. Expand on what is meant by the terms science, technology, basic research, and development.
3. Consider the implications of confusing technology with science.
4. Suggest some approaches for scientists to use in the coming years that may prove to be productive.

How are the current problems in dealing with science and technology different from those encountered in the past? I believe there are factors that make it difficult for us to act objectively. *First*, the development of computer technology has produced some of the most rapid changes in society that have ever before been seen. In addition, the advent of this new tool has been confusing and, indeed, frightening for many laymen and scientists. I believe that many are at a loss as to how to cope with the problems and solutions to problems created by this powerful capability. I'm sure many persons view computer cabability equivalent to Big Brother in Orwell's 1984 (2). They forget that we, not the computer, are in control. *Second*, there are the economic factors. A depressed economy does not lend itself to considerations of well planned short-term or long-term solutions to problems. *Third*, there is a change in policy and level of government support of research and science education. Along with this change there is an increased reliance upon private industry to fund research. This shift in funding and change in emphasis is coming at a time when there is an out-cry for the development of a scientifically literate population as well as for jobs for the unemployed.

A key question is, "Are we, as a group of scientists providing the type of leadership that is necessary for the growth of science and for the development of a scientifically literate population? Do our actions really reflect our concern for science education? Are we, along with society, in our overzealousness to attack the immediate problems of today, confusing what is meant by science as compared to technology; research compared to development. Are we using a form of 'Newspeak', as described in Orwell's 1984 (2), where 'Technology is science' and 'development is research'? Are we technologizing science?"

Let me give you some examples. A popular magazine (3) counsels young people considering careers, "The key question you have to ask yourself is, 'Will there be a strong demand for my particular expertise in the future, . . .?'. The all-important given is—-you guessed it—-technology." Actually the 1980 forecasts by the Bureau of Labor Statistics predict that high-technology occupations, as a group, will account for only 7% of all new jobs between 1980 and 1990 (4). In last Sunday's Family Weekly magazine (5) the caption for the lead article read "Futureworld: How Will Science Change the Way You Live". The article actually deals with technological advances such as robotics, talking toasters and applications of computers to psychiatry. The word, science, is not used in the article.

R. Van Norman, in the textbook *Experimental Biology* says,

> "The public impression of the goal of science seems to be approximately the following: Science is working hard (1) to find ways of raising enough food to feed all the people, (2) to improve medicine so that the people can stay alive to eat the food, and then (3) to develop more terrible weapons to wipe out this larger, healthier population. These and other technological aspects of science make good news stories, even though they give a distorted picture of science."

The following are quotes from persons who are responsible for guiding the course of science in the nation, including the Presidential science advisor. "Then there is the whole question of accountability in basic research. Is basic research contributing to society in ways Congress and the public expect it to be? Has it fulfilled the endless frontier spirit?" (7). "I think we've shown this year that government will respond enthusiastically when it's presented with programs, **even as esoteric as basic research,** with clear relevance and importance to national objectives. (emphasis mine) (8)." ". . . while researchers may pursue basic knowledge it should be attuned to the opportunities of the industrial world." (9). A secondary school teacher confided in me that she was not allowed to buy supplementary teaching materials for her classes because most of the budget was now going to computers. There is obviously confusion about what science, basic research and technology really are.

There is a tendency to look for immediate solutions to problems that have been in the making for a long time and to jump on band-wagons. I believe that calling support for technology support for science can be misleading and costly and will not lead to solutions to the problems of society and improving the scientific literacy of our people.

The primary aim of science is not application, it is gaining insights into the causes and laws which govern natural processes. This is not to say that science must be conducted, or ever is conducted in a vacuum. In 1972, Victor Weisskop, a member of the National Academy of Sciences, said, "I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsence it has been my fortune to stumble upon." (10) H.B.G. Casimir, commenting at the Symposium on Technology and World Trade in 1966, gave the followings as examples of how decisive technological progress was made by scientists who did not work at all for a well-defined practical aim are:

1. Basic circuits in computers were not found by people who wanted to build computers, but instead were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.

2. The nucleus of the atom was not discovered by people who wanted a new power source, but by the Curies and Rutherford and Fermi and a few others.

3. Electrons were not discovered by people in search of a different light source, but by people like Thomson and Lorentz.

4. The discovery of electromagnetic waves was not the outgrowth of of an urge to provide better communication, but by Hertz who emphasized the beauty of physics and who based his work on the theoretical consideration of Maxwell (11).

Weisskopf concludes that there is hardly any example of twentieth century innovation which is not indebted to basic scientific thought. In searching for new insights the scientist is often forced to extend the technological frontier.

In a letter to the editors of Chemical and Engineering News, Paul Lindenmeyer, President of Dynamic Materials, Inc. says, "It is surprising how few people are able to distinguish clearly between science and technology, between research and development. . . . so few people realize that the second item is impossible to achieve without a sufficient amount of the first. It is not possible to achieve new technology without sufficient knowledge of the underlying science or to have a successful development without the required results of research." (12) He further points out that commercial companies will spend millions to develop marginally improved technologies, but refuse to spend money for research. He suggests that one must distinguish between science and technology and research and development and that the first is not only essential to the second, but also can be accomplished for only a fraction of the cost of the latter.

What are the implications of saying technology when we mean science—what are the problems with technologizing science? *First*, defining expected outcomes of basic research and science encourages what is fashionable at the expense of off-beat work that might be truly creative. In a recent seminar, a noted researcher stated, "Writing some parts of research proposals have become a little like writing science fiction." At the present time it would have been difficult, if not impossible for Dr. McClintock to have done the work which led to receiving this year's Nobel prize in medicine. Now, the emphasis on immediate results far out-weighs the traditional search for scientific truth. The emphasis on publication as a necessary criterion for advancement discourages long term thoughtful research. I was sorry to hear a scientist state, "We must get another paper accepted for publication, so that we can get enough money to continue our research." That is not the reason for publishing scientific papers. I recognize that this problem of publishing has always existed but in today's scientific climate, its effect has been magnified. Equating immediate results with the ability to continue scientific research is counter-productive. I would not suggest that results are not important. I am more concerned with the timing.

This leads to the real concern that opportunities to increase the scientific base are diminishing. Ten years ago Weisskopf said, "One could conclude that tasks are for applied science only and that research . . . not directed toward one of the specific problems is not necessary. It may be harmful since it takes away talented manpower and resources. This is not so. The spirit of basic research is . . . to find connections and dependencies, causes and effects, laws and principles. This attitude of basic research is necessary for the solution of today's pressing problems because it leads people to search for causes and effects in a systematic way, regardless of any ulterior aim." (10) These words, I believe, are even more relevant today than they were ten years ago.

Second, an emphasis on results leads to a disproportionate concern for protecting those results. Whatever can possibly be patented is being patented. Doctoral students are being counseled to patent their doctoral dissertations whether they contain marketable material or not. Graduate theses, written by students supported by industry, are not publishable until they are released by those corporations. Some of the cooperative efforts between universities and industry have been successful, but much of the resultant research has been directed toward the achievement of immediate results and are not being shared with the rest of the scientific world. Free communication of scientific knowledge is also being restricted by the present administration. Frank Press, the president of the National Academy of Sciences, has warned, "standards and laws preventing open communication would be counterproductive and harmful."

Editors of the Christian Science Monitor commented ". . . the United States must maintain a strong foundation of fundamental scientific and engineering research if it is to compete in today's world . . . but this foundation which depends on free communication and on support for widespread creativity, cannot be maintained if basic science is to be fettered by constraints that are more appropriate for the development of weapons or of proprietary products 'attuned to the opportunities of the industrial world'." (9)

Third, the crisis in science and mathematics education cannot be solved by simply buying more computers for more schools that have teachers who are unprepared for using them effectively in teaching science and mathematics. The public truly believes that we are making inroads into solving our problems in scientific literacy by buying more computers. I believe it is unfortunate that the term computer science has come to be used so indiscriminately. There is a science which should be called computer science, but too often the term is used to refer to the use of computer languages, word processing, and game-playing. We, as scientists need to gain expertise in using computers to further our science and to teach science more effectively. We cannot, however, allow society to confuse buying more computers with funding science education.

In writing about "Science and the Atari Generation", Sheila Widnall, Massachusetts Institute of Technology, asks, "Is it necessary to be an electrical engineering or computer science major to participate in the computer revolution?" (13). She concluded that most students must believe so. From 1973 to 1983, the course preference of new undergraduates for physics declined from 19 to 8 percent, for mathematics from 18 to 6 percent and for chemistry from 8 to 2 percent, while engineering majors increased from 38 to 75 percent. In addition, she notes that the students who do not choose science are the best.

Fourth, funding for both science and technology is important if we are to deal with the problems of the future; but let's be clear about what we are funding. It is of interest to look at the federal budget for research and development for the last ten years (14). In constant dollars, federal funding for basic research was 2.6 billion dollars in fiscal year 1967 compared to an estimated 2.8 billion dollars in fiscal year 1983, 2.5 billion in 1982 and 2.4 billion in 1981. Funds for applied research have also remained at a relatively constant level. The dollar amounts are similar but this is illusory when one considers that the rules of the game have changed. The administration is targeting its support to fields where it can foresee some immediate payoff. Are we encouraging what is currently fashionable at the expense of truly creative work? When we confuse what is meant by science and by technology, we do not notice that actual support for science is diminishing.

In conclusion, I believe that, as members of the scientific community and as members of the Indiana Academy of Science, we have an obligation to work toward the stated objectives of this organization. If we are to do so, we must understand clearly what we are about and communicate the meaning of science to students, the public and policy makers. We are fortunate in having a framework for this task already in place. Through our various committees we have the mechanisms for interpreting science to the people of our state, providing scientific input into the functioning of state agencies, and providing leadership in the policy-making processes. By maintaining close relationships with the Junior Academy of Science we can serve as models for junior and senior high school students who can observe scientists in action and communicate directly with them. Through our research grants programs we are able to encourage and support quality research projects of senior scientists. Each year talented high school students are also benefiting from these programs. Many of these young people are presenting results of their studies at state and national science meetings and Science Fairs. How better to learn the meaning of research than to do it yourself? It is in these activites that we have the best opportunity to have an impact on the future scientists of our state. It is here that we are able to convey to them the meaning of the scientific process and separate science from technology. By expanding our newly founded Fellowship for Secondary Science Teachers program we will be able to help more teachers understand more clearly the research process so they can provide research opportunities for their students and teach the true the meaning of science. Through these and other programs of the Academy we will hope to have a positive impact on science in the state. What we do in the state of Indiana is only a small part of a larger effort, but none the less an important one.

As individual scientists we also can promote good science. I believe we have an obligation to help establish guidelines for funding research, both from the public and private sector. We must provide this leadership and not leave it to those who are less informed about the meaning of science. We need to be aware of the rules of the game we are playing when those of us in the academic community enter joint ventures with governmental agencies and private industry. We must ask these questions: "What are the restrictions in the project?" "Am I simply working part-time for that organization, providing data for projects they designed?" "Will I be able to freely communicate my findings with other scientists?" "Is this project detracting from my established research interests?" These questions should be answered within the framework of a clear understanding of the meaning of science and research.

Science contains many activities, most of which can be achieved more efficiently with the use of mordern technology. Out of this science will emerge the basis for future technology. However, this cannot be the sole purpose of science. Science cannot develop unless it is pursued for the purpose of pure knowledge and insight. If we 'technologize science' we will not only stand in the way of scientific development, we will also obstruct the development of technological advancements.

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During a luncheon break, several longtime members of the Academy discuss plans for the centennial year. Clockwise, beginning at left, are Robert H. Cooper, William A. Daily, Charles B. Heiser, Jr., Fay (Mrs. William) Kenoyer Daily, and Mrs. Robert H. Cooper.