Science Education in Global Perspective: Lessons from Five Countries

Edited by Margrete Siebert Klein
and F. James Rutherford

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About the Book

The decline in the quality of American public school instruction, particularly in science and mathematics, is a well-documented subject of concern for our nation. This book examines the educational systems in Japan, the People's Republic of China, East and West Germany, and the Soviet Union, countries that have developed particularly innovative approaches to science education. By providing an international cross-section of data, this volume serves as a comparative document of value to American educators, lawmakers, and the involved public.

About the Series

The *AAAS Selected Symposia Series* was begun in 1977 to provide a means for more permanently recording and more widely disseminating some of the valuable material which is discussed at the AAAS Annual National Meetings. The volumes in this *Series* are based on symposia held at the Meetings which address topics of current and continuing significance, both within and among the sciences, and in the areas in which science and technology have an impact on public policy. The *Series* format is designed to provide for rapid dissemination of information, so the papers are reproduced directly from camera-ready copy. The papers are organized and edited by the symposium arrangers who then become the editors of the various volumes. Most papers published in the *Series* are original contributions which have not been previously published, although in some cases additional papers from other sources have been added by an editor to provide a more comprehensive view of a particular topic. Symposia may be reports of new research or reviews of established work, particularly work of an interdisciplinary nature, since the AAAS Annual Meetings typically embrace the full range of the sciences and their societal implications.

WILLIAM D. CAREY
Executive Officer
American Association for
the Advancement of Science

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Margrete (Gretchen) Siebert Klein is the director of the Visiting Professorships for Women Program and the Research Opportunities for Women Program at the National Science Foundation. She spent 1976 and 1977 living in the German Democratic Republic, where she studied the East German system of education. Her research culminated in a book, The Challenge of Communist Education: A Look at the German Democratic Republic. At the invitation of the East German Ministry of Higher Education, Klein returned to the GDR in November 1982 to undertake a study of issues in East German higher education. She holds a B.S. in mathematics from Baldwin-Wallace College, an M.S. in physics from the University of Michigan, and a Ph.D. in science education from Northwestern University.

F. James Rutherford, chief education officer at the American Association for the Advancement of Science, previously served as the first Assistant Secretary for Educational Research and Improvement at the U.S. Department of Education and as Assistant Director for Science Education at the National Science Foundation. He was executive director of Harvard Project Physics, a national curriculum project, and chairman of the department of science education at New York University. Rutherford has served as a consultant to the science education division of UNESCO and deputy leader of the precollege science education delegation to the People's Republic of China in 1979. He has published extensively on science education and curriculum development, and earned an A.B. from the University of California, Berkeley, an M.A. from Stanford University, and an Ed.D. from Harvard University.

Kathleen Mary Fisher is an associate professor of biological science education at the University of California at Davis, where she obtained her doctorate in molecular genetics. Previously, she was a Senior Fulbright Lecturer at the University Sains Malaysia and a program associate in the National Science Foundation's Research in Science Education Program. Fisher has produced instructional television programs and computer software, and authored numerous books, articles, manuscripts, and columns on audiovisual/computer instruction, science writing, and genetics. She also holds a B.S. in biological sciences from Rutgers University.

Paul DeHart Hurd, professor emeritus of education at Stanford University, led the science delegation to the People's Republic of China in 1979. He is a member of the National Committee on United States-China Relations and a science education consultant to the National Science Board. With degrees in science education, botany, and plant ecology, Hurd has published extensively on precollege science education in the United States and the People's Republic of China. He is a Fellow of AAAS and holds a doctorate in science education from Stanford University, an M.A. in plant ecology and an A.B. in botany from the University of Northern Colorado.

Joseph I. Lipson is group director of WICAT Systems, Inc., a nonprofit educational institute devoted to the use of advanced educational technology and instructional design to improve the quality of education. He has directed the Division of Science Education Development at the National Science Foundation. Holding degrees in physics from Yale University and the University of California at Berkeley, he has taught college physics, geology, and science education. Lipson has published many papers on the educational uses of computer technology, physics, and geology, and is a Fellow of AAAS.

Charles Posa McFadden, director of continuing education at the Technical University of Nova Scotia, has authored many articles and monographs on science education in the Soviet Union, Cuba, and Canada. As project director of the Atlantic Science Curriculum project, he developed intermediate science textbooks. McFadden holds Ph.D. and M.Sc. degrees in geophysics from the Universities of Western Ontario and British Columbia, respectively, a B.Ed. in education from Saint Mary's University, and a B.Sc. in mathematics and physics from the University of British Columbia.

Kay Michael Troost, a professor in the department of sociology and anthropology at North Carolina State University, has been a Visiting Fulbright Professor to Hiroshima and Hiroshima Shudo Universities, as well as a visiting researcher at the National Institute for Educational Research in Tokyo and a North Carolina Japan Center Faculty Fellow at North Carolina State. He has published many articles on the Japanese educational system, influences on adolescent learning of science, and group interaction. Troost holds a B.A. in sociology from Carleton College and M.A. and Ph.D. degrees in sociology from the University of Minnesota.

Izaak Wirszup has been teaching mathematics at the University of Chicago since 1949. Under a grant from the National Science Foundation, he intensively studied the Soviet mathematics and science education system. The preliminary report of his findings was a factor in President Carter's call for a review of science and technology education in the United States by the National Science Foundation and the U.S. Department of Education (*Science and Engineering Education for the 1980's and Beyond*, Fall 1980), and he has testified before the U.S. Senate regarding appropriations for science education. He has consulted on mathematics and science education programs in South America, Africa, and India. He holds a Magister of Philosophy in

Mathematics from the University of Wilno and a Ph.D. in mathematics from the University of Chicago.

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Dr. Hurd credits the criticisms, questioning, and contributions provided by the reviewers of the draft version of his report with providing significant benefits to the preparation of his manuscript. He takes responsibility for the synthesis of their comments. He gratefully acknowledges the assistance of Thomas Fingar, China Specialist and Director, United States-China Relations Program, Stanford University; Fu Juan Ming, Associate Professor, Institute of Foreign Education, Beijing Normal University, People's Republic of China; and Wang Yingjie, Research Associate, Beijing Normal University. Roy Cheng Tsung, United States-China Relations Program, Stanford University, did the science textbooks translations. Douglas P. Murray, Vice-President, East-West Center, Honolulu, Hawaii, contributed much of the data included in the tables. Dr. Hurd sends many thanks to these people and to the science teachers, scientists, and administrators in China who inspired his interest in their educational system. He is especially indebted to the National Committee on United States-China Relations, who coordinated his visit to China and generated the stimulus for the writing of his chapter.

Dr. Klein wishes to acknowledge the supportive role of the American Association for the Advancement of Science in making this book possible. Its publication is due largely to the encouragement and support of the outstanding staff of AAAS. In the early stages, the contributions of Gary Todd, whose participation was always characterized by skill, cooperation, and good cheer, and Joellen Fritsche, whose support was a key factor underlying the initiation of this book, need to be recognized. Production of a final manuscript would not have been possible without the diligent efforts of AAAS publication office staff members Kathryn Wolff, David Savold, Susan O'Connell, and particularly, Valerie Montenegro.

Preface

American education today is at a crossroads. Numerous studies bear witness to a general decline in the quality of public school instruction, especially in science and mathematics. We are warned of a national crisis with serious implications for the future vigor and health of American intellectual and industrial society. The present situation has attracted the attention of serious students of American education, members of the American scientific community, and concerned lawmakers across the political spectrum. We can be certain that, at least in the near term, a full range of quick-fix and superficial approaches to the problem will be proffered in the educational marketplace. Such proposals, if accepted, will give the impression of response and action. But they will fail if they do not redress basic problems in both the structure and substance of American science education. Only the development of durable programs and educational strategies will, over the long term, lead to the revitalization of American public instruction. My optimism about the resourcefulness of American society leads me to believe that we will follow the latter course, and the present volume is presented in the positive spirit of participation in that task.

In rethinking American science and mathematics education, it is essential to approach the task from a global perspective. Our national interest requires us to examine in detail the various models and approaches to science education undertaken by those who are or will be our major economic and ideological competitors. The aim of this book is to provide a comparative document that will assist American educators, lawmakers, and the concerned public in developing this international perspective. The authors describe the educational systems of countries that have developed particularly innovative approaches to science education. The book is initiatory in the sense that it is the first to provide an international cross-section of data on this topic, but it is by no means definitive. Further study will be required to ascertain the applicability of particular approaches to the American educational system.

Of particular interest, however, is the polytechnical approach to general education in Communist countries. That approach provides instruction in many scientific and technical subjects throughout the elementary and secondary school years. It is explored here with full recognition of the gap between the advanced level of scientific and technical knowledge being acquired by a comparatively large segment of the youth in these countries and the inability of these same regimes to translate such knowledge into the economic well-being of citizens. This gap, which implies a failure in socioeconomic theory, in no way detracts from the achievements of Communist educational theorists. In Communist countries, research in education is treated seriously, as is education policy, which is designed to achieve maximum efficiency in the interests of the state. An examination of Communist successes in this area should not be dismissed on ideological grounds alone, since it is in our own best interest to be aware of both their successes and failures. On the other hand, the technological and industrial advances made by Japan and the Federal Republic of Germany are too well-known to need further comment here. Their school systems also provide models of effective science education, and they too underscore the importance of a cross-cultural examination of educational practices.

This volume grew out of a symposium entitled "A Challenge for American Education: Scientific Literacy in Japan, the Germanies, and the Soviet Union." This symposium, which I co-chaired with Dr. Joseph I. Lipson, then director of the Division for Science Education Development and Research at the National Science Foundation, was presented at the Annual Meeting of the American Association for the Advancement of Science held in Washington, D.C., in January 1982. Other symposium participants included Professor Izaak Wirszup, Dr. Kay Michael Troost, and Dr. Vivian Edmiston Todd. Although at the time Professor Wirszup's work on mathematics education in the Soviet Union and my own work on science education in the Communist countries as represented by the German Democratic Republic had already come to national attention, the symposium was the first presentation at a general scientific meeting of this research on the approaches to science education in Japan and the Federal Republic of Germany. In a very real sense the authors of the present volume are among the pioneers in developing an understanding of the deficiencies in American science and mathematics education through comparisons with other countries.

Since our symposium presentations, Dr. Troost has returned to Japan and I have traveled to both East and West Germany to undertake further research. Both Dr. Troost's chapter on Japan and my own chapter on the two Germanies have been updated to include our most recent data. Professor Wirszup's paper has also been fully revised to cover information on Soviet science teaching to 1984.

A few words concerning the heroism of Vivian Edmiston Todd are in order. During the early planning stage of the symposium, the vitality and enthusiasm of Dr. Todd were an inspiration to both Dr. Lipson and me. We were unaware, however, that at that time she was terminally ill. Despite the tragedy of her personal circumstances, Dr. Todd's commitment to the revitalization of American science education was such that she felt compelled to participate in the symposium. With the assistance of her husband Leonard, Dr. Todd outlined her involvement with and perspectives on science education in Japan. Two weeks after the symposium, she passed away at her home in Long Beach, California. Her perseverance and commitment, however, are a lasting tribute to her outstanding career. As curriculum specialist for the Allied military government in Japan, Dr. Todd established, through the reconstituted Japanese Ministry of Science, Education, and Culture, a universal science education program that begins in first grade and continues uninterrupted through the universities and technical institutes. In Japan, she is known as the "grandmother" of Japanese science education, and much of what Japan is today in terms of its technological capability can be attributed to her pioneering efforts.

In addition to the contributions of the symposium participants, this book is enhanced by the work of several other experts. F. James Rutherford, Chief Education Officer at AAAS, joined me in the task of editing the volume. Dr. Rutherford also contributed a final chapter, in which he summarizes the lessons to be learned and makes recommendations for American science education. Dr. Kathleen Fisher, associate professor of biological sciences education at the University of California, Davis, graciously contributed her insights into the sociology of American science education to the introductory chapter, which she coauthored with Dr. Lipson. We are pleased to include a new chapter by Professor Paul DeHart Hurd, an eminent science educator with first-hand experience in the People's Republic of China. He describes how the Chinese are attempting to develop an educational system that will optimize the scientific and mathematical talents of their young people. We include this chapter because it provides another example of an educational system that stresses training in science from the earliest school years and because it provides a unique view of the educational plans of a nation encompassing one quarter of the world's people. Finally, we are grateful to Dr. Charles McFadden, a Canadian-based science educator with first-hand experience in the Soviet Union, for permission to include his chapter describing aspects of Soviet science education.

The present work highlights three major areas of concern for American educators. First, it will become apparent to readers of this book that the preferred approach to science and mathematics instruction in the countries described is the teaching of an array of disciplines, over a period of years. This is in contrast to current practice in American public secondary schools where students are taught one science for one academic year, then move to another discipline the following year, and in public elementary schools, where science may not be taught at all.

Second, policymakers understand in each of the countries described that young people cannot participate effectively in modern, technological society unless they have a broad understanding of technology and its application in industry. The implementation of this attitude has resulted in the polytechnicalization of general education, particularly in the Communist countries. As a consequence, instruction in mathematics and the sciences has become more closely linked to the requirements of modern industrial society than it has in the United States.

Third, as more countries achieve industrialization, the United States is facing greater and greater challenges in the marketplace. Policymakers in countries studied in this volume understand the key role played by education in their nation's technological development. Our effective utilization of their educational innovations will help us remain technologically competitive and may, in fact, ultimately contribute to the survival of Western democratic traditions.

Margrete Siebert Klein
Washington, D.C.

Kathleen M. Fisher, Joseph I. Lipson

Introduction: Science Education in Other Countries— Issues and Questions

Japan, China, the two Germanies, and Russia command our attention as major nations on the world stage. They are of great interest both culturally and economically. Our national history has been intimately involved with them in both war and peace; their history and myths have captured a place in our national imagination; and their strengths as competitors challenge us daily. China, Russia, and East Germany consider themselves to be Marxist nations, and this ideology influences almost every aspect of their national and daily life. Japan and West Germany are now democracies and capitalist economies. In World War II, Japan was conquered and occupied by the United States, and we shall see in Chapter 1 that our occupation staff influenced the Japanese educational system in important ways. While the United States also played a major role in the conquest and post-war occupation of West Germany, the structure of the school system in the Federal Republic was not substantially affected and has continued an earlier tradition of tripartite education.

The People's Republic of China (PRC) has also gone through major political upheavals since the beginning of this century, and this has affected its educational system in major ways. Today, with one-fourth of the world's population, China is attempting to provide a basic education in science and technology for a whole population in order to join the ranks of major industrialized nations by the end of this century -- just as those nations are trying to achieve an even higher level of technology based on ever greater scientific and engineering knowledge. A common thread that unites all five of these nations is the major emphasis that each is placing on science and technology education for <u>all</u> students during the nine, ten, or twelve years the students are required to spend in school.

As the impact of science and technology on events and decisions continues to grow, U.S. science education policies and practices are in serious need of restructuring. The authors and editors of this book believe that an examination of the educational systems of other nations will help us understand our own. This volume, prepared by authors with first-hand experience in the countries they write about, describes certain aspects of science education in each of these five nations that should help us explore alternative approaches. While the information presented here cannot supply answers to all of the pressing educational problems being debated today, it does offer perspectives on the central place of required science and mathematics in the educational programs of these other nations, and on the means they employ to promote high-quality science education for all their citizens.

As with any other highly complex system, an examination of the way nations educate their children in science requires that we selectively focus on the issues and dimensions we judge to be important. Thus, the list of issues examined here is neither definitive nor exhaustive. However, we hope readers will accept the discussion as the beginning of a national conversation which will continue and in which they will become active participants. To this end, we offer a number of comments and questions which will, we hope, serve to keep the conversation ongoing.

The principal benefits of looking at other approaches to science education are, first, to see how science education systems might be organized, and second, to see some of the relative merits and liabilities of particular systems. The science education practices of any country can be thought of as a series of natural (uncontrolled) experiments. Extreme caution is required in interpreting them, however, because of the differences among societies and the vast number of variables, many of them unknown, that may influence the outcome of any social system. Cultural heritage, customs, and values are only some of the factors which interact to produce a particular educational system and make it more or less effective in achieving that country's stated educational goals. The social and political milieu, natural resources, and economic conditions also have substantial impacts on educational systems. Stated another way, a particular philosophy or practice is not easily transported from one country to another. When such an adoption is attempted, as in the grafting of many American ideas into the Japanese educational system after World War II, an intricate pattern of adjustments occurs as the new ideas interact with previous practices and traditions. Thus, the outcome of a particular intervention may be substantially different in different settings, and it may have unexpected positive or negative side effects.

The questions which led to this book, and the lessons to be learned from it, are general ones. We can observe the practices of other countries and some aspects of their educational achievements. We can ask what the apparent risks and benefits are. We can look for hints of relationships between science education and other social phenomena. Finally, a review of the practices of other countries can provide a checklist of ideas and possible actions to help us understand the strengths and overcome the weaknesses of our own science education system.

The next few pages offer the reader a framework for viewing the subsequent chapters, and, we hope, identifying specific situations, interesting questions, and salient comparisons applicable to the United States.

POSSIBILITIES FOR CHANGE

Long-term trends are often easy to see, but the factors responsible for the trends are usually difficult to identify. Yet if a society is going to exert a deliberate influence on its own future, it must understand causal relationships. In the United States, for example, standardized achievement test scores in mathematics and science have declined steadily over a twenty-year period. Educators have struggled to determine the causes of this trend and find ways to reverse it. Their limited success leads us to ask, How much control can we as a society exert over the outcomes of our educational processes? What are the steps to achieving significant, nationwide changes?

In China, for example, as Chapter 2 makes clear, the educational system has responded rapidly to changes in the political climate. The impressive gains made after the 1949 Communist victory were seriously compromised during the decade of the Cultural Revolution (1966-1976). Now the educational system seems to be responding again with amazing rapidity to changes in other sectors of the society. Are the Chinese successfully implementing a massive new push to provide science and technology education for all citizens? Would any of China's methods for bringing about an increase in the level of science learning be useful, appropriate, or even possible, in a democratic society? The other nations we examine here have also recently made significant, if not so drastic, changes in their educational systems. In what follows, we look at important choices each has made.

SCIENCE LITERACY VERSUS A SCIENTIFIC ELITE

The United States has long depended, with considerable success, upon a small educated elite to provide scientific and technological progress for the nation. So long as science attracts its share of the most talented young people, it has been widely assumed, the rest of the population can afford to be relatively illiterate scientifically. Do these other countries accept this model? We will see that, while our five countries strike somewhat different balances between educating a scientific elite and giving all citizens a fairly rigorous education in science and mathematics, each is attempting to do both. Communist China, in fact, first concentrated on developing an elite, suffered the destruction of that group, then reversed its policies, and now is trying to bring its entire population up to a new level of scientific knowledge while restoring the elite.

The USSR has also reversed its stance on the importance of a scientifically literate society. Until recently, the Russians concentrated on early identification of special talents and intensive "hothouse" cultivation of an elite in each technical field. But in the last fifteen years, and particularly since about 1975, the USSR has launched an ambitious program to provide a challenging scientific and technological education to every citizen.

Chapters 4 and 5 report on an impressive educational effort, although in the absence of Soviet participation in international achievement tests in science or mathematics, it is difficult to assess their progress.

We should take note of the general problem of separating rhetoric from reality, dogma from fact. Investigators depend greatly on government reports, and a single investigator cannot sample enough of a nation's schools to determine whether official reports on methods and achievement are accurate. When government goals generate a conflict between reality and official expectations, distortions may occur. There is also the ever-present problem of loss of subtleties when translating from one language to another, and from one educational system to another, especially in the absence of measurements on a common standard of performance. However, the superior performance of the Japanese student body *as a whole* on international examinations offers reliable evidence of that nation's success in achieving its stated goal of giving all its students (95+ percent) an intensive science education. In addition, Japan trains a strong scientific elite at its major universities.

East Germany (GDR) and West Germany (FRG) offer an interesting comparison between systems that share a common language and heritage but have made different decisions about single versus multitrack educational systems. The tripartite educational system of West Germany allocates students into a low-middle-elite hierarchical system with selection heavily influenced by family background. One unfortunate result, as Chapter 3 points out, is that the school system tends to "program" students for unequal job opportunities as early as the fourth grade. In contrast, East Germany mandates a uniform and demanding science curriculum for all students through a 10-year general polytechnical program, and gives special support to interested and talented science students through extracurricular classes and academic *Olympiaden*.

So at least three countries in our sample -- USSR, GDR, Japan -- appear to provide a fairly rigorous scientific and technological education to more than 90 percent of their youngsters while continuing to find and educate students of high talent to carry on the scientific and technological activities of the future. These examples suggest that a scientific elite does not have to be produced at the expense of the rest of the populace, nor does the elite have to be sacrificed in order to achieve mass education. But the real question is, Why have these nations, each with a lower GNP than the United States, invested so much effort in the science education of a whole nation? They say that they see a relationship between science education and the economic prosperity and well-being of their nations. If that is so, how should we tackle this issue in the United States, given the following conditions:

- Our amazing diversity;
- The variable quality, quantity, and availability of science education at present;

- A system of elective courses that allows almost any student to choose to learn only a small fraction of what all students are required to learn in these other countries.

These and many other factors make the task of improving U.S. science education formidable.

CENTRALIZATION VERSUS DECENTRALIZATION

The American educational system is more decentralized than that of almost any other developed or developing country. The PRC and the USSR are comparable to the United States in geographic size and diversity of population (although both are larger, more diverse, and multilingual as well), but their educational systems are heavily centralized. East and West Germany provide a contrast in centralization and decentralization. East Germany relies on centralized authority and strives for uniformity, while West Germany is highly decentralized and prides itself on its diversity. In Japan, the post-war educational system owes much of its character to the highly centralized authority of the Mombushō -- the Ministry of Education, Science, and Culture -- in educational affairs. Uniformity of quality, equality of opportunity, and economies of scale are some of the benefits of centralization claimed by those who support centralization. Flexibility and creativity are often cited as benefits of decentralization. What is the optimal balance?

UNIFYING PHILOSOPHY

Scientific knowledge is reproducible, public knowledge. It represents a particular state-of-the-art view of reality which is shared in common by scientifically knowledgeable people. Whatever the passions and biases of any individual scientist, the methods of scientific investigation generally will eliminate gross errors within a reasonable period of time. Unifying principles are established that best represent current understanding of reality and predict future events in many novel situations. And, as some predictions fail, principles are modified and/or new ones discovered.

A repeated theme in the descriptions of Communist countries is the harmony between science and the dialectical materialism of Marx, Lenin, Engels, and Mao Zedong. Thus, an education in science is considered an enlightenment that cannot be at odds with Communist theory. Students are to understand concepts (rather than memorize facts) and apply scientific theories and principles to every aspect of society. In this context, science teaching and learning are valued endeavors, strongly supported by the central government. In addition, science education produces a technologically skilled workforce essential for the economic well-being of the nation. Thus, in Communist countries, there is a consensus that a high-quality science education is essential for every individual, and that the state has a responsibility to make that education available to all citizens.

Does rigorous mass learning <u>require</u> a stable ideology that values and rewards such learning? Stated another way, Do ideological conflicts and contradictory messages from the society erode the will and capacity for widespread intellectual achievement? The perceived value of education in the United States, for example, has declined at the same time that higher degrees have proliferated and job opportunities for many "overqualified" degree holders have declined. Many factors seem to reduce motivation for teaching and learning science in this country, yet the sales of popular scientific magazines are increasing steadily, and computers are already found in many homes. What are the principal sources of motivation for the study of science in this country, and do they carry anything equivalent to the force of a powerful political ideology whose leaders also control who gets what jobs?

While admiring their successes, we should not overlook contradictions in the approach of Communist governments to science. Given the expressed belief in dialectics and scientific enlightenment, how and why did the Soviet Union promote Lysenko's theories long after they had been disproven in the West? What led to the suppression of the theory of relativity in the USSR? On the other hand, how do we explain the power of Creationism in the United States, or the strong resistance to the metric system? Political, religious, and social ideologies are often incompatible, or at least inconsistent, and can have simultaneously positive and negative effects on scientific learning and scientific progress. Can we in this country develop science curricula to avoid these conflicts?

TEAMWORK, SOCIAL SUPPORT, AND INDIVIDUAL COMPETITION

We read a great deal these days about Japanese industry and the role of teamwork in its success. Japanese firms are known for a management style that involves a sharing of both risk and responsibility among all employees. To what extent does this style evolve from, or penetrate into, the educational system?

Japanese classrooms aim to promote teamwork, group effort, and social support of the individual student. Competition for grades is minimized in the early years. Students are encouraged to help one another in preparing for the critical external examinations. A warm, supportive learning environment is said to be provided both at home and in school, a claim largely confirmed by American observers. On the other hand, Japanese children face a battery of external examinations that are critical in determining each child's future. They even must compete for the relatively few openings in prestigious kindergartens!

It is difficult to separate the effects of teamwork in the classroom, on the one hand, from effects of external examinations on the other. From a psychological point of view, both may be helpful (to a degree) for maximizing learning. Since learning means taking risks and making mistakes, a warm, supportive environment at the point of learning seems desirable. At the same time, since most of us are stimulated by external pressure, a decisive consequence (such as an external examination score) that is a function of our own learning effort ought to be a powerful incentive. What is the optimal balance? The extent and form of exam-generated stress and the discouragement associated with being "tested out of" many potential opportunities at an early age should not be overlooked.

The American system of rewards and pressures seems quite different from that of the Japanese. In our classrooms, there is a strong emphasis on individual competition. Adults expect students to compete for grades within the class, yet peer pressure often discourages students from making a commitment to academic excellence and disparages the "grind." Standardized national exams are less critical here than in Japan, for example, in determining a person's future. There are many different post-secondary institutions with space available and many opportunities for another academic chance in this country. It may well be that such a forgiving system reduces incentive as compared to the anticipation of a once-in-a-lifetime challenge. At the same time, depersonalization and devaluation of the student seem to be problems in many schools, and support of the learning process at home may be decreasing as all family members spend increasing amounts of time away from home.

THE CURRICULUM

Perhaps the two most interesting curricular approaches described in the following chapters are the spiral curriculum in science and math, and the polytechnical concept of general education.

In a spiral curriculum, each science is taught over a period of several years, beginning with concrete experiences to build an intuitive understanding of a subject. Gradually, students progress to practical and more quantitative work and, finally, to abstract, theoretical analysis. The spiral approach is based on psychological theory and research on human learning which has been conducted largely in Europe and the Soviet Union. Applying this research, each science, and geometry and algebra, are typically taught for four or five years. This contrasts sharply with the U.S. practice which allots one year of study per subject. Critics of the spiral system say it is potentially repetitious and boring. Critics of the one-year, one-subject system say that it promotes superficial learning and rapid forgetting. Our performance in recruiting students into science instruction and teaching them effectively is of sufficient concern that we should at least reexamine our curricular approach. What design is best suited for our students and the world they will encounter?

Yet another difference between the United States and East Germany, the USSR, China, and Japan is the latter countries' emphasis on the polytechnical system. That is, instead of separating students into theoretical and applied tracks as we do, all students are required to study both. Soviet children take ten years of shop. In the German Democratic Republic, schools are associated with factories in which students take classes and do productive work. In China, the products of student labor help to support the school system. In Japan, children perform many of the functions that require paid workers in the United States, such as cleaning rooms and grounds, preparing meals, etc. Is much of this merely child-labor? Or is it an important part of the curriculum, contributing to the morale and group spirit of the class and well integrated with the more theoretical classes?

There has been relatively little empirical research reported in U.S. educational research journals comparing the polytechnical and theoretical approaches. It would be interesting to compare the effects of the two methods along a variety of dimensions, including the following: What knowledge and skills do students have at the end of their educational experience? What are their attitudes toward science and technology? Toward work? What are their "world views"? What are their images of science and scientists? The value of a polytechnical emphasis, most clearly seen in East Germany, seems particularly important to explore. Properly implemented, it may represent a way to incorporate experiential learning into the formal curriculum in a bold and systematic way.

TEACHERS

Whatever the curriculum, its effectiveness depends upon the knowledge and skills of the teachers who must implement it. Well-educated teachers are a necessary precondition for the education of a nation's youth. The attention that a society pays to the selection, education, and rewarding of teachers reveals much about the attitudes of that society toward the entire educational process.

Three aspects of teacher preparation are highlighted in the chapters which follow: teacher specialization, requirements for initial certification, and in-service education. For instruction as early as the fourth grade, teachers are often required to be subject matter specialists. In some countries, science teachers are trained to a level equivalent to an M.S. or Ph.D. degree in their field. Each country has provision for in-service education. Many also use mass-circulation, government-supported journals to help science teachers keep up to date. Russian science teachers are required to take a refresher course at least once every five years and to attend periodic seminars and conferences and weekly discussions of science teaching. Japanese teachers are actively and directly involved in the process of curriculum development, and teacher associations influence the direction of future revisions. And although the Japanese feel that in-service education is still a major problem, their teachers have access to some 200 government-funded science education centers located around the country that offer many opportunities for improvement of skills and science knowledge.

In addition, teachers in these countries are often relieved of extraneous clerical and supervisory tasks so that they can concentrate on their instructional responsibilities. Trained assistants are available to help with audiovisual and scientific demonstrations. Discipline in the classroom is a relatively minor problem, allowing for greater time-on-task for all. Opportunities are provided outside of school for science projects, clubs, and competitions. Government-supported research institutes study science learning and teaching, and attempt to translate their findings into practical and useful guidance for the educational system. In all of these ways, the value attached to teaching and learning is made clear.

What lessons can we learn from these observations? Could teacher centers, for example, be fruitfully incorporated into our own educational system? Would they be used effectively? How important is it for teachers to have strong preparation in the subjects they teach? How important is time-on-task?

EXAMINATIONS AND THE QUALITY OF LEARNING

An old adage holds that it doesn't really matter what you teach, it's what and how you test that counts. Standardized national exams are the gates through which a society can exert control over what is studied and what skills are developed. Such tests can provide a form of quality control; as such, they represent tangible goals toward which students and teachers can work. National exams are employed in all five of these countries, and there are disadvantages as well as advantages.

The pressure of the Japanese college entrance exams is well known. These exams shape much of the content and style of Japanese schools even though there is no "college preparatory" track. They also influence parental behavior, since parents frequently pay for special courses to help their children prepare for the exams or try to place their children in special schools. Indeed, in Japan children are even given special preparation for entrance exams to kindergarten!

In West Germany, entrance to the university is determined by an examination taken at the end of secondary school, but the precondition is set at age 10, when the child and his or her parents select the track to be taken: Hauptschule, Realschule, or Gymnasium. Only the Gymnasium provides the education necessary to qualify for and to succeed in the college entrance exams.

Exams in the other countries also have a substantial impact on the course of a student's entire life, and the stress associated with such exams is hard for us in the United States to imagine. This is especially true when one considers that universities in these five countries can accept only 5 to 10 percent of the nation's youths, a truly elite minority. One wonders what price is paid in addition to the occasional suicides one reads about. At the same time, there are surely dividends that accrue from raising learning to so serious an enterprise and from the respect that is accorded the students and teachers engaged in it. A change in this direction would be refreshing indeed in the United States.

One wonders if the United States, by making higher education so easily accessible to all, has thereby diminished both the value of such an education and the motivation to strive for it. What is the optimal balance between expectation of high performance and forgiveness of poor performance? We have seen that Japanese youth dramatically out-perform American children on international exams in mathematics and science. To what extent do standardized national exams that control college entrance contribute to enhanced performance at all grade levels?

EQUALITY OF OPPORTUNITY

There appear to be few satisfactory answers regarding equality of educational opportunity. For example, while Russia claims to provide a very high level of scientific education for all, some schools seem to be more equal than others. Connections as well as talent appear to influence entry into preferred schools and prestigious colleges. Similarly, Japan requires a rigorous science education for <u>all</u> students, and their top performance on international exams suggests that they succeed. Ethnic, geographic, and sex differences apparently have a negligible impact on the performance of Japanese children in science at elementary through high school levels, making at least that part of that school system seem exceptionally egalitarian. Yet equality begins to disappear when students are selected for the limited number of places in the most prestigious precollege schools. Even though females perform as well as males through secondary school, males from well-to-do families dominate the student bodies of top-ranking universities. Once again, it appears that social expectations and discrimination against professional working women persuade talented girls not to invest their energies in science. The West German school system seemingly assures perpetuation of a class-oriented society, while the East German system appears to provide considerable opportunity for breaking down class lines.

How strongly can the educational system shape the social structure of society? Do most students typically become aware of unspoken social expectations, make a tacit investment analysis, and allocate their intellectual energies accordingly? How important is the perception of economic reward and social approval to the learning process in the United States? Is this a more powerful explanation for sex and class differences in achievements in mathematics and the sciences than any other consideration? And does the use of the schools to mitigate social inequities necessarily weaken science education programs, unless the society is already relatively homogeneous?

A CLOSING QUESTION

The chapters that follow are rich in the descriptive information and the insights essential for thinking about education in general and science education in particular. Children starting school now will complete college by the beginning of the twenty-first century. Will our educational system have given them the intellectual and practical preparation for a satisfying and effective life in a country still a leader among nations? Clearly, the answer depends on what we do now -- and on what lessons we can learn from both the successes and failures of other nations around the world.

be the sole judge of entrance? Are family and youth motivated to support such a massive involvement of time and energy?

Science education centers would seem to be a worthy, if small, adoption. Kagaku no zasshi, the science magazine for primary school students, would be a particularly useful adoption if it served to strengthen the link between family, student, and classroom; for as we have seen, when family and classroom reinforce one another, more learning takes place. The United States could learn much from Japanese primary education, which is highly successful in imbuing an intuitive grasp and reservoir of interest in science. While this interest may decline due to a natural specialization of interest, the Japanese primary school experience lays the base for a scientifically literate populace.[107]

Equality of opportunity has encouraged a higher level of learning in Japan. Because it is combined with measures that encourage or ensure mastery of the subject, such as a demanding curriculum and examinations, the outcome is equal mastery. For science, this means high science literacy for all. American higher education is comparatively successful, and American scientists pride themselves upon the image of American science. Perhaps these feelings of pride in the higher reaches of science can be used to strengthen the call for a stronger mass base of science literacy. If the base is not widened in the United States, it is open to question whether American science or American society can successfully withstand the challenge from abroad.

NOTES

1. Mombushō, Mombushō (1981), p. 16.

2. Ibid. pp. 15, 18.

3. Ibid., p. 16. Last figure from Mombushō, Mobutōkeiyōran (1979), p. 72.

4. Mombushō, Education in Japan (1978), p. 11; Mombushō, p. 88.

5. Mombushō, Education in Japan, p. 51.

6. Figures for 1980 are from Mombushō, Mombushō, pp. 8, 84-85. Figures for 1981 are from the National Institute for Educational Research (NIER), Basic Facts and Figures about the Educational System in Japan (Tokyo: March 1982), p. 33.

7. S. Okuda, Lecture, Japan Foundation, July 1982.

8. William K. Cummings, Education and Equality in Japan (Princeton, N.J.: Princeton University Press, 1980), p. 8.

9. Ibid.

10. Kay Michael Troost, "Educational Equality of Opportunity in Japan: Family Background and Gender," unpublished paper, NIER (July 1982).

11. Mombushō, Education in Japan, p. 102.

12. Mombushō, Mombushō, pp. 43, 88.

13. Cummings, Education and Equality, p. 75.

14. "Teachers shall fight for equality of opportunity in education." This is the first item in the 1952 Nikkyōso "Code of Ethics for Teachers." See Cummings, Education and Equality, p. 38.

15. For an extended treatment from a pro-union source, see Cummings, Education and Equality, especially chapter 3.

16. Christopher Jencks, Inequality (New York: Basic, 1972) and Who Gets Ahead (New York: Basic, 1979). See also Troost, "Pathways to Learning: The Central Role of the Home Environment," Hiroshima Forum for Psychology (1980) 7:35-46. NSF Grant no. SED 7919784.

17. Thomas P. Rohlen, "The Juku Phenomenon: An Exploratory Essay," Journal of Japanese Studies (1980) 6:207-242.

18. See L. C. Comber and John Keeves, Science Education in Nineteen Countries (New York: Halsted Press, 1973). In the spring and fall of 1983, the second IEA study of science and mathematics was conducted in Japan by the National Institute for Educational Research (NIER) (Kokuritsu Kyōiku Kenkyūjo in Meguro-ku, Tokyo) under the direction of Shigeo Kojima; the mathematics study was under the direction of Toshio Sawada.

19. The twelve countries studied were Australia, Belgium, England, Finland, France, West Germany, Israel, Japan, the Netherlands, Scotland, Sweden, and the United States.

20. The nineteen countries studied were Australia, Belgium (French), Belgium (Flemish), Chile, England, West Germany, Finland, France, Hungary, India, Iran, Italy, Japan, the Netherlands, New Zealand, Scotland, Sweden, Thailand, and the United States.

21. Cummings, Education and Equality, p. 174.

22. Comber and Keeves, Science Education in Nineteen Countries, p. 258.

23. Equality and equality of opportunity are interrelated. In Japan, there is more income equality than in the United States. Using GINI coefficients where .00 indicates full income equality and 1.00 total equality, Andrea Boltho found Japan with .32 in 1965 and .28 in

1979; the United States had a score of .40 in 1964, indicating greater income equality for households in Japan than in the United States. See Boltho, Japan: An Economic Survey, 1953-1973 (New York: Oxford University Press, 1975).

24. See Troost, "Educational Equality of Opportunity in Japan," for a more extended discussion on enrollment percentages, advanced degrees, entrance examination success rates, and employability of advanced degree holders.

25. Cummings, Education and Equality, pp. 20, 169.

26. Comber and Keeves, Science Education in Nineteen Countries, p. 248. The correlation (r_{xy}) was equal to -.08, that is, boys were slightly higher in achievement; the mean for the nineteen countries was -.11.

27. Ibid., p. 258. Comber and Keeves found a correlation of -.28 between gender and cognitive achievement in science (mean rxy = -.20, U.S. = -.22, West Germany = -.30).

28. See Cummings, Education and Equality, pp. 160, 172; Thorsten Husen, International Study of Achievement in Mathematics (New York: Halsted Press, 1967), pp. 22-25, 274ff; and Comber and Keeves, Science Education in Nineteen Countries, pp. 159ff, 208, 217, 251, 261.

29. Hideo Ohasi, "Evaluating Curriculum Change in Japan," Journal of Science Education in Japan (1980) 4:136.

30. While the first exam is the same for all National Universities, the second is both university- and faculty-specific. The second exam is given on the same day by each national university so the student must assess his chances of passing before choosing whether to apply to Hiroshima, Kyoto, or Tokyo University, for example. Scores on the first exam do give some indication of the likelihood of success on the second.

31. See, for example, Christie Kiefer, "The Psychological Interdependence of Family, School, and Bureaucracy in Japan," in Takie Sugiyama Lebra and William P. Lebra, eds., Japanese Culture and Behavior (Honolulu: University of Hawaii Press, 1974), pp. 342-56, and Cummings, Education and Equality, especially chapters 5 and 7.

32. Some private schools, especially junior colleges and others of lower rank, do consider grades to varying degrees. See Mombushō, Mombushō, p. 40.

33. This is especially true in compulsory education. See also Kiefer, "Psychological Interdependence."

34. Don Spence, personal communication.

35. The Mombushō and Nikkyōso are at odds over what values

should be taught, and this has resulted in minimization of political value issues and emphasis on psychological concerns.

36. Kiefer, "Psychological Interdependence."

37. Troost, "Familial Pathways to Learning: The Influence of Parental Background, Number of Siblings, and Home Environment Upon Affect for and Achievement in Science -- A First Report." Unpublished paper, Kyoikugakabu, Hiroshima (1980).

38. For greater detail, see Shokichi Iyanaga, "Mathematical Education in Japan," Journal of Science Education in Japan (1981) 5:121-31.

39. Michinori Oki, "School Systems and Chemical Education in Japan," Journal of Science Education in Japan 3 (1979):191.

40. Personal communication, Hideo Ohashi, former director of NIER and currently director of Komaba Toho High School; Shigeo Kojima, director of the Science Education Center, NIER; Yoneji Ebitani, former dean of the Faculty of Education at Hiroshima and currently professor at Fukuyama University; and Shigekazu Takemura, professor in the Faculty of Education and Graduate Study, Hiroshima University.

See also Ohashi, "Some Problems of Science Education in Japan," unpublished paper of NIER presented at the preparatory Group Meeting of Science Education in Seoul (July 1975); Ohashi, "Evaluating Curriculum Change in Japan"; and Masao Miyake, "National Science Curriculum Case Studies," unpublished paper, National Institute for Educational Research (Tokyo, 1981).

41. Ohashi, "Evaluating Curriculum Change in Time," p. 134. See also Ronald S. Anderson, Education in Japan (Washington, D.C.: Government Printing Office, 1975), pp. 150-51.

42. Edward Bradford Titchener, Systematic Psychology: Prolegomena, Rand B. Evans and Robert B. MacLeod, eds., (Ithaca, N.Y.: Cornell University Press, 1972).

43. Ohashi, "Some Problems of Science Education in Japan," p. 3.

44. Masao Miyake, "National Science Curriculum Case Studies," pp. 12, 14.

45. Ohashi, "Some Problems of Science Education in Japan," p. 4.

46. Personal communication with N. Ohsumi, a staff member in the audiovisual aids for science at the Science Education Center of NIER; see also Ohsumi, "Development of Teaching Materials and Instruments for Science Education at Elementary School Level in Japan," unpublished paper, NIER, Country Report for Regional Workshop for the Compilation of an Inventory of Appropriate Aids for Science Teaching (Tokyo, November 1981), p. 3.

47. Cummings, Education and Equality, pp. 160, 172ff; Comber and Keeves, Science Education in Nineteen Countries, especially p. 159ff.

48. The influence of between-school variation upon student science achievement was almost nil in the Japanes IEA sample; see Comber and Keeves, Science Education in Nineteen Countries, pp. 208, 217, 251, 261.

49. Cummings, Education and Equality, pp. 155-56.

50. Ibid., p. 155.

51. Because the course of study applies uniformly throughout Japan, the formal describability of Japanese education exceeds that of the United States where the curriculum varies from state to state and school district to school district. In Japan, only "the hidden curriculum of juku" remains informal and unregulated, while in both societies, the role of television cannot be fully assessed.

52. Mombushō, Course of Study for Upper Secondary Schools in Japan (1976), pp. 63-77.

53. Ibid., p. 83.

54. Ibid., p. 87.

55. See Thomas P. Rohlen, Japan's High Schools (Berkeley: University of California Press, 1983), p. 157, for a comparison of science and mathematics in U.S. and Japanese high schools.

56. Several universities specializing in science and technology have been established in the last decade, chief among them the new Tsukuba University. Two new universities of teacher education Jōetsu and Hyōgo, were established in 1978 (see NIER, "The New Teachers' Training Program at Hyōgo University of Teacher Education," National Institute for Educational Research, Tokyo, NIER Occasional Paper 03/82: June 1982).

A cautionary note about university-level education in Japan, including teacher education is appropriate. While in the United States, college or university days are apt to be more rigorous academically than high school or junior high, the same is not true in Japan. John Zueguer, of Worcester Polytechnic Institute, has described Japanese universities as "high entry, low exit," that is, while they are very difficult to get into, they tend to require less of their students than has been expected of them prior to entrance and less than is typical in other societies.

57. Mombushō, Mombushō, p. 15.

58. Mombushō, Mobutōkeiyōran, p. 72, 202.

59. Ibid., p. 72.

60. NIER, Basic Facts and Figures, p. 22.

61. Ibid., pp. 22-24.

62. Anderson, Education in Japan, p. 166.

63. Personal communication with Ohashi, creator and former director of the Science Education Center at NIER.

64. Oki, "School Systems and Chemical Education in Japan," pp. 180-81.

65. Comber and Keeves, Science Education in Nineteen Countries, pp. 81, 82.

66. Ibid., p. 181.

67. NIER, Basic Facts and Figures, p. 24.

68. Cummings, Education and Equality, especially chapters 3 and 9.

69. Ibid., p. 255. See also Delbert Miller, Handbook of Research Design and Social Measurement (New York: Longman, 1977), pp. 217-18.

70. Miller, Handbook.

71. Comber and Keeves, Science Education in Nineteen Countries, pp. 81, 82.

72. Statistics Bureau, Prime Minister's Office, Japan Statistical Yearbook (Tokyo: Nihon Statistical Association, 1981), p. 612.

73. Even in the field of elementary education discrimination in administrative positions occurs in Japan. In 1971, only 2.7 percent of head teachers and only 1.1 percent of principals were women. Fujin ni kansuru shomondai chosa kaigi, Gendai Nihon Josei no Ishiki to kodo (Tokyo: Okurasho Insatsu-kyoku, 1974), p. 181. See also Samuel Coleman, Family Planning in Japanese Society: Traditional Birth Control in a Modern Urban Culture (Princeton, N.J.: Princeton University Press, 1983).

74. Miyake, "National Science Curriculum Case Studies," p. 9.

75. NIER, "The New Teachers' Training Program at Hyōgo University," pp. 1-2, 5ff.

76. Herbert Their, "In-Service Training of Elementary School Science Teachers: A 1976 United States-Japan Seminar," Science Education 60 (1976):551ff.

77. Ohashi, "Some Problems of Science Education in Japan," p. 8.

78. Comber and Keeves, Science Education in Nineteen Countries, pp. 82-83. For additional information on science education and professional societies, see The Journal of Science Education in Japan, one issue of which is published each year in English (in 1982, issue 2, formerly issue 4). English language materials are becoming increasingly common with the internationalization of Japan. Indeed, in one of my site visits to education classes at a National University, I found students using some English textbooks from America. This is possible because English is one of four required areas on university entrance examinations.

79. I witnessed an excellent demonstration illustrating the inquiry method by Satoshi Itagaki, who teaches science at the primary school attached to Tsukuba University, the premier primary school for science in Japan. Itagaki was president of the Primary School Teachers Association in 1981-82.

80. Comber and Keeves, Science Education in Nineteen Countries, pp. 82-83.

81. Ibid.

82. For example, in March 1982, the publisher gave the monthly circulation of Gakken's Kagaku no zasshi as 980,000 copies per month for the first grade, 990,000 for the second grade, 970,000 for the third grade, 940,000 for the fourth grade, 900,000 for the fifth grade, and 890,000 for the sixth grade. The magazine is published twelve times a year for each grade.

83. Circulation for other science magazines in the United States is also low. For example, Popular Science has an average circulation of 1,803,309; Science 81, 699,633; Discover, 750,545; and Scientific American, 713,000. (Circulation figures for Scientific American from the 1982 World Almanac, p. 428; all others are from the World Almanac, p. 430.)

84. Comber and Keeves, Science Education in Nineteen Countries, pp. 281-82.

85. Ibid., p. 261.

86. Ibid., p. 217.

87. Ibid., p. 283.

88. Ibid., p. 245.

89. Ibid., p. 258.

90. Troost, "Pathways to Learning" and "Familial Pathways to Learning."

91. Troost, "Science and Peace Education and the Home Environment," unpublished report, Shudo University, Hiroshima (1983).

92. Comber and Keeves, Science Education in Nineteen Countries, p. 259 (r = .49).

93. Ibid., p. 258.

94. Data for the second study were to be collected in May and August 1983.

95. Fukaya Masashi, "Socialization and Sex Roles of Housewives," Merry I. White and Barbara Molony, eds., Proceedings of the Tokyo Symposium on Women (Tokyo: International Group for the Study of Women, 1979), pp. 133-49.

96. The visits serve to dramatize the learning situation of the school. One school official apologized that a planned parent meeting would not be available in the next month; school photo book dates suggest 3 to 4 visits per year. One Mombushō official suggested that family members might visit the school between 3 and 4 times up to as many as 6 or more times per year; Cummings (Education and Equality, p. 141) reports monthly visits. Specific days are set aside for mothers and fathers, with fathers coming in on a Sunday and Monday becoming a holiday. In some districts such as Mitaka, a suburban town outside of Tokyo where the teachers and city government are socialist and where teachers take education particularly seriously, these visits can be as frequent as one or two weeks. Notes between teacher and mother are also used to communicate about progress or about what the child did as homework. In special circumstances, this can become a daily correspondence. There are also weekly forms, as well as summer vacation forms, for the parent to fill out regarding teeth brushing, chores around the house, and hours spent watching TV, playing with friends, or doing homework. Two Japanese friends told me they found these forms invasive rather than an expression of interest; they filled them out as they thought was expected so that their children would not be viewed as deviant and the parents scolded by the teacher for not being concerned about their child's welfare.

97. Ezra Vogel, Japan as Number One (New York: Harper and Row, 1980), p. 165.

98. Ohashi, "Report on Out-of-School Science and Technology Education," unpublished paper, NIER (Tokyo, 1978), p. 1. See also Kunio Umeno, "Short Report on the Out-of-School Science Activities in Japan," unpublished paper, NIER (Tokyo, June 1981).

99. Vogel, Japan as Number One, pp. 164-65.

100. Competition for grades may emerge late in junior high school and develop in high school as students become concerned about whether or not they are members of the Japanese equivalent of the Calvinist "elect"; at lower school levels, competition is personal, and learning can be a cooperative effort of parent, teacher, and

student.

101. Comber and Keeves, Science Education in Nineteen Countries, pp. 122-24.

102. Ibid., p. 159.

103. Ibid.

104. In 1983, a second survey was conducted. It is reasonable to suppose that the Japanese will maintain their position in the lead. Whether the United States falls further behind or not will be interesting to see. The National Assessment of Educational Progress report titled "National Report Card on Education During the 1970s" (1983) showed "significant declines" in science achievement among fourth, eighth, and eleventh graders in the United States (p. 1ff).

105. Comber and Keeves, Science Education in Nineteen Countries, p. 259.

106. While many have argued that the emphasis on rote learning leaves Japanese students ill prepared for creative work or for developing their own ideas, this is perhaps more true of in-class than post-school learning, both on and off the job. People in industry are able to develop new ideas, and the wider population seems to have a lifelong commitment to learning in the creative sense. Finally, at the university level, the best students do develop their own ideas, and I think the same is probably true of students in the United States as well.

107. In most societies, there is a higher level of interest in science in primary school than there is later in life. This may be due in part to changes in teaching methods and the like, but it must also be due to what I call the natural specialization of interest; that is, given the limitations of time, there is a natural tendency for people to limit their occupational and leisure pursuits.

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emphases, however, are different in the two Germanies. In the GDR, about half the total instruction time is devoted to the natural sciences, mathematics, and technical studies, whereas in West Germany, instruction in these areas accounts for approximately one-fourth of the total curriculum. East German teenagers spend about 24 percent of their time learning science, compared to 11 or 12 percent in the Federal Republic, and 8 percent in the United States. Mathematics study comprises about 16 percent of the East German school curriculum, 13 percent in West Germany, and 12 percent in the United States.

Given the breadth and depth of the program for science education in the GDR, as well as the mathematics and technical programs that support science learning, it is obvious that the GDR is doing a far better job than the United States in providing _all_ young people with a scientific basis for understanding the technological age in which we live. Compared to their American counterparts, East German teenagers spend about triple the time learning science and a third more time learning mathematics in a curriculum that balances theoretical learning with the application of theory in industry and agriculture.

The variation in West German schools makes it more difficult to compare the overall science and mathematics literacy of teenagers in the FRG and the United States. However, given the greater homogeneity of West German society, the nationally developed guidelines, the firmer control that the states have over science and mathematics requirements, and the actual hours of required high school science and mathematics, one must conclude that the West Germans are also doing a better job in providing most young people with a basis for understanding science.

Finally, the scope and depth of the program of study in East German general schools and the West German Gymnasien assures that the 10 to 12 percent of students who go on to the universities have a good understanding of physics, chemistry, botany, zoology, and mathematics, including calculus. Since universities are the training places of future leaders, the approach to preuniversity education in both Germanies assures that all senior officials in government, business, and industry will have an understanding of science that matches the needs of leadership in an era of rapidly expanding technologies.

NOTES

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Democratic Republic (Washington, D.C.: Government Printing Office, 1981), p. 6.

3. Karl Marx (1818-1883) and V.I. Lenin (1870-1924). According to Marxist-Leninist theory, human culture evolves through a succession of stages from Primitive-communal, through Slave-owning, Feudal, Capitalist, and Socialist to Communist. Contemporary "Communist" societies which consider themselves to be in an advanced stage of Socialism are: Bulgaria, Czechoslovakia, the German Democratic Republic, Hungary, Poland, Romania, and the Soviet Union. For purposes of this overview, the words "Communist" and "Socialist" will be used interchangeably.

4. Two groups of children, both comparatively small in number, are not educated in these schools; they are (1) students who attend special schools for the physically and mentally handicapped and (2) students who attend specialized schools in art, music, sports, science and mathematics, or languages, etc., because they have exceptional talent. Statistical Pocket Book, 1980, p. 96.

5. GDR, Council of Ministers, The Ministry of Education, Act on the Integrated Socialist Educational System of the German Democratic Republic (Berlin: Staatsverlage der Deutschen Demokratischen Republik, 1972), p. 37.

6. Marx and Engels, Concerning Education and Training (Berlin: n.p., 1961), p. 162, quoted in Heinz Frankiewicz and others, Paedagogische Enzyklopedie, II (Berlin: VEB Deutscher Verlag der Wissenschaften, 1963), p. 731.

7. Heinz Frankiewicz, Technik und Bildung in der Schule der DDR (Berlin: Volk und Wissen Volkseigener Verlag, 1968), pp. 50-53.

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9. Statistical Pocket Book, 1980, pp. 98-100.

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13. Information obtained during discussion with Prof. Dr. Hansjoachim Lechner at the Humboldt University East Berlin, November 1982.

14. Information for this section was gathered during a tour of East German universities in November 1982 which included discussions with educational administrators, university instructors,

and graduate students, and parents of teenagers in the GDR.

15. Philip J. Hilts, "A Big Military Seems to Mean Less Spending on the Sciences," Washington Post, May 31, 1983.

16. Secretariat of the Standing Conference of Ministers of Education of the States of the Federal Republic of Germany, The Educational System in the Federal Republic of Germany (New York: College Entrance Examination Board, 1979), p. 6.

17. Dietmar Bolscho, Lehrplaene zum Sachunterricht (Kiel: Institut fuer die Paedagogik der Naturwissenschaften, 1978), p. 11.

18. Information, 15, Public Document (Bonn: Press and Information Office of the Government of the Federal Republic of Germany, 1980).

19. Ibid.

20. Secretariat of the Standing Conference, pp. 9-10.

21. Information, 15.

22. John Dornberg, "Outward Calm Belies Youth Discontent," International Herald Tribune, April 1979, p. 9S.

23. Wolfgang Buender and Karl Frey. Discipline-related Curriculum Studies as Part of the Study Course for Science Teachers of Grade 5-13 at the Universities in the Federal Republic of Germany. Institute fuer die Paedogik der Naturwissenschaften (IPN) Report in Brief, #21. Kiel, 1980.

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25. Ibid., pp. 30-31.

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27. Herr Hauser, Labor Counselor, Embassy of the Federal Republic of Germany, Washington, D.C., February 1983, personal communication.

28. Bolscho, pp. 9-27.

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31. Michael Koehne, Die Physiklehrplaene fuer die Sekundarstufe I (Kiel: Institut fuer die Paedagogik der Naturwissenschaften, 1979), pp. 5-180.

32. Peter Kriesel, Die Chemielehrplaene fuer die Sekundarstufe I (Kiel: Institut fuer die Paedagogik der Naturwissenschaften, 1979), pp. 9-193.

33. The discussion in this section is based on Dr. Lore Hoffmann, "Consequences for Science Education based on the results of Girls' Learning Interest," in Contributions Girls and Science And Technology (GASAT)-Conference 1981, pp. 123-44, Eindhoven, the Netherlands.

34. Iris R. Weiss, Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education (North Carolina: Research Triangle Park, 1978), p. 24.

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36. Neuner, pp. 153-58.

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American secondary education.

- Create permanent national curriculum centers and a national review board in science and technology. These bodies should include the nation's top scientists and engineers with educational expertise, researchers, outstanding teachers, educators, and psychologists. They would supervise the development of new curricula and review the implementation of programs and text materials.

CONCLUSION

As a national concern, education is as vital as defense and foreign policy, and, like them, it requires national leadership. This will require a sustained effort by all segments of our society, private and public investment, and, above all, imaginative and engaged leadership at all levels of government.

We must acknowledge that an educated population and a well-trained work force are essential to the recovery of our country's dynamic spirit and economic strength. Then we must go beyond mere recognition of the problem and mount a serious effort, a genuine national mobilization for education to bring us to the worthy goal proposed by the National Science Foundation, namely, "providing the Nation's youth with a level of education in mathematics, science, and technology that reflects the needs of the Nation and is the highest quality attained anywhere in the world." This will require creativity, energy, wisdom, and patience. From leaders of industry to concerned parents, the American people are looking for national leadership and a decisive program, for they are ready to apply their optimistic spirit and practical ingenuity to an educational revival. To give up, to procrastinate, or to plan only for the short term would be to mortgage our freedom and our future.

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and what matters most right now, is not how we compare to other countries and to our own past, but how well we are doing in fulfilling our promise. Looking at others and looking backward, from time to time, can help us judge where we are headed and how we are moving. But it is our vision of the future, our future, the world's future, that counts most. If science and technology are to be a major part of that future -- and who would doubt it? -- then we must prepare all of our young people to meet the world of science and technology head on -- with understanding, style, and care, and with a vision of their own that is worthy of a country still committed to the promise of educational opportunity for all who would claim it.

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