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PUBLIC PERCEPTIONS OF SCIENCE AND TECHNOLOGY

A Comparative Study of the European Union, the United States, Japan, and Canada

Jon D. Miller
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Fundación BBV

In the last two decades a new area of interdisciplinary study has emerged that focuses on the public's reception of and attitudes toward science and technology. It examines the general population's understanding of scientific images of the natural world, its values and attitudes, and the relations between these two major dimensions. As science and technology have gained influence on the structure and functioning of advanced societies, from the economy to the natural environment and culture, these societies increasingly have to rely on not only professionals well trained in crucial areas of science and technology, but also on an at least minimal level of understanding of scientific findings, values, and methods in the general population. At the threshold of the 21st century, the population's familiarity with scientific methodologies and perspectives constitutes one of the most important "invisible assets" of advanced societies, with repercussions in both the public and private spheres, from the workplace to the articulation of preferences and demands in the political domain.

As science and technology have penetrated a wide range of social domains, ethical and political dilemmas have emerged that, in democratic political systems, raise the question of the extent, the form, and the direction public participation should take in decision-making processes that involve science and technology directly or indirectly. The question of what basic perceptions and what cognitive and attitudinal patterns the adult population brings to bear on this field of potential intervention therefore takes on enormous importance.

This monograph, based on research carried out in collaboration by the BBV Foundation and the Chicago Academy of Sciences, is the first systematic comparative analysis of the public's knowledge, images, and attitudes regarding science in Europe, Japan, the United States, and Canada. It focuses on the development of a set of indicators to explore the relations between interest in scientific issues, level of understanding of substantive and methodological dimensions of science, and patterns of attitudes toward science and technology. This analysis leads to the formulation of hypotheses about the public's role in the frequent controversies that involve science and technology. The statistical techniques of confirmatory factor analysis and structural equation modeling take this study beyond simple data analysis by exposing data structure and advancing explanatory models. These tasks, in the authors' view, should inform a new series of comparative analyses of scientific culture in advanced societies.

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Public Perceptions of Science and Technology

CONTENTS

PROLOGUE

At the threshold of the 21[st] century, we have the opportunity to examine, with the advantage of the long-term perspective, the relative contribution of different forces to the shaping of social structures, of life styles in many areas of the planet, and even of the environment itself.

Among the large number of variables that have shaped the structure and evolutionary dynamics of modern societies, the one that stands out without any question is the complex edifice of theories, information and data that make up scientific knowledge, which has experienced unprecedented growth and expansion in this century. Scientific activity has become an area of professional specialization for a large sector of advanced societies, and has made its way into the great majority of professions, even those apparently least related to scientific theories and methodologies. The educational system has also seen an increase of the scientific training that every individual needs so as to achieve an adequate understanding of large areas of the natural and social worlds and to be able to intervene in them. In structural terms, one can say that our complex turn-of-the-century societies presuppose, and are based upon, infrastructural networks that have emerged from the advancement and technological extension of science. The acceleration of the rhythm of scientific progress, the shortening intervals of its translation into technology, and the combination of technological clusters (new materials, electronics, information technology, telecommunications, biotechnology) have paved the way for what some theorists of innovation call a "change of techno-economic paradigm": that is, the emergence of new ways of designing, producing, marketing and even recycling a wide range of goods.

Undoubtedly, advanced societies at the end of the 20[th] century are knowledge societies, at least in the sense that they cannot function without the unceasing production of the "intangible" outcomes of the scientific process. Paradoxically, however, as this monograph documents, the great majority of the population in these societies (Europe, the United States, Canada, and Japan) benefits from many applications of science in areas ranging from the workplace to health care, but has not achieved an even elementary understanding, in broad outline, of the scientific knowledge that has been accumulated since the beginning of modernity. This gap leads on occasion to unfounded hopes that science all by itself has the potential to resolve some of our most pressing problems, or, alternatively, to no less unfounded fears of scientific progress. What the authors of the First Report to the Club of Rome called "technological miracle-working", and its counterpart, which we might want to label "anti-scientific romanticism", both derive from a cultural and social context characterized by a low level of understanding of science, of the images of the natural and social worlds it offers, and of the possibilities and limits of scientific-technological knowledge.

In the transition to the 21st century, the problem of the "two cultures" diagnosed by C. P. Snow--the lack of communication between professionals in the humanities and sciences--is aggravated by the question of how to integrate both of them with technological knowledge. At the same time, the urgent question arises of how to convey this knowledge to the great majority of society, so that every individual can broaden his or her range of options, as a consumer, worker, community member, and citizen capable of articulating preferences and demands. In addition, there is the fundamental issue of how to reconceptualize the role of science and technology in the context of an educational philosophy that acknowledges humans' role as "symbolic animals": their ability to interpret the world around them rationally, using theories, conceptual schemas, images, and data as well as the values compatible with the knowledge of each historical period (what the philosopher Quine called "all the science of the moment").

Never has there been as wide a range of opportunities on the individual, family, community, and organizational levels as in this century, and few factors have been as significant in this broadening of possibilities as scientific-technological knowledge. Along with these possibilities, risks and ethical dilemmas of unprecedented magnitude have arisen, from serious changes (if not destruction) of basic life-cycles on the planet to the genetic manipulation of life, job creation in a highly automated production system, or the reconceptualization of the very notion and meaning of "work" in an era in which the interaction between worker and machine (or "technological system") has undergone dramatic change.

For all these reasons, it is necessary to rethink the ideal of the educated or informed individual, and the role of science and technology in achieving this ideal throughout the individual's life-cycle. This task must be undertaken in a variety of contexts, from the home and school to the workplace, the mass media as well as social and political structures. The BBV Foundation has therefore chosen the analysis of issues relating to scientific culture in advanced societies as one of its strategic areas of activity. This analysis must take advantage of comparative scientific-social research carried out with the best methodologies available for the production and interpretation of the appropriate data. It has been a true pleasure and privilege for our Foundation to develop the project presented in this book in collaboration with The Chicago Academy of Sciences and its International Center for the Advancement of Scientific Literacy, without question the leading institution at a global scale in this field of study. We trust that its publication and discussion among academics will raise the level of multi-disciplinary reflection on scientific culture at the threshold of the new century --an indispensable prerequisite for developing effective programs to communicate scientific and technological advances to the entire population.

José Angel Sánchez Asiaín
President, BBV Foundation

INTRODUCTION

The 20th century has witnessed two major revolutions: one in science and technology and one in democracy. The task for the 21st century will be to maintain the growth and benefits of science and technology within the structures of modern democratic systems. It is a welcome challenge, but it would be a serious error to think that few tensions or difficulties will occur in fostering both of these revolutions simultaneously.

The remarkable achievements of 20th century science and technology are well known, but to a great extent, they are only the opening act of an exciting new drama. We have become the masters of atoms and molecules, acquiring the ability to build and modify a vast array of natural and man-made materials to serve our interests. We have learned how to travel around our planet quickly, comfortably, and relatively inexpensively. An individual can now pick up a telephone or log onto a computer terminal and hold instantaneous conversations with people around the world. We are now on the brink of understanding the operation of our genetic system, opening the possibility of solving some of mankind's oldest diseases and problems.

Despite a century of warfare, more people live in democratic political systems at the end of the 20th century than at any other time in human history. There is now a worldwide sense of basic human rights and a general opposition to genocide. More people have a larger impact on the policies of their governments and the actions of their leaders than ever before. The growing role of survey research in democratic societies is more than curiosity or entertainment; it is recognition by political and economic leaders that they need to understand what the public is thinking.

In the 21st century, effective citizenship will require an increased level of understanding of the issues facing society. Ironically, despite vast scientific and technological growth, the majority of the public in every major industrial country lack a level of understanding sufficient to participate effectively in the resolution of a public policy dispute involving science or technology. One of the challenges that must be addressed in the 21st century is the improvement of education to fully enfranchise citizens to understand and participate in the formulation of a wide range of public policies, including those involving science and technology.

From its founding 140 years ago, The Chicago Academy of Sciences has been committed to the advancement of scientific literacy for all citizens. Our original charter lists this task as one of our primary purposes, and for more than a century the leadership of the Academy has sought to enhance the scientific understanding of our fellow citizens. As a part of this commitment, the Academy founded an International Center for the Advancement of Scientific Literacy in 1991 to reach out to scholars and friends around the world to work together toward this objective.

We are pleased to join with the Bank of Bilbao and Vizcaya Foundation and its Center for Science, Technology, and Society in the publication of this important work. This monograph, written by three of the leading scholars in the world in this field, provides a solid empirical foundation for understanding that our commonalties exceed our differences, and that all nations will face essentially the same set of challenges in the 21st century. The development of a scientifically literate citizenry is not a horse race among nations, but an ongoing challenge to match our scientific progress in the laboratory with educational achievement in our classrooms and through museums, newspapers, magazines, and libraries. This monograph provides a solid foundation for the recognition, understanding, and discussion of this challenge.

Paul G. Heltne
President, The Chicago Academy of Sciences

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This monograph is a collaboration of three authors, European Commission staff, consultants, and institutional colleagues and their resources in numerous countries. Each individual has made a valuable contribution to the study. The proper acknowledgment of the intellectual, financial, and staff debts of even a single author is a difficult task at best. Therefore, the acknowledgment of our collective debts will unintentionally, but undoubtedly, omit friends, helpers, and colleagues to whom we extend our apologies in advance.

We wish to acknowledge the foresight and leadership of Jean Gabolde of the European Commission, who initiated the idea for this analysis. We are, of course, grateful to the European Commission for its financial contributions to this work. We appreciate European Commission staff assistance from Gregorio Medrano, in the early stages of this project, and from Barbara Rhode, in the later stages of this work.

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Modern social science is largely conducted within institutions. All of the authors have been supported and encouraged by their respective institutions to pursue and complete this work. We wish to express our gratitude to José Angel Sánchez Asiaín, President of the Bank of Bilbao and Vizcaya Foundation; Paul Heltne, President of The Chicago Academy of Sciences; and John LaTourette, President of Northern Illinois University. Elizabeth Altman provided invaluable editorial services, and Linda Kimmel and Noreen Kelly of The Chicago Academy of Sciences worked tirelessly on the data and the manuscript drafts.

Leading scientific agencies in each country provided financial and organizational support for conducting the surveys that form the basis for comparative analysis. We, and all social scientists who seek to study patterns across nations, appreciate the support of the European Commission, the National Science Foundation of the United States, the National Institute of Science and Technology Policy in Japan, and the Canadian Research Council.

Finally, we wish to express our appreciation to the 18,000 individuals in Canada, Europe, Japan, and the United States who participated in a survey and shared their thoughts and ideas with our interviewers. Cross-national social science comparison depends on the tacit consent and support of the citizens of democratic societies to share their views and thoughts. We are most grateful.

Jon Miller
Rafael Pardo
Fujio Niwa

CHAPTER I

A FRAMEWORK FOR THINKING ABOUT SCIENCE AND PUBLIC POLICY

In the last 50 years, governments, political leaders, and activists have come to recognize the importance of educating citizens to be scientifically literate. They understand the value of adults being able to understand and participate in the formulation of science and technological policy. They perceive the benefit of the public participating in debate and making choices.

In less than three decades, the theoretical approach and practical objectives of public understanding of science have evolved both in response to advances in survey methodology and data analysis and in response to the widening impact of science and technology on individuals, organizations, and communities. In the first phase, from 1945 through the late 1950's, public awe and admiration were widespread for the work of scientists and engineers in producing a series of miracle drugs, jet aircraft, ever-improving communications, and a rising standard of living. With the launch of *Sputnik I* in 1957 and the advent of the space race, the popular standard for intelligence became the rocket scientist. This pattern was apparent in the United States, Canada, and the more developed nations of Europe. Japan and the less developed nations of Europe followed a similar pattern, but a few years later.

A second phase began in the 1960's, marked by books and events that emphasized important public policy choices regarding science and technology. Rachel Carson's *Silent Spring* (1962) revealed the long-term negative effects of the excessive use of DDT and other pesticides, overturning the popular perception during the preceding decade that post-war development of pesticides was one of the miracles of modern science. Developers, manufacturers, and users had not anticipated the effect on nature of these modern products (Bosso 1987). Similarly, new drugs such as thalidomide were found to have catastrophic results when taken by pregnant women, resulting in laws in the United States and other major industrial nations requiring an extensive review of drugs prior to their distribution in the market (Mintz 1965).

The third phase evolved from institutional cynicism following the Vietnam War, combined with a growing awareness of actual and potential damage to our world. It grew into the environment movement in the United States and into the green movement in Europe. A major policy dispute during this period involved the use of nuclear energy to generate electricity (Nelkin 1977; Morone and Woodhouse 1989). The anxieties about the technological application of nuclear energy, fostered in part by the use of the first atomic bombs, grew with new data and events that revealed the long-term side effects of its use. By the beginning of the 1980's, government, corporations, and scientific and technological organizations, as well as the scientific community, recognized that the public could veto a program or project if sufficiently aroused.

A growing body of knowledge, research, and literature among the adult populations of developed and developing countries helped to create a framework for thinking about the public perception of science. This monograph presents the results of comparative analysis of public perceptions of science and technology in the European Union, the United States, Japan, and Canada. Agencies responsible for science, technology, and related public policy generally support these studies, reflecting their need to understand public attitudes. An interdisciplinary research has evolved, building on these studies and parallel publications in journals.

In this chapter, public understanding of science as a research discipline is profiled, basic concepts relevant to the analysis of public understanding and perceptions are introduced, and the rationale for developing research on public perceptions toward science and technology is discussed. Subsequent chapters examine the public's interest in science and technology issues, methods of conceptualizing and measuring civic scientific literacy, the structure of public participation in formulating science and technology policy, and public attitudes toward general and specific science and technology issues. The final chapter recommends opportunities for future research to understand the factors that affect developing, maintaining, and changing of public attitudes toward science and technology.

The Role of Scientific Literacy in Modern Societies

The original concept of scientific literacy reflected the concerns of citizen groups and the scientific community and focused on information required to fulfill citizenship responsibilities. The knowledge, experience, and skills needed for effective citizen participation continue to be an essential component of the research agenda.

Individuals are likely to experience science, and especially technology, as workers and consumers. It is important to focus on specific individual needs and problems and for scientists to conceptualize multiple literacies. For example, a study of biomedical literacy in the United States has become the basis for a handbook guiding medical professionals and health communicators to effectively share information with citizens in terms that are appropriate to age, gender, education, and level of biomedical literacy (Miller and Pifer 1995; Miller and Kimmel 1998).

New efforts to define basic scientific and technological literacies for workplace performance, parenting, and personal comfort will improve people's competence, understanding, and appreciation of scientific issues. Many individuals learn to cope with the complex technological society of the late 20th century by utilizing low-level knowledge of the know-how type, such as cooking without knowledge of chemistry, driving a car without any knowledge of mechanics, word processing without training in computer science, and the skills related to the use of technical products (Lévy-Leblond 1992; Pardo 1998).

The need to elaborate the definitions of scientific or technological literacies is due, in part, to one of the most striking features of technological evolution in the late 20th century--its ability to overtake quickly until it becomes essential (Burke 1978). It has gone beyond the principles of classical ergonomics to include usability factors. It has evolved so that neither advanced scientific or technological knowledge nor a long operational learning process is required (Winograd and Adler 1992). This technological evolution explains how millions of users, including children, gained access to a tool as complex and versatile as the computer, which only a few decades ago required the knowledge of a programming language for simple addition.

Apart from the use of new machines and technologies, individual and collective decisions demand a degree of formal scientific or technological understanding combined with practical experience. Some analysts have noted that societies at the end of the 20th century can be considered high-risk societies (Beck 1994). The growing influence of science and technology in virtually all dimensions of socioeconomic life of today's global society offers opportunities previously unheard of, and at the same time exposes serious risks personally and collectively.

Although many alternatives exist for coping with this emergent structural feature of late modern societies, one critical dimension is an individual's familiarity with science and technology. For example, individuals who understand the risk and prevention factors associated with certain diseases may make better choices about diet and personal behaviors. Patients who must decide among medical treatments, especially alternatives involving new technologies such as gene therapy, may make better decisions if they have a conceptual understanding of *DNA*. Citizens and civic leaders who have familiarity with basic scientific constructs [1] of energy, the ecosystem, the ecological impacts of human practices and probability and risk assessment may make better public policy decisions on issues ranging from landfill placement to reactor locations.

Formulating Science Policy in Democratic Political Systems

In industrialized nations, most citizens face a growing number of competing demands for their time. Although the length of the workweek differs significantly in the countries studied, most advanced societies have decreased the workweek to 40 hours in recent decades. Reductions below 40 hours have been difficult to accomplish. The pressure on individuals to manage their time efficiently has increased in combination with other trends such as two-job families, which have been growing steadily for at least three decades, and changes in overtime allocations by companies.

Studies show that Americans feel more rushed now than a generation ago, although, by the clock, they have gained an additional hour of free time per day since 1965. This fact is partially associated with life-style change trends. Fewer Americans are married today than a generation ago, and fewer still are parents, with the consequence that two time-consuming activities, housework and child care, have decreased. In addition, people are retiring at earlier ages. The bulk of this new free time has gone to watching TV: "The increase in TV-watching has cut into the time we have allocated to almost everything else in our lives--but most especially to activities outside the home" (Putnam 1997).

[1] *Construct* refers to an understanding of a set of scientific concepts that creates a model such as atomic structure.

The typical resident of Amsterdam, Berlin, Chicago, Hiroshima, London, Madrid, Paris, or Tokyo chooses most evenings among 10 to 20 television channels, thousands of rental videotapes, live musical or dramatic performances, sports events, non-credit or credit university courses, and a wide array of recreation activities such as bowling or tennis. Competition for an individual's time has grown over the last several decades, and that pressure continues to increase.

Politics and public policy face stiff competition for an individual's time. Citizens must decide how much time, energy, and what or how many resources to devote to becoming and remaining informed about politics, and to actively participate. The evidence indicates that politics is losing its marketshare (Miller 1983a; Verba, Schlozman and Brady 1995). The decision to become involved with political affairs is referred to as *political specialization.* While many measures of adult political specialization exist, one simple indicator is the number of adults who vote in national and local elections--a clear indication of declining interest.

Among those citizens who decide to devote time and energy to public policy issues, a second level of specialization involves the choice of which issues to follow. The range of issues at the national level is broad, and combined with state, provincial, and local issues, the range of potential public policy issues is too vast for an individual to master. Inevitably, citizens who follow political affairs focus their attention on a smaller set of issues, referred to as *issue specialization.* Previous studies suggest that few citizens follow more than two or three major issue areas (Almond 1950; Rosenau 1974; Miller 1983a; Popkin 1994).

Approximately half of the citizens in industrialized societies become involved in public policy issues (Miller 1983a; Verba, Schlozman and Brady 1995). Within this context, public interest in scientific and technological policy must be assessed. Scientific and technological issues compete reasonably well for a share of the public's interest, even during times of dramatic international events. The role of the public in formulating science and technology policy is explored in Chapter IV.

The Need for Scientific Literacy in the Workplace

Changes in the workplace demand higher levels of basic scientific and technological training for many workers. This parallels the growing need for an understanding of science and technology in order to formulate public policy. New process technologies tend to yield their greatest benefits when they are aligned with a highly skilled workforce (Adler 1992). Computers and new communication technologies have transformed the work environment and skill expectations for a wide array of jobs, from office work to manufacturing. Office workers are expected to understand and operate computers, fax machines, copiers, laser printers, scanners, and numerous other machines as well as to integrate different systems and to participate in their maintenance and upgrading. The ability to read the appropriate instruction or repair manual has become a basic skill requirement for a large number of jobs.

Additionally, workers in many corporate, private, and governmental organizations, rather than simply following procedures and rules, are expected to determine their own responsibilities on the basis of institutional policies and goals. This change requires higher levels of training and autonomy than were necessary for traditionally organized workplaces. The creation and design of flexible production systems and high performance work systems (semi-autonomous groups, quality control circles) often assume broad job definitions, substantial skills in problem solving, teamwork, and continuous learning on the part of staff (Osterman 1994; Lawler 1995). To succeed in this independent environment, many workers need higher levels of training, specifically scientific and technological training, beginning with formal schooling and continuing with on-the-job learning.

Life in a Scientific Culture

Persons who live in the scientific culture of the late 20th century appreciate science, its capacity to speak to the imagination, and its contribution to the satisfaction of the human desire to know. The demand for access to information about scientific and medical achievements has grown in recent decades despite the difficulty of communicating science and technology to non-scientists and the low levels of previous scientific or technological training of many adults. Millions of adults in the European Union, the United States, Japan, and Canada watch scientific documentaries on television and read science articles in newspapers and magazines. Many people pursue an interest in cosmology, for example, although they do not expect to find any practical use for it. The magnitude of the demand for scientific knowledge requires creative and effective mechanisms for satisfying it.

It is reasonable to assume that a significant portion of the adult population should develop and sustain an understanding of basic scientific constructs. This level of understanding is referred to as *civic scientific literacy*. Methodological issues used to define and to measure civic scientific literacy and estimates of civic scientific literacy in the European Union, the United States, Japan, and Canada are compared and discussed in Chapter III.

Developing Appropriate Indicators

In 1972, the U.S. National Science Foundation began collecting and publishing biennially a comprehensive set of indicators of scientific and technological activities. Comparable indicator reports have been compiled and published by the European Union, the Japanese National Institute of Science and Technology Policy, and the Canadian Research Council. Each report includes traditional indicators such as the proportion of the gross domestic product devoted to research and development expenditures or the number of scientists and engineers. These are insufficient to assess the level of scientific and technological resources and potential of a society. The invisible asset of scientific literacy on the part of the public has to be included among the measurements (Pardo 1992). Measuring public attitudes toward science and technology has increased, responding to the changing roles and needs of individuals as citizens, workers, consumers, and members of modern industrial societies.

Growing interest in the public understanding of science and technology, as well as substantive advances in the development of accurate and useful indicators, is commendable. Diverse research conducted through focus groups, in-depth interviews, national surveys, quasi-experiments, media content analysis, and panel studies of adult populations is encouraged.

Formal comparative analysis and the study of temporal changes can be achieved through a series of surveys administered to random population samples in various countries, utilizing a core of relatively common questions. These data provide a sufficient basis for building precise and powerful models to explain differences and patterns in public understanding of science and technology within countries and among countries. The pluralism of goals, lines of research, and methodologies should be preserved and expanded, enhancing the current state of research, with a simultaneous dialogue among the various research communities.

It is essential to view public understanding of science and technology as an important component in a complex system of policy formulation, acceptance, and implementation in modern industrial societies. Even when public involvement in formulating policy is limited to tacit consent, successful acceptance and implementation of public policies may depend on both public understanding of basic scientific concepts and a foundation of positive attitudes toward organized science. In overt controversies, public involvement will be more substantial. In all circumstances, public understanding and attitudes interact with other components of policy formulation and implementation systems. The survey data sets analyzed in this monograph provide an important perspective on public understanding and policy development.

Available Comparable Information

During the last decade, several national surveys have been conducted in major industrial nations and in emerging industrial nations. For the purpose of this comparative analysis, four data sets were selected that include extensive survey responses from the citizens of 15 countries. For analytic purposes, the 11 member states of the European Union [2] in 1992 are treated as a single entity. The four major studies included in this analysis are:

> **Eurobarometer, 1992.** For more than 20 years, the European Commission has conducted a semiannual survey of all of its member states, focusing on a core of questions about their knowledge of, and their attitudes toward, the European Union. Each survey incorporates additional items relevant to one or more of the general directorates of the Commission. The 1992 Eurobarometer utilized personal interviews with 12,147 adults in the 11 member states [3] to measure interest in, knowledge about, and attitudes toward science and technology, reflecting the concerns of Directorate General XII. Dr. Karlheinz Reif was the director of the general Eurobarometer program in 1992. The science survey was coordinated by Dr. Gregorio Medrano from Directorate General XII.
>
> **United States Science Indicators Study, 1995.** This study is one of a series of national studies of the public understanding of and attitudes toward science and technology in the United States, sponsored by the

[2] *European Union, EU* and *Europe* are used interchangeably in this monograph to refer to the 11 countries which participated in the 1992 Eurobarometer with sufficient responses to be valuable in this monograph. The use of *Europeans* or *European adults* refers to the survey participants.

[3] The 11 member states surveyed were Belgium, Denmark, England, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, and Spain.

National Science Foundation. The 1995 study interviewed 2,006 individuals in a national probability sample of households with telephones. The 20-minute interview included an extensive set of items measuring interest, knowledge, attitudes, and information acquisition. The study was directed by Dr. Jon D. Miller, Vice President of The Chicago Academy of Sciences and Professor of Political Science at Northern Illinois University.

Japan National Study, 1991. This national study was conducted under the sponsorship of the National Institute of Science and Technology Policy in Japan and is based on personal interviews with 1,457 respondents. The study included numerous items in common with parallel studies in the European Union and the United States, including items on interest, knowledge, attitudes, and information acquisition. The study was directed by Mr. Hajime Nagahama of Toyo University.

Canadian National Study, 1989. This study of 2,000 Canadian adults was conducted by telephone and includes a wide array of interest, knowledge, attitude, and information acquisition items. This study was directed by Professor Edna Einsiedel of the University of Calgary.

All four data sets used in this monograph have been deposited in the Archive of the International Center for the Advancement of Scientific Literacy at The Chicago Academy of Sciences[4].

The analyses in this monograph utilize the best available statistical methods and tools to understand the structure and content of public attitudes toward and knowledge about science and technology. Whenever possible, scales are used rather than single items, and multivariate analytic techniques, including confirmatory factor analysis and structural equation modeling, are used to assess the structures and relationships within the data sets. Descriptive tabulations are provided, when possible, to provide adequate non-technical explanations of the results. Introductions to Confirmatory Factor Analysis and Structural Equation Modeling are located in Appendices A and B.

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[4] Requests for access to a data set should be addressed to Archive, International Center for the Advancement of Scientific Literacy, The Chicago Academy of Sciences, 2060 North Clark Street, Chicago, Illinois 60614, USA. Inquires may be made by fax (773-549-5199), e-mail (icasl@icasl.org), or the World Wide Web (http://www.icasl.org). A nominal fee may be required for handling and documentation, but fees may be waived for dissertation research.

CHAPTER II

PUBLIC INTEREST IN SCIENTIFIC AND TECHNOLOGICAL ISSUES

It is essential to recognize that citizens in complex, modern industrial societies may elect to pay little or no attention to politics or public policy issues. Despite the gains in free time for most social groups, the dramatic expansion of choices creates a "time famine", a feature of everyday life for citizens at the end of the 20th century and virtually unknown at any previous time in human history. The proportion of citizens who choose not to allocate time or energy to learning about or seeking to influence the political process or the formulation of specific public policies differs among the countries studied. A discussion of the structural differences among sociopolitical systems and the implications of these differences for meaningful public involvement in the formulation of science and technology policy is included in Chapter VI.

The Structure of Policy and Issue Interests

Individuals were asked to report their levels of interest in selected public policy issues, including issues involving science and technology, in the surveys carried out in the European Union, the United States, Japan, and Canada. While there were minor differences in the wording and format of the questions, all of the questions included a *very interested* choice as the highest level of self-reported interest. Although it is informative to look at the distribution of responses for each of the areas included in this analysis, it is important to go beyond these descriptive results and inquire into the structure of these self-reported levels of interest. Do these results support the specialization hypothesis outlined in Chapter I? Is there a clustering of interest in scientific and technological issues, or do individuals become interested in one facet of science and technology in a particularistic or in an eclectic manner?

A series of exploratory and confirmatory factor analyses were conducted to examine these questions. As a general approach, each analysis started with the full set of interest reports from individual respondents, exploring the structure of interest within each sociopolitical system and working with the full population sample. The structure of issue interest among the best-educated segment of each society was examined to see if, and how, the structure of their interests differed from that of the overall adult population. The volume and complexity of the work conducted dictate that the results are presented by country, beginning with the European Union and the United States followed by Japan and Canada. Findings are separated by issues, education, the number of respondents, and the levels of their interest. It is interesting to note differences among the sociopolitical systems. A concluding summary examines similarities in the structure of public policy interests among the countries.

European Union

In the 1992 Eurobarometer, respondents were asked to indicate whether they were *very interested, moderately interested,* or *not at all interested* in the following areas: environmental issues, new medical discoveries, new scientific discoveries, new inventions and technologies, politics, and sports news. A majority of Europeans reported that they were very interested in environmental issues, and 46% were very interested in new medical discoveries (see Table 1). Roughly two out of five Europeans were very interested in new scientific discoveries, and 35% were very interested in new inventions and technologies. Only three out of 10 Europeans were very interested in politics or sports news.

An index was constructed to provide a simple descriptive indicator of interest in selected issues. It scored 100 points for being very interested, 50 points for being moderately interested, and zero points for being not at all interested. For each national or demographic grouping, the scores on the Index of Issue Interest could range from zero to 100. Applying this index to the 1992 Eurobarometer data, interest in environmental issues ranked highest with 75 points and sports news ranked lowest with 48 points (see Table 1).

To explore interest among Europeans, all six of the 1992 interest items were examined in an exploratory factor analysis. (An introduction to confirmatory factor analysis is located in Appendix A.) For this analysis, each item was dichotomized into very interested and responses indicating a lower level of interest, recognizing the

TABLE 1
Level of Interest in Selected Issues, European Union, 1992

Issue	Education Level	Level of Interest (%)			Index of Issue Interest	Number of Cases
		Very	Moder-ate	Not at all		
Environmental Issues	Total	56	38	6	75	12,147
	Lower	53	40	7	73	9,739
	Higher	67	31	2	83	2,339
New Medical Discoveries	Total	46	44	10	68	12,147
	Lower	44	45	11	67	9,696
	Higher	53	42	5	74	2,342
New Scientific Discoveries	Total	38	45	17	61	12,147
	Lower	34	47	19	58	9,652
	Higher	54	40	6	74	2,336
New Inventions and Technologies	Total	35	47	18	59	12,147
	Lower	32	48	21	56	9,674
	Higher	49	44	7	71	2,334
Politics	Total	29	52	19	55	12,147
	Lower	25	54	22	52	9,726
	Higher	46	47	8	70	2,346
Sports News	Total	28	39	33	48	12,147
	Lower	28	38	34	47	9,738
	Higher	27	42	31	48	2,345

The Index of Issue Interest ranges from zero to 100. For each respondent, a response of *very interested* is given a score of 100; a response of *moderately interested* is given a score of 50; and a response of *not at all interested* is given a score of zero. For the total sample or any given subsample, the mean score on the Index of Issue Interest reflects the relative level of interest in that issue.

inability of traditional factor analysis to handle ordinal data [5]. The analysis revealed two factors (see Table 2). The first factor was defined by new medical discoveries and environmental issues, reflecting a general concern about health which was strongly linked to environmental quality. The second factor was defined by new scientific discoveries and new inventions and technologies and indicated a clustering of the two primary interest indicators in

[5] Inability is particularly severe when the number of ordered categories is less than five or six, as in the data files used for this monograph.

TABLE 2
Exploratory Factor Results for Issue Interests, European Union Adults, 1992

Issue	Factor 1	Factor 2	Proportion of Variance Explained
New Medical Discoveries	.53	−.18	.38
Environmental Issues	.78	.10	.56
New Scientific Discoveries	.30	−.76	.83
New Inventions and Technologies .	.27	−.63	.60
Politics	.27	−.01	.08
Sports News	−.01	−.03	.00
Correlation between Factor 1 and Factor 2 = .38 Number of Cases = 12,147			
An exploratory factor analysis examines the correlation matrix of a set of variables and identifies the correlation of each variable with one or more underlying dimensions, or factors. An orthogonal exploratory factor analysis sets the angle between factors to 90°, assuring that each factor is statistically independent of all other factors. An oblimin (oblique) exploratory factor analysis allows the factors, or dimensions, to be correlated and computes the degree or correlation or association between factors. This analysis is based on an oblimin (oblique) analysis.			

science and technology. Using an oblimin (oblique) rotation, the correlation between the two factors was .38. Neither politics nor sports news loaded significantly on either factor.

A strong single factor reflecting both science and health would not be expected, given this finding. To test this proposition, a confirmatory factor analysis was conducted, using the variables in their original ordinal form (Long 1983). Using the LISREL program, an initial confirmatory factor analysis was attempted, using 12,147 respondents in the 1992 Eurobarometer who were 18 years of age or older (Hayduk 1987; Loehlin 1987; Jöreskog and Sörbom 1993). Four issues (new scientific discoveries, new inventions and technologies, new medical discoveries, and environmental issues) did not form a single factor. The final model had only one degree of freedom and 45.7 chi-squares, which was a clear failure to fit.

The same procedure was attempted on a random half sample which included 6,021 cases, since a large number of cases can generate a high chi-square even when the model appears to fit otherwise. This model failed to fit with one degree of freedom and a total of 32.7 chi-squares. This modest reduction in error indicates that it is unlikely that further reductions in sample size would produce an acceptable fit.

At the conceptual level, the basic political specialization model outlined in Chapter 1 argues that in complex modern societies some individuals may become interested in political and public policy matters while others focus their time and energies on other pursuits. It is possible that individuals with fewer years of formal education have a difficult time understanding scientific and technological issues and would report relatively little interest in these matters. If this pattern were sufficiently pervasive, a factor analysis of the entire population would be unlikely to find structure, since the dominant pattern would be no interest at all. To explore this possibility, a set of confirmatory factor analyses was conducted on data from only those respondents who reported more years of formal schooling [6].

The results of a confirmatory factor analysis for this upper-education subsample revealed that the four scientific and technological issues constituted a single factor. The standardized factor loadings indicate that each of the four items contributed to the factor significantly (see Table 3). The factor was defined by interest in new medical discoveries and new scientific discoveries. This result suggests that better-educated Europeans tend to recognize a relationship among new medical discoveries, new scientific discoveries, new inventions and technologies, and environmental issues. This pattern of higher interest in scientific issues among better-educated respondents is consistent with the political specialization model.

TABLE 3
Confirmatory Factor Results, Upper-Education Group, European Union, 1992

Issue	Factor	Proportion of Variance Explained
New Medical Discoveries	.85	.73
New Scientific Discoveries	.76	.57
New Inventions and Technologies	.64	.41
Environmental Issues	.56	.31

χ^2 = .18/1 degree of freedom; Root Mean Square Error of Approximation (RMSEA) = .00;
Upper limit of 90% confidence interval for RMSEA = .038;
Number of Cases = 2,172

In contrast to the search for correlation in an exploratory factor analysis, a confirmatory factor analysis is a simple test of whether a set of variables selected on theoretical or other grounds has, or does not have, a specified factor structure.

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[6] Operationally, all 1992 Eurobarometer respondents who reported leaving full-time study at age 20 or later were included in an upper-education subsample, which included 2,172 individuals, or about 22% of the population age 18 and over.

United States

A set of 10 or 11 interest items has been asked in each biennial Science Indicators Study conducted in the United States since 1979. Miller and Prewitt first tested the present form of the interest question in the 1979 study, in conjunction with a set of hypothetical newspaper headlines, to assess various approaches to measuring interest. The direct inquiry format was found to be as effective a measure of interest as the longer and more time-consuming set of hypothetical newspaper headlines (Miller, Prewitt and Pearson 1980).

In the 1995 study, Americans were substantially more interested than Europeans in new medical discoveries, and somewhat more interested than Europeans in new scientific discoveries and new inventions and technologies. Europeans were slightly more interested in environmental issues than Americans (see Tables 1 and 4). The level of American interest in new medical discoveries exceeded American interest in any other area. The level of interest in scientific and technological issues was higher than interest in defense and military policy, foreign policy, and agricultural issues.

An exploratory factor analysis of data from all U.S. adults age 18 and over, using the same procedure as the analysis of the European Union information, found three factors, using an oblimin (oblique) rotation (see Table 5). The first factor was defined by a high level of interest in new scientific discoveries, new inventions and technologies, and space exploration. Interest in new medical discoveries loaded on this first factor, but also on a second factor. The first factor accounted for approximately 26% of the total variance in the analysis. A second factor was identified by interest in environmental issues, local schools, and new medical discoveries, with agricultural issues loading weakly on this factor. The second factor accounted for approximately 12% of the total variance in the analysis and was correlated with the first factor at the level of .24. A third factor was identified by interest in defense and military policy and foreign policy, with a significantly lower loading by economic policy. This factor may be viewed as a traditional national politics factor. It accounted for 10% of the variance in the analysis, and displayed a correlation of .45 with the first factor and .36 with the second factor.

These results indicate a definable structure in the level of issue interest which exists in the adult population of the United States. While individuals may have little or no interest in specific political issues, the pattern demonstrates that these same individuals may have a high level of interest in one or more clusters of issues.

TABLE 4
Level of Interest in Selected Issues, United States, 1995

Issue	Education Level	Level of Interest (%)			Index of Issue Interest	Number of Cases
		Very	Moder-ate	Not at all		
New Medical Discoveries	Total	69	27	4	82	2,006
	Lower	68	27	5	82	1,615
	Higher	71	27	2	85	391
Environmental Issues	Total	53	40	7	73	2,006
	Lower	52	41	7	72	1,615
	Higher	56	40	4	76	391
Local Schools	Total	57	31	12	72	2,006
	Lower	57	31	12	72	1,615
	Higher	55	33	12	72	391
Economic Policy	Total	47	42	11	68	2,006
	Lower	44	43	13	66	1,615
	Higher	60	36	4	78	391
New Scientific Discoveries	Total	44	45	11	66	2,006
	Lower	40	47	13	63	1,615
	Higher	62	35	3	80	391
New Inventions and Technologies	Total	43	46	11	66	2,006
	Lower	39	48	13	63	1,615
	Higher	58	37	5	76	391
Defense/Military Policy	Total	37	46	17	60	2,006
	Lower	36	45	19	59	1,615
	Higher	40	48	12	64	391
Nuclear Power (for Electricity)	Total	29	49	22	54	2,006
	Lower	28	49	23	52	1,615
	Higher	34	52	14	60	391
Space Exploration	Total	25	48	27	49	2,006
	Lower	22	48	30	46	1,615
	Higher	35	53	12	62	391
Foreign Policy	Total	21	53	26	47	2,006
	Lower	17	52	31	43	1,615
	Higher	36	57	7	64	391
Agricultural Issues	Total	21	53	26	47	2,006
	Lower	57	31	12	72	1,615
	Higher	55	33	12	72	391

TABLE 5
Exploratory Factor Results for Issue Interests, United States Adults, 1995

Issue	Factor 1	Factor 2	Factor 3	Proportion of Variance Explained
New Scientific Discoveries . . .	.73	.02	.06	.31
New Inventions and Technologies	.65	–.08	–.08	.30
Space Exploration	.42	–.04	–.15	.20
New Medical Discoveries	.36	.35	.04	.19
Nuclear Power (for Electricity) .	.29	.21	–.23	.23
Local Schools	–.02	.42	.05	.07
Environmental Issues	.20	.41	–.10	.18
Agricultural Issues	–.08	.31	–.10	.06
Defense and Military Policy . . .	–.07	.10	–.59	.17
Foreign Policy	.04	–.05	–.51	.14
Economic Policy	.15	.01	–.31	.14

Correlation between Factor 1 and Factor 2 = .24
Correlation between Factor 1 and Factor 3 = –.45
Correlation between Factor 2 and Factor 3 = –.36
Number of cases = 2,006

Having found one factor reflecting a cluster of science and technology issues, a confirmatory factor analysis identified more precisely the components of that dimension. A confirmatory factor analysis, using the original ordinal responses, found six items (new medical discoveries, nuclear power, new scientific discoveries, space exploration, new inventions and technologies, and environmental issues) that loaded on a single factor at .5 or above (see Table 6). This pattern contrasts with the European result, which did not find a single science factor for all European adults.

Two possible rationales explain the apparent difference between findings in Europe and the United States. One is methodological. The methodology of the 1992 Eurobarometer study included a smaller number of issue items. It is possible that a social desirability factor encouraged false reports of interest (Crowne and Marlowe 1964). If individuals felt that it was socially expected that they display a level of interest in public policy issues and therefore reported higher levels of interest than they actually held, the variance in the data set would be reduced, making it difficult to find a clear factor structure. Evidence exists for this hypothesis. Using the Index of Issue Interest, the levels of reported interest in Europe ranged from 59 to 75 for the four scientific interest items, a range of 16 points. Among U.S. adults, the level of reported interest ranged from 49 to 82 for the six scientific interest items, a range of 33

TABLE 6
Confirmatory Factor Results for Scientific Issues, United States Adults, 1995

Issue	Factor	Proportion of Variance Explained
New Medical Discoveries	.75	.56
Nuclear Power (for Electricity)	.72	.52
New Scientific Discoveries	.64	.42
Space Exploration	.62	.39
New Inventions and Technologie	.59	.35
Environmental Issues	.58	.34

χ^2 = 4.5/4 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .01;
Upper limit of the 90% confidence interval for RMSEA = .035;
Number of Cases = 2,006

points. It is impossible to determine from these data whether this pattern reflects the impact of socially desirable responses or real differences in the structure of issue interest in Europe and the United States. One way to test this question would be to expand the number of issues in future Eurobarometer studies and to examine the resulting patterns of reported issue interest.

A second rationale for the apparent difference is substantive. The exploratory factor analyses found a more pronounced differentiation between scientific issues and health or medical issues among European adults than among American adults. It was possible, however, to identify a single four-item factor among university-educated Europeans. A comparable confirmatory factor analysis of the 20% of American adults who had completed a baccalaureate degree found the same six-item science and technology interest factor among U.S. college-educated adults as was observed among all adults (see Table 7). These results suggest that many non-university educated European adults make an implicit or explicit distinction between health or medical issues and other scientific issues, but that this differentiation does not occur among American adults.

TABLE 7
Confirmatory Factor Results, United States College Graduates, 1995

Issue	Factor	Proportion of Variance Explained
New Scientific Discoveries	.86	.73
Nuclear Power (for Electricity)	.78	.61
New Inventions and Technologies	.71	.50
New Medical Discoveries	.64	.41
Space Exploration	.60	.36
Environmental Issues	.41	.17

χ^2 = 10.3/8 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .03;
Upper limit of the 90% confidence interval for RMSEA = .069;
Number of Cases = 391

Japan

The 1991 Japanese National Study asked adults to rate their levels of interest in 14 issues, including many items comparable to studies in the European Union and the United States. The Japanese study, unlike the other studies, offered four levels of interest to measure very interested, moderately interested, hardly interested, and not at all interested. For the calculation of the Index of Issue Interest, 100 points were assigned for very interested, 67 points for moderately interested, 33 points for hardly interested, and zero points for not at all interested in order to have a comparable Index with other countries. The resulting distribution appears to be a reasonable estimate of the level of issue interest.

Japanese adults expressed their highest levels of interest in senior citizen issues, taxes, and environmental issues, producing an Index of Issue Interest score above 70 in these three areas (see Table 8). The scientific issue of greatest interest was new medical discoveries, with an index score of 65. In contrast, only 17% of Japanese adults were very interested in new scientific discoveries, with an interest index score of 50. The interest index score for new inventions and technologies was 53, and 45 for space exploration. In general, Japanese adults were relatively more interested in economic matters and local issues, such as land use, than in science and technology issues. A significantly higher proportion of college-educated Japanese respondents reported substantial interest in scientific and technological issues, as in Europe and the United States.

TABLE 8
Level of Interest in Selected Issues, Japan, 1991

Issue	Education Level	Level of Interest (%) Very	Moderate	Hardly	Not at All	Index Score	Number of Cases
Senior Citizen Issues	Total	43	39	15	3	74	1,457
	Lower	44	38	15	3	74	1,134
	Higher	39	43	17	1	74	323
Taxes	Total	39	40	16	5	71	1,457
	Lower	39	39	16	6	70	1,134
	Higher	39	43	16	2	73	323
Environmental Issues	Total	36	46	13	5	71	1,457
	Lower	34	45	15	6	69	1,134
	Higher	45	46	8	1	78	323
New Medical Discoveries	Total	31	41	22	6	65	1,457
	Lower	29	40	23	8	64	1,134
	Higher	36	44	18	2	72	323
Land Use Issues	Total	29	43	21	7	65	1,457
	Lower	27	42	23	8	62	1,134
	Higher	37	47	14	2	73	323
Economic Policy	Total	30	42	22	6	65	1,457
	Lower	28	41	23	8	63	1,134
	Higher	36	45	18	1	72	323
Education/Schools	Total	27	39	25	9	62	1,457
	Lower	24	38	28	10	59	1,134
	Higher	38	43	16	3	72	323
Energy Issues	Total	23	41	27	9	59	1,457
	Lower	21	39	29	11	56	1,134
	Higher	29	48	22	1	68	323
National Defense Issues	Total	18	42	31	9	56	1,457
	Lower	17	40	32	11	54	1,134
	Higher	2	47	28	3	63	323
Agricultural Issues	Total	20	36	34	10	56	1,457
	Lower	20	33	36	11	54	1,134
	Higher	19	48	28	5	61	323
Foreign Policy	Total	17	40	33	10	55	1,457
	Lower	14	37	37	12	51	1,134
	Higher	27	52	18	3	68	323

TABLE 8
Level of Interest in Selected Issues, Japan, 1991 (continued)

Issue	Education Level	Level of Interest (%)				Index Score	Number of Cases
		Very	Moderate	Hardly	Not at All		
New Inventions and Technologies	Total	16	37	36	11	53	1,457
	Lower	14	33	39	14	49	1,134
	Higher	25	48	25	2	65	323
New Scientific Discoveries	Total	13	36	40	11	50	1,457
	Lower	10	33	43	14	46	1,131
	Higher	22	43	32	3	62	323
Space Exploration	Total	13	28	41	18	45	1,447
	Lower	11	25	42	22	42	1,134
	Higher	20	37	39	4	58	323

An exploratory factor analysis was performed on the six scientific and technological issues included in the study (new inventions and technologies, energy issues, new scientific discoveries, environmental issues, space exploration, and new medical discoveries). Although the analysis employed an oblimin (oblique) rotation to search for multiple factors, the procedure found a single factor accounting for 58% of the total variance (see Table 9). New inventions and technologies, energy issues, and new scientific discoveries displayed the highest loadings on this factor. A confirmatory factor analysis of the six items for all Japanese adults age 18 and over found the same one-factor result (see Table 10). In short, these factor analyses document the existence of a strong single science and technology factor among Japanese adults, in contrast to the two-factor structure found among Europeans.

A confirmatory factor analysis for Japanese college-graduates, using the same six items, found a single factor (see Table 11). Interest in new scientific discoveries was the defining item for the factor for Japanese college graduates, as was found in Europe and the United States. New inventions and technologies was the second strongest loading item; this item loaded lower on the same factor among college graduates in Europe and the United States. New medical discoveries loaded lowest on the science interest factor among Japanese college graduates.

TABLE 9
Exploratory Factor Results for Issue Interests, Japanese Adults, 1991

Issue	Factor	Proportion of Variance Explained
New Inventions and Technologies	.85	.72
Energy Issues	.83	.68
New Scientific Discoveries	.81	.66
Environmental Issues	.69	.48
Space Exploration	.69	.48
New Medical Discoveries	.65	.48
Number of Cases = 1,457		

TABLE 10
Confirmatory Factor Results for Issue Interests, Japanese Adults, 1991

Issue	Factor	Proportion of Variance Explained
New Inventions and Technologies	.95	.90
New Scientific Discoveries	.90	.81
Energy Issues	.82	.68
Space Exploration	.78	.61
Environmental Issues	.66	.44
New Medical Discoveries	.62	.39
χ^2 = 7.8/6 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .01; Upper limit of the 90% confidence interval for RMSEA = .039; Number of Cases = 1,457		

TABLE 11
Confirmatory Factor Analysis Results, Japanese College-Educated, 1991

Issue	Factor	Proportion of Variance Explained
New Scientific Discoveries	.91	.83
New Inventions and Technologies	.84	.70
Energy Issues	.69	.47
Space Exploration	.69	.47
Environmental Issues	.46	.21
New Medical Discoveries	.41	.17
χ^2 = .2.7/6 degrees of freedom; Root Mean Square Error of Approximation = .00; Upper limit of the 90% confidence interval for RMSEA = .038; Number of Cases = 323		

Canada

The 1989 Canadian National Study included a similar set of interest items. Using the same format as the American and European studies, the Canadian study asked respondents their levels of interest in new medical discoveries, environmental issues, new scientific discoveries, new inventions and technologies, economic policy, politics, space exploration, computers and related technology, sports news, and agricultural issues. These data are interesting to review for their structural characteristics as a result of the larger number of interest items included in the survey.

Canadians expressed more interest in medical and health issues than other issues, with an interest index score of 77 (see Table 12). Canadians expressed a high level of interest in environmental issues, new scientific discoveries, and new inventions and technologies. Canadians, like Europeans, reported a lower level of interest in politics and sports news than in any of the scientific and technological topics. Canadians, unlike respondents in the United States, expressed slightly more interest in new scientific discoveries and new inventions and technologies than in economic and business issues.

Canadians with a college education, like respondents in Europe and the United States, were significantly more interested in new scientific discoveries and new inventions and technologies than less well-educated Canadians. Little significant difference existed in the level of interest in medical or health issues between college and non-college graduates in Canada as was true in Europe and the United States. College-educated Canadians were significantly more interested in environmental issues than less well-educated citizens.

An exploratory factor analysis was conducted on six scientific or technological issues to explore the structure of issue interest in Canada. The exploratory factor analysis, using an oblimin (oblique) rotation, found a two-factor structure for the six items similar to that found for the European Union, and with a positive correlation of .44 between the two factors (see Table 13). To explore the strength of these two dimensions, a confirmatory factor analysis was performed on the same data set using the original ordinal responses. This analysis found that the six items loaded on a single factor. This single factor is defined by new inventions and technologies, environmental issues, new scientific discoveries, computers and related technologies, and space exploration. Health and new medical discoveries loaded on the factor, but with a substantially lower loading (see Table 14). A confirmatory factor analysis of a set of four items included in the 1992 Eurobarometer found a single factor, defined by interest in new scientific discoveries and new inventions and technologies (see Table 15).

TABLE 12
Level of Interest in Selected Issues, Canada, 1989

Issue	Education Level	Level of Interest (%)			Index Score	Number of Cases
		Very	Moder-ate	Not at All		
New Medical Discoveries	Total	59	35	6	77	2,000
	Lower	59	35	6	77	1,794
	Higher	58	39	4	78	206
Environmental Issues	Total	55	38	7	74	2,000
	Lower	54	39	7	73	1,794
	Higher	71	26	3	84	206
New Scientific Discoveries	Total	41	44	15	63	2,000
	Lower	39	44	17	61	1,794
	Higher	59	36	5	77	206
New Inventions and Technologies	Total	33	49	18	58	2,000
	Lower	32	49	19	56	1,794
	Higher	47	46	7	70	206
Economic Policy	Total	26	52	22	52	2,000
	Lower	24	52	24	50	1,794
	Higher	45	45	10	68	206
Politics	Total	28	44	28	50	2,000
	Lower	25	45	30	48	1,794
	Higher	53	33	14	70	206
Space Exploration	Total	28	41	31	48	2,000
	Lower	27	40	33	47	1,794
	Higher	36	48	16	60	206
Computers and Related Technology	Total	18	49	33	43	2,000
	Lower	16	49	35	41	1,794
	Higher	35	46	19	58	206
Sports News	Total	22	40	38	42	2,000
	Lower	22	39	39	42	1,794
	Higher	22	45	33	45	206
Agricultural Issues	Total	19	43	38	41	2,000
	Lower	19	42	39	40	1,794
	Higher	14	57	29	42	206

TABLE 13
Exploratory Factor Results for Issue Interests, Canadian Adults, 1989

Issue	Factor 1	Factor 2	Proportion of Variance Explained
New Inventions and Technologies . .	.80	–.03	.62
Computers and Related Technologies	.58	–.09	.30
Space Exploration	.49	.14	.32
New Scientific Discoveries	.46	.26	.39
Environmental Issues	.07	.69	.52
Health and New Medical Discoveries .	–.04	.64	.39
Correlation between Factor 1 and Factor 2 = .44; Number of Cases = 2,000			

TABLE 14
Confirmatory Factor Analysis Results, Canadian Adults, 1989

Issue	Factor	Proportion
New Inventions and Technologies	.94	.89
Environmental Issues	.75	.56
New Scientific Discoveries	.67	.45
Computers and Related Technologies	.67	.45
Space Exploration	.59	.35
Health and New Medical Discoveries	.40	.16
χ^2 = 1.6/4 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .00; Upper limit of the 90% confidence interval for RMSEA = .021; Number of Cases = 2,000		

TABLE 15
Confirmatory Factor Results for European Union Issues, Canadian Adults, 1989

Issue	Factor	Proportion of Variance Explained
New Scientific Discoveries	.82	.68
New Inventions and Technologies	.77	.60
Environmental Issues	.62	.38
Health and New Medical Discoveries . . .	.50	.25
χ^2 = .62/1 degree of freedom; Root Mean Square Error of Approximation (RMSEA) = .00; Upper limit of the 90% confidence interval for RMSEA = .054; Number of Cases = 2,000		

The Canadian data illustrate an important point about searching for an underlying interest structure. The answer depends, in part, on the question asked. An exploratory factor analysis, for example, asks what the best fit is for a set of items, and the oblimin (oblique) rotation allows for factors to be correlated. A confirmatory factor analysis asks whether a specific set of variables fits a specified model (see Appendix A). In this case, the results suggest that two highly correlated dimensions exist in the data, and the dimensions are sufficiently correlated that a single factor can be used to summarize the dimension. In contrast, the interest data from the full adult sample for the European Union could not be summarized with a single factor, suggesting that the two dimensions were farther apart in the European data.

A Comparison of Interest Levels and Patterns

It is possible to compare the levels of interest in selected issues and to look for patterns in these results, using the Index of Issue Interest. In general, a substantial level of similarity among the European Union, the United States, Japan, and Canada exists. For all four sociopolitical systems, the Index of Issue Interest in environmental issues is in the low-to-middle 70's range. Adults in both the United States and Canada expressed a higher level of interest in health and medical issues than did Europeans or Japanese (see Table 16). Significantly lower proportions of Japanese indicated a high level of interest in new scientific discoveries and new inventions and technologies than Europeans or North Americans [7].

TABLE 16
Index of Issue Interest Scores for the European Union, United States, Japan, and Canada

Issue	Mean Scores			
	Europe	United States	Japan	Canada
New Scientific Discoveries . . .	61	66	50	63
New Inventions and Technologies	59	66	53	58
New Medical Discoveries	68	82	65	77
Environmental Issues	75	73	71	74
Space Exploration	–	49	45	48
Energy/Nuclear Power	–	54	59	–
Computers and Related Technologies	–	–	–	43
Economic Policy	–	68	65	52
Education/Local Schools	–	72	62	–
Agricultural Issues	–	47	56	41
Military/Defense Issues	–	60	56	–
Foreign & International Policy .	–	47	55	–
Politics	55	–	–	50
Sports News	48	–	–	42
Taxes	–	–	71	–
Land Use Issues	–	–	65	–
Senior Citizen Issues	–	–	74	–

[7] *North Americans* refers to respondents from Canada and the United States.

Democratic political systems depend on a sufficient level of citizen interest in each issue to produce an attentive public able to participate effectively when a major dispute occurs. At the same time, the pressures of specialization discussed in Chapter I indicate that most citizens cannot be expected to devote the time and energy needed to become, and remain, informed about scientific and technological issues. It is unclear what level of public interest in science and technology issues is desirable, or necessary. To some extent, the answer may depend on the input and processing structures of each sociopolitical system. In a political system such as that in the United States with a strong and diverse legislative committee system receptive to individual and group input on issues, a smaller attentive public may be sufficient to sustain democratic participation in the policy-formulation process. In a party-driven legislative system such as Great Britain with relatively weak substantive committees, a larger attentive public may be necessary to sustain meaningful democratic participation.

CHAPTER III

CONCEPTUALIZING AND MEASURING SCIENTIFIC LITERACY

Understanding the concept of scientific literacy requires an appreciation of the meaning of literacy in today's society. *Literacy* defines a minimum skill level for reading and writing that is needed for written communication. Literacy is a threshold measure; one is literate or illiterate. The concept of literacy inherently measures this threshold.

Historically, individuals were considered literate if they could read and write their names. Recently, basic literacy skills have been redefined to include the ability to read a bus schedule, a loan agreement, or the instructions on a bottle of medicine (Dossey 1997; Steen 1997). Adult educators use the term *functional literacy* to refer to this definition of the minimal skills needed to function in a contemporary industrial society (Harman 1970; Cook 1977; Resnick and Resnick 1977; Kaestle 1985). Social science and educational research indicates that about 25% of Americans are functionally illiterate. It is reasonable to expect that this proportion applies in most developed industrial nations, with a higher rate occurring in emerging industrial nations (Ahmann 1975; Northcutt 1975; Guthrie and Kirsch 1984; Cevero 1985).

The changing definition of literacy suggests important characteristics in understanding the basic concept of literacy. First, the level of skills required to be considered literate changes over time. Literacy is a relative measure, not an absolute standard.

Second, the definition of functional literacy is not the same for both advanced industrial societies and third-world agricultural societies or for each of the diverse social and economic systems on this planet. The definition of literacy is relative to the type of society to which it applies.

Third, the selection of a threshold level is a judgment based on a set of considerations about the minimal acceptable determination for the definition of literacy. It is established by those who understand a subject in depth and reflects a minimal acceptable level required to function in a specific society. In regard to functional literacy, for example, different tests reflect the perceptions of individual test authors about the mix of skills necessary to function in society. A comparison of those tests reveals a consensus on the skills and knowledge needed to be functionally literate, and most of the tests measure a common set of skills (Murphy 1975; Cevero 1985).

The serious problems of literacy in our society are relevant to our concerns about a broader public understanding of science and technology. The world of science seems as inaccessible to millions of adults who are functionally illiterate as is the planet Pluto. A high proportion of people who drop out of high school join the ranks of the functionally illiterate, virtually eliminating the possibility of achieving scientific literacy.

Conceptualizing Scientific Literacy

The scope of scientific literacy is critical to the basic concept. *Scientific literacy* could be defined as the ability to read and write about science and technology (Miller 1983b, 1987a, 1995). Scientific literacy might include different components ranging from a practical one such as reading the nutritional facts label on a food package or repairing an auto to a cultural one such as seeing the newest images from the Hubble telescope.

The public's understanding of science and technology might be divided into practical scientific literacy, cultural scientific literacy, and civic scientific literacy based on the wide array of scientific and technological applications in everyday life. *Civic scientific literacy* refers to a level of understanding of scientific terms and concepts sufficient to read a newspaper or magazine and to understand the essence of competing arguments on a controversy. Shen argued:

> Familiarity with science and awareness of its implications are not the same as the acquisition of scientific information for the solution of practical problems. In this respect civic science literacy differs fundamentally from practical science literacy, although there are areas

> where the two inevitably overlap. Compared with practical science literacy, the achievement of a functional level of civic science literacy is a more protracted endeavor. Yet, it is a job that sooner or later must be done, for as time goes on human events will become even more entwined in science, and science-related public issues in the future can only increase in number and in importance. Civic science literacy is a cornerstone of informed public policy.

The amount of information required for civic scientific literacy becomes important as demonstrated in studies of a nuclear power controversy in Sweden (Nelkin 1977). In the early 1970's, Sweden sought to develop a national policy on using nuclear power to generate electricity. The Swedish government provided grants for study circles to facilitate a broader public debate on the nuclear power issue. Study circles met in groups of 10 to 15 citizens with materials and a facilitator to provide a balanced presentation of the issues. After months of discussions by 80,000 Swedish citizens, Sweden's National Board of Civic Information learned from a study that the portion of Swedish adults who felt unable to make a decision, having heard all arguments set forth, increased from 63% prior to the study circles to 73% after at least 10 hours of study and discussion.

A salient point is the difficulty for the public to familiarize itself with the implications of a scientific-technological controversy and to take a position based on the newly acquired information in a relatively short time period. It appears that a long-term familiarity with the way science operates and the image of the world it offers must be introduced so that new information about a specific issue could be processed. This is a challenging task, but a necessary one if decision-making on scientific and technological issues and the public's influence on them is to be based on scientific information and not simply on values or, perhaps less desirably, on holistic conceptions that incur fallacies such as those Karl Popper criticized vigorously 40 years ago (1957).

The public becomes involved in the resolution of scientific and technological disputes primarily at the point of controversy (Miller 1983a). As a result, it is essential to have a sufficient number of civic scientifically literate citizens to understand and evaluate the essential points of competing arguments.

An extreme view reserves definition of *true scientific literacy* for individuals who understand the third law of thermodynamics in essentially the same terms as a physicist (Shamos 1995). Shamos concludes that citizens can never acquire sufficient understanding to participate in science and technology disputes, and embraces the long-discredited concept of a science court to remove science policy from the democratic process. Unable to shed his own training in physics, Shamos fails to recognize that society's political institutions are extremely reluctant to exclude decision-making from democratic influence. This is highlighted in the uneasy experiment with independent regulatory commissions for securities, trade practices, and communications over the last 40 years in the United States. Further, efforts to exclude science policy from the democratic processes would foster similar non-democratic arrangements from other interest groups and, above all, could alienate important segments of the public from science policy and the scientific community, paving the way for a more confrontational intervention of the public in scientific and technological issues.

Science and technology policy will continue to be set by the political systems in most countries. Therefore, it is important to define useable and consistent measures of civic scientific literacy to assist in assessing citizen participation. Miller (1983b, 1987a, 1989, 1995) has built an empirical estimate of the proportion of American adults who are civic scientifically literate, based on a series of national surveys initiated in 1979. This monograph utilizes Miller's work as the basis for the operational definition of and measurement of civic scientific literacy since it is the only empirical definition in this area.

The Issue of Dimensionality

An important issue in defining civic scientific literacy is whether it is a unidimensional or multidimensional construct. This issue has important implications for measurement. In its simplest form, a unidimensional concept of civic scientific literacy reflects a single set of positively correlated knowledge items, while a multidimensional concept of civic scientific literacy represents distinct clusters of knowledge or understanding which should be viewed as separate though not independent dimensions.

Miller (1983b, 1987a, 1989, 1995) argues that civic scientific literacy is multidimensional. In his early work, he suggests that civic scientific literacy has three related dimensions: a vocabulary of basic scientific constructs sufficient to read opposing views in a newspaper, an understanding of the process of scientific inquiry, and an understanding of the impact of science and technology on individuals and society (Miller 1983a). A reasonable understanding of these three dimensions would reflect a competence to comprehend arguments on science and technology policy in the media.

However, in recent cross-national studies of civic scientific literacy, Miller (1996) found that the third dimension "the impact of science and technology on individuals and society" varies substantially among nations. As a result, he has adopted a two-dimensional measure for cross-national analyses.

A two-dimensional structure for measuring scientific understanding was recognized by Durant, although he opted to use a continuous index of 27 items to measure public understanding for analytic purposes (Durant, Evans and Thomas 1989, 1992; Evans and Durant 1995). In recent work, Durant discusses a three-dimensional model (a comprehension of basic scientific concepts, an understanding of scientific methodology, and an understanding of the institutional dimension of science) but has used for analysis only a single summated scale that merges the vocabulary and process dimensions (Bauer, Durant and Evans 1994).

A consensus emerges that civic scientific literacy can be conceptualized as a two-dimensional measure, reflecting a dimension for a vocabulary of basic scientific constructs and a dimension for process or inquiry. The possible third dimension may reflect the impact of science and technology within a single political system, or among political systems with essentially common scientific and technological experiences, while a fourth dimension relates the understanding of the organizational structure with institutional functioning of science. A reliable two-dimensional measure, however, is appropriate for cross-national research.

Measuring Civic Scientific Literacy

It is important to create a measure of civic scientific literacy that provides a time-series indicator that will be useful over a period of years. When an indicator is revised, it becomes difficult to separate the variation attributable to changes in measurement from changes over time. The current debate over the composition of the consumer price index in the United States and in other major industrial nations is a reminder of the need for stable indicators over a period of time.

Early efforts to develop measures of public understanding of science in the United States suffered from the use of nondurable measures. In 1957, the National Association of Science Writers (NASW) commissioned a national survey of public understanding of, and attitudes toward, science and technology (Davis 1958). The 1957 study was completed only a few weeks prior to the launch of *Sputnik I* and is the only measure of public understanding and attitudes prior to the beginning of the space race. Unfortunately, the four major items used to determine substantive knowledge were Strontium 90 (from radioactive fallout), fluoridation in drinking water, polio vaccine, and space satellites. Within 20 years, at least three of these items were no longer useful to the measurement of public understanding.

As a result, Miller attempted to identify a set of basic constructs, such as atomic structure or *DNA*. These constructs are a necessary intellectual foundation for understanding debates over contemporary scientific issues and will be more durable measures over time than specific terms, such as the fallout of strontium 90 from atmospheric testing.

In the late 1970's and the early 1980's, the National Science Foundation began to support comprehensive national surveys of public understanding and attitudes in the United States, building on the 1957 NASW study. The first U.S. studies relied heavily on each respondent's self-assessment of his level of understanding of various terms and concepts. This approach presumes that when respondents are offered a trichotomous set of choices (do you have a *clear understanding*, a *general sense*, or *not much understanding?)*, individuals who chose clear understanding would be more likely to understand, while individuals who were unsure might select either of the other two choices (Oppenheim 1966; Dillman 1978; Labaw 1980; Sudman and Bradburn 1982; Converse and Schuman 1984). Self-assessment questions, which are still used in Japan's national studies, provide basic estimates, but lack the precision of direct substantive inquiries.

An expanded set of direct questions on scientific concepts was developed in a 1988 collaboration between Geoffrey Thomas and John Durant in the U.K. and Jon Miller in the U.S. A combination of open-ended and closed-ended items provided significantly better estimates of public understanding than had been collected in any prior national study. The core set of knowledge items that emerged has been used in studies in the European Union, Japan, Canada, China, Korea, New Zealand, and Spain. These core items provide a robust set of measures of a vocabulary of scientific constructs, with some additions and deletions.

Measuring public understanding of the nature of scientific inquiry is difficult. A single open-ended inquiry in the 1988 U.K.-U.S. study concerned the meaning of *scientific study*. A joint coding exercise demonstrated the feasibility of double-blind, open-ended coding, producing coefficients of reproducibility in the .9 range. Subsequently, Durant developed a set of closed-ended inquiries for use in the 1992 Eurobarometer, and Miller and Pifer developed open-ended inquiries for a 1993 U.S. Biomedical Literacy Study, which was subsequently incorporated into the National Science Foundation *Science and Engineering Indicators.*

Measuring Scientific Construct Understanding

It is useful to examine the development of measures of the public understanding of basic scientific constructs in the search for durable measures. Many measures used over the last decade emerged from the 1988 U.K.-U.S. collaboration, which produced a set of open-ended items, several multi-part questions, and a closed-ended true-false quiz.

A two-step procedure was developed to obtain open-ended responses. An open-ended question concerning *DNA* is a good example. The question began with a closed-ended inquiry:

> When you read the term *DNA* in a newspaper or magazine, do you have a clear understanding of its meaning, a general sense of its meaning, or not much understanding of its meaning?

Respondents who indicated that they had either a clear understanding or a general sense of the meaning of *DNA* were then asked the open-ended question:

> Please tell me, in your own words, what does *DNA* mean?

The interviewers, regardless of whether the interview was conducted in person or over the telephone, recorded the responses verbatim, which were subsequently coded independently by teams of individuals using a standard definition of the meaning of *DNA.* Double-blind coding procedures were used (Montgomery and Crittenden 1977; Perreault and Leigh 1989; Hughes and Garrett 1990), and full sets of text responses were coded by both American and British coders to assure cross-national comparability. The results of this work demonstrated that double-blind coding practices could produce reliable data, with few cross-national variations in coding.

In subsequent U.S. studies, similar open-ended questions were employed to measure the understanding of basic constructs regarding molecule, radiation, acid rain, computer software, and the thinning of the ozone layer around the Earth. In the 1995 U.S. study,

study, the vocabulary dimension included open-ended questions concerning the meaning of *DNA* and *molecule*.

A set of multi-part, closed-ended items was first developed in the 1988 U.K.-U.S. collaboration. A two-part question about the movement of the Earth and the Sun has been widely cited in the popular press. Respondents were asked whether "the Earth goes around the Sun, or the Sun goes around the Earth". Respondents who indicated that the Earth goes around the Sun were asked whether the Earth goes around the Sun "once a day, once of month, or once a year". Approximately 33% of British respondents and 47% of American respondents answered that the Earth moves around the Sun once each year. The percentage of Americans answering this question correctly has remained stable since 1988.

Another series of items in the 1988 U.K.-U.S. study used a true-false format with an option for an unsure response. This less stressful form of inquiry was considered useful in reducing the pressure of answering too many open-ended questions, especially in a telephone setting where the respondent can terminate the interview by hanging up. Examples of items in this quiz include:

> Lasers work by focusing sound waves.
>
> All radioactivity is man-made.
>
> The earliest human beings lived at the same time as the dinosaurs.
>
> The center of the Earth is very hot.
>
> Antibiotics kill viruses as well as bacteria.
>
> The continents on which we live have been moving their locations for millions of years and will continue to move in the future.
>
> Radioactive milk can be made safe by boiling it.

A few items were asked as direct inquiries. For example, respondents were asked: "Which moves faster, light or sound?"

Studies in Japan and Canada have collected comparable knowledge measures by using various sets of these questions on understanding. In 1991, the National Institute of Science and Technology Policy (NISTEP) in Japan sponsored a study that included a smaller core set of items identical to, or comparable to, those used in the

European and U.S. studies. The Canadian National Study in 1989 included a substantial number of items identical to those in the 1988 U.K.-U.S. studies, including the open-ended question about *DNA*.

Although the exact items vary from study to study, these sets should be viewed as a sample of knowledge required for civic scientific literacy. The range of items developed by Project 2061 reflects the substantive concepts that constitute a universe of relevant measures.

The process of constructing reliable and comparable measures of civic scientific vocabulary can be understood by examining the indices for the 1992 Eurobarometer study and the 1995 United States study. A common core of nine knowledge items was asked in both studies (see Table 17). Examining the percent of correct responses suggests little difference between European Union and United States adults. European Union adults answered an average of 4.9 items correctly while American adults answered an average of 5.1 questions correctly. Cross-national comparisons can be limited to those items asked in a comparable manner in each study, but such limitation does not allow utilization of the full array of information available and may eliminate cross-national comparison when there are minor variations in wording or translation.

An alternative measurement approach combines factor analysis and Item-Response Theory (IRT) scores to create a common metric suitable for comparing results across nations. A reasonable measure of the vocabulary dimension may be created if a sample of items includes an appropriate range of substantive constructs and reflects a unidimensional structure. A confirmatory factor analysis represents the best means of assessing the scalar characteristics of a set of items. Applying a confirmatory factor analysis to the items in the 1992 Eurobarometer study, the 1995 U.S. study, the 1991 Japanese study, and the 1989 Canadian study, a single construct vocabulary factor emerges, with similar items loading on each factor (see Tables 18, 19, 20, and 21). A confirmatory factor analysis, focusing only on the construct vocabulary dimension, identified nine items in the European Union, the United States, and Canada, and five items identified as comparable factors in Japan.

The construct vocabulary dimension for the European Union included six items identical to items in the U.S. factor, and three items not included in the U.S. factor. All of the European items were closed-ended. The European construct vocabulary dimension was anchored by a true-false question on plate tectonics (.70), followed by three true-false questions concerning radioactivity and

TABLE 17
Construct Vocabulary, Open-Ended Items, European Union, 1992, and United States, 1995

Construct Vocabulary Measures	% Correct	
	Europe	United States
Provide a correct open-ended definition of a molecule	**	9
Provide a correct open-ended definition of DNA	**	21
Disagree that "Antibiotics kill viruses as well as bacteria"	27	40
Disagree that "Lasers work by focusing sound waves"	36	40
Agree that "Electrons are smaller than atoms"	41	44
Indicate that the Earth goes around the Sun once each year through a pair of closed-ended questions	51	47
Disagree that "The earliest humans lived at the same time as the dinosaurs"	49	48
Disagree that "All radioactivity is man-made"	53	72
Indicate that light travels faster than sound	**	75
Disagree that "Radioactive milk can be made safe by boiling it"	66	61
Agree that "The continents on which we live have been moving their locations for millions of years and will continue to move in the future"	82	78
Agree that "The center of the Earth is very hot"	86	78

** = not asked

lasers. The European dimension included three items (making radioactive milk safe by boiling it, antibiotics kill viruses, and the center of the Earth is very hot) that were asked in the 1995 U.S. study, but which did not load on the U.S. vocabulary dimension at the .40 level or higher.

The construct vocabulary dimension for the 1995 U.S. study was anchored by the pair of open-ended questions requiring a definition of *DNA* and of a *molecule*, with factor loadings of .79 and .77, respectively. The two-part question about the movement of the Earth and the Sun had the third highest loading (.69), followed by a pair of true-false questions on lasers and radioactivity that required false responses. The speed of light and sound question had a loading of .56, and a pair of true-false questions about humans and dinosaurs and about plate tectonics had loadings of .46. These nine items illustrate a range of knowledge from basic atomic structure (the definition of a *molecule* and the whole-part relationship of an atom and an electron) to basic biological constructs (definition of *DNA*) to earth science (plate tectonics). Although it is not an exhaustive

TABLE 18
Dimensions of Civic Scientific Literacy, European Union, 1992

Construct Vocabulary Measures	Construct Knowledge Dimension	Process Knowledge Dimension	Proportion of Variance Explained
Agree that "The continents on which we live have been moving their locations for millions of years and will continue to move in the future"	.70	–	.49
Disagree that "All radioactivity is man-made"	.69	–	.48
Disagree that "Lasers work by focusing sound waves"	.69	–	.48
Disagree that "Radioactive milk can be made safe by boiling it"	.66	–	.43
Disagree that "The earliest humans lived at the same time as the dinosaurs"	.57	–	.32
Agree that "The center of the Earth is very hot"	.56	–	.31
Disagree that "Antibiotics kill viruses as well as bacteria"	.54	–	.29
Indicate that the Earth goes around the Sun once each year through a pair of closed-ended questions	.51	–	.26
Agree that "Electrons are smaller than atoms"	.47	–	.22
Demonstrate an understanding of the meaning of the probability of one-in-four by applying this principle to an example of an inherited illness in four separate questions	–	.57	.33
Indicate that astrology is not at all scientific	–	.52	.27
Select a two-group experimental model in a closed-ended question	–	.34	.12

χ^2 = 32.3/23 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .01;
Upper limit of the 90% confidence interval for RMSEA = .01;
Correlation between two factors = .87;
Number of Cases = 12,147

A confirmatory factor analysis is a technique for testing a hypothesis about the relationships among a set of items. The confirmatory factor analysis hypothesized that civic scientific literacy was organized into two dimensions, reflecting construct understanding and process understanding. This technique examined the correlation among the items and identified two sets of items with high inter correlations among the items on each dimension, but not necessarily with the items on the other dimension. In this case, the confirmatory factor analysis revealed that the two factors were positively correlated.

This note is not repeated on subsequent tables describing the results of other confirmatory factor analyses utilized in this analysis.

set, it taps basic scientific constructs from a broad spectrum of scientific disciplines.

The construct vocabulary dimension for Japan included five closed-ended items, anchored by an item asking whether all radioactivity is man-made. The other items, in the order of their factor loading, were plate tectonics, the relative size of electrons and atoms, the composition of lasers, and whether antibiotics are capable of killing viruses. All five of these items were used in one or more of the national studies in Europe, the United States, and Canada. This high

TABLE 19
Dimensions of Civic Scientific Literacy, United States, 1995

Construct Vocabulary Measures	Construct Knowledge Dimension	Process Knowledge Dimension	Proportion of Variance Explained
Provide a correct open-ended definition of *DNA*	.79	–	.62
Provide a correct open-ended definition of a *molecule*	.77	–	.59
Indicate that the Earth goes around the Sun once each year through a pair of closed-ended questions	.69	–	.48
Disagree that "Lasers work by focusing sound waves"	.65	–	.42
Disagree that "All radioactivity is man-made"	.59	–	.35
Agree that "Electrons are smaller than atoms"	.59	–	.34
Indicate that light travels faster than sound	.56	–	.31
Disagree that "The earliest humans lived at the same time as the dinosaurs"	.46	–	.22
Agree that "The continents on which we live have been moving their locations for millions of years and will continue to move in the future"	.46	–	.21
Demonstrate an understanding of experimental logic by selecting a research design and explaining in an open-ended response the rationale for a control group . .	–	.83	.68
Provide an open-ended explanation of the meaning of studying something scientifically	–	.68	.46
Demonstrate an understanding of the meaning of the probability of one-in-four by applying this principle to an example of an inherited illness in four separate questions	–	.63	.38

χ^2 = 91.1/45 degrees of freedom; Root Mean Square Error of Approximation = .02;
Upper limit of the 90% confidence interval for RMSEA = .029;
Correlation between two factors = .86; Number of Cases = 2,006

level of linkage is especially important in view of the smaller number of items loading on the construct vocabulary dimension in Japan [8].

[8] In the confirmatory factor analysis, two additional items loaded on the vocabulary dimension, but did not scale appropriately. One item on evolution had a poor fitting item-response curve, and an item on sunlight as a cause of

TABLE 20
Dimensions of Civic Scientific Literacy, Japan, 1991

Construct Vocabulary Measures	Construct Knowledge Dimension	Process Knowledge Dimension	Proportion of Variance Explained
Disagree that "All radioactivity is man-made"	.73	–	54
Agree that "The continents on which we live have been moving their locations for millions of years and will continue to move in the future"	.66	–	.43
Agree that "Electrons are smaller than atoms"	.56	–	.32
Disagree that "Lasers work by focusing sound waves"	.54	–	.29
Disagree that "Antibiotics kill viruses as well as bacteria"	.44	–	.19
Demonstrate an understanding of the meaning of the probability of one-in-four by applying this principle to an example of flower genetics in four separate questions	–	.51	.26
Demonstrate an understanding of the nature of experimentation in a pair of closed-ended questions	–	.43	.18

χ^2 = 15.9/10 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .02;
Upper limit of the 90% confidence interval for RMSEA = .038;
Correlation between two factors = .88;
Number of Cases = 1,457

The construct vocabulary dimension for Canada was anchored by an open-ended item concerning the meaning of *DNA*, followed by closed-ended items concerning the composition of lasers, the size of electrons and atoms, the temperature of the center of the Earth, the relative speed of light and sound, the rotation of the Earth and the Sun, plate tectonics, and whether humans and dinosaurs co-existed. All of these items were used in the 1992 Eurobarometer or the 1995 U.S. Science Indicators study and the items loaded in a pattern similar to the U.S. results.

To facilitate cross-national comparisons, it was necessary to create summary measures of this dimension across the four studies. Multiple-group IRT methods, as implemented in the BILOG-MG program, provide a means for computing item values and test scores that take into account the relative difficulty the items, and

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cancer had a low threshold value (meaning that it was easily compared with other national surveys) reducing the estimated vocabulary score for Japanese respondents.

TABLE 21
Dimensions of Civic Scientific Literacy, Canada, 1989

Construct Vocabulary Measures	Construct Knowledge Dimension	Process Knowledge Dimension	Proportion of Variance Explained
Provide a correct open-ended definition of *DNA*	.82	–	.67
Disagree that "Lasers work by focusing sound waves"	.65	–	.42
Agree that "Electrons are smaller than atoms"	.61	–	.37
Agree that "The center of the Earth is very hot"	.60	–	.36
Indicate that light travels faster than sound	.59	–	.35
Indicate that the Earth goes around the Sun once each year through a pair of closed-ended questions	.58	–	.34
Agree that "The continents on which we live have been moving their locations for millions of years and will continue to move"	.51	–	.26
Disagree that "Radioactive milk can be made safe by boiling it" . .	.49	–	.24
Disagree that "The earliest humans lived at the same time as the dinosaurs"	.40	–	.16
Provide an open-ended explanation of the meaning of studying something scientifically	–	.66	.43
Indicate that astrology is not at all scientific	–	.39	.15

χ^2 = 53.3/37 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .02;
Upper limit of the 90% confidence interval for RMSEA = .023;
Correlation between two factors = .90;
Number of Cases = 2,000

the different composition of each test (Bock & Zimowski 1997). The program places the items from all tests on a common scale by jointly estimating the item parameters and the latent distribution of each group, or nation, and uses the maximum marginal-likelihood method. This method is capable of providing reliable results for tests or scales with fewer than 10 items (Bock and Aitken 1981).

The basic concept of IRT is that responses to a knowledge item will form an item-response curve (see Figure 1), a probability distribution of responses to each item, usually of a logistic nature (although it can be a normal distribution). Assuming that all respondents taking a test could be arrayed in an order reflecting their knowledge of the area being tested, the x-axis of the item-response

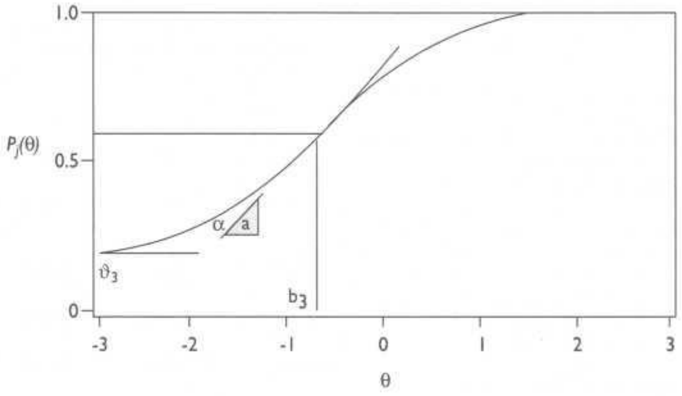

FIGURE 1:
Item Response Curve

curve is an estimate of knowledge or ability. The y-axis is the probability the question will be answered correctly, given the respondent's ability. The item-response curve indicates that few individuals with a low level of knowledge of the subject will be able to answer the hypothetical question in Figure 1, and that most of the respondents with a high level of knowledge will be able to answer it.

For each item in the four studies, the BILOG-MG program calculates three separate IRT parameters (a threshold parameter, a slope parameter, and a guessing parameter) to discriminate between subjects with different degrees of knowledge. Curves to the left of the figure indicate items of a lower difficulty level than items located on the right, and items with steeper curves represent greater discrimination capacity than items with flatter curves (see Table 22). The threshold parameter is a measure of item difficulty, with higher values meaning that fewer respondents were able to answer it correctly. The slope parameter estimates the measurement efficiency of the item. The guessing parameter provides a correction for guesses in closed-ended questions, or for coding errors in open-ended questions. In the hypothetical item-response curve shown in Figure 1, the guessing parameter raises the base from a zero correct level to a level that would be obtained by guessing alone, with no substantive knowledge of the domain. All of the item parameters are estimated in a standardized form, with

TABLE 22
IRT Parameters for Basic Scientific Construct Items

Basic Scientific Construct Items	Threshold Parameter	Slope Parameter	Guessing Parameter
Provide a correct open-ended definition of *DNA*	1.191	1.006	0.020
Provide a correct open-ended definition of a *molecule*	1.902	1.179	0.000
Indicate that light travels faster than sound	-0.872	0.775	0.234
Indicate that the Earth goes around the Sun once each year through a pair of closed-ended questions	0.066	0.600	0.077
Disagree that "Lasers work by focusing sound waves"	0.435	0.893	0.018
Disagree that "All radioactivity is man-made"	-0.185	1.044	0.117
Agree that "Electrons are smaller than atoms"	0.312	0.535	0.000
Disagree that "The earliest humans lived at the same time as the dinosaurs"	-0.074	0.536	0.000
Agree that "The continents on which we live have been moving their locations for millions of years and will continue to move in the future"	-1.636	0.750	0.000
Disagree that "Radioactive milk can be made safe by boiling it" . .	-0.499	0.853	0.169
Agree that "The center of the Earth is very hot"	-1.887	0.863	0.000
Disagree that "Antibiotics kill viruses as well as bacteria"	1.158	0.534	0.000

a mean of zero and a standard deviation of 1.0 in the combined latent distributions of the groups.

The responses from all adults participating in the four studies were used for computing item parameters for this set of basic scientific constructs. This produced one set of item parameters that applied to all items in the four studies. The common, or linked, questions provide a means for placing on the same scale the parameters for items asked in some countries but not in others. It is possible to compute comparable scores from each set of items since all of the item parameters are placed on a single metric.

The computation of individual scores by BILOG-MG utilizes a standardized metric, with a mean of zero and a standard deviation of 1.0 in the combined pool of respondents. This standardized metric, however, is confusing since approximately half of the respondents would have a negative score. To obtain a more comprehensible metric, the mean for the combined pool of respondents in the four studies is set to a value of 50, with a standard deviation of 20. In practice, this means that for all respondents within 2.5 standard deviations of this common mean, the score will vary between zero and 100. The approximately 1% of respondents who might fall outside this range are truncated into the zero to 100 scale. Using this metric, the mean vocabulary score was 49.3 for the European Union, 54.5 for the United States, 36.1 for Japan, and 46.3 for Canada. These results are consistent with the mean percent correct responses on the nine common items between the European Union and the U.S., but provide more precise individual scoring, allowing comparisons among nations with overlapping, but not identical, sets of knowledge items (Miller 1996).

It is necessary to determine the minimum score for the analytic identification of individuals capable of following and understanding a public policy dispute over a scientific or technological issue. In previous estimates of civic scientific literacy, Miller (1987a, 1989, 1995, 1996) has used a threshold level of 67 or more, reflecting the ability of a respondent to score two-thirds of the possible points on the construct vocabulary index. When this standard is applied to the 1995 U.S. data, 27.2% of Americans score at or above the 67-point level compared with 20.2% of Europeans [9] and 17.4% of Canadians. This result suggests that approximately three of four adults in the United States and four of five adults in Europe and Canada would be unable to read and understand news or other information utilizing basic scientific constructs such as *DNA*, molecule, or radiation.

The application of IRT parameters to the data from Japan caused problems. The 1991 Japanese survey included a smaller set of knowledge items than the other studies, and the questions tended to have lower threshold values; they were ranked easier by IRT scoring. As a result, a Japanese respondent who answered all five of the items in the vocabulary scale correctly would not have achieved 67 points. The IRT parameters for each question can be compared with the difficulty score assigned to various dives in Olympic diving competitions. An easier dive might have a difficulty value of 2.9 while a very difficult dive might have a value of 4.1. Each Olympic judge scores the dive on a zero to 10 scale, and this score is then multiplied by the difficulty score assigned to the dive. In IRT scoring, a respondent gets the item either right or wrong, which might be thought of as having the values of one and zero

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[9] In a separate analysis of 14 industrial nations, Miller (1996) found that the proportion of adults meeting this standard within the European Union ranged from 27.2% in the Netherlands to 6.6% in Greece.

respectively, and each correct response is multiplied by its IRT parameters to compute a total score.

The five items with adequate characteristics to be included in the construct vocabulary dimension for Japan had sufficiently low thresholds that their collective total was markedly lower than the collective sets of items in the other countries. The level of difficulty, not the number of items included, created the scoring problem. Even nine or more items of this relatively lower difficulty level would have produced the same result. This is analogous to a diver who makes five excellent, but easy, dives. Even though the diver might have done well on more difficult dives, no evidence supports or opposes that possibility.

The two choices for this analysis were to drop the Japanese study results from the comparison, or to lower the minimum standard since the composition of the 1991 Japan interview questionnaire made it impossible for anyone to meet the standard of 67 points. A review of Japanese adult scores showed a break in the data just below 60. Rather than drop the Japanese study from the comparison, the minimum standard was reduced from 67 to 60 to estimate the percentage of Japanese adults with a sufficient vocabulary of basic scientific constructs to read and to follow science and technology policy issues in the news. Approximately 25% of Japanese adults met this standard.

A Typology of Process Understanding

Measuring public understanding of the nature of scientific inquiry is parallel to measuring construct understanding. Civic scientific literacy requires that an individual display a minimal understanding of the empirical basis of scientific inquiry. Ideally, an individual would understand science as theory development and testing. An important component of understanding the nature of scientific inquiry is the idea that scientific theories are propositions logically connected in a deductive manner and, in principle, subject to empirical scrutiny, with the possibility of being falsified (Popper 1959). Respondents in scientific literacy surveys are expected to provide a general notion of scientific inquiry consistent with the Popperian paradigm.

In his original U.S. studies, Miller (1983b, 1987a, 1989, 1995) utilized a combination of a single open-ended inquiry about the meaning of scientific study and a closed-ended question about astrology as scientific or non-scientific to identify respondents who held at least a minimal understanding of the *process of scientific inquiry*. Respondents were asked whether they had a *clear under-*

standing, a general sense, or *not much understanding* of what it means to study something scientifically. Individuals who reported that they had a clear understanding or a general sense were asked to describe, in their own words, what it means to study something scientifically. The responses were collected verbatim and were coded by teams of three or more independent coders. In the 1988 U.K.-U.S. study, British and American teams coded all of the responses from both countries, and the final results had an inter-coder reliability coefficient above .90.

A common response to the open-ended question about the meaning of scientific study was that it involved doing an experiment. This was, often, the only response provided, and it was coded as correct, but an expanded measure of the meaning of *experiment* was needed. Miller and Pifer (1995) introduced a new question concerning experimentation in the 1993 Biomedical Literacy Study:

> Now, please think of this situation. Two scientists want to know if a certain drug is effective against high blood pressure. The first scientist wants to give the drug to 1,000 people with high blood pressure and see how many experience lower blood pressure levels. The second scientist wants to give the drug to 500 people with high blood pressure, and not give the drug to another 500 people with high blood pressure, and see how many in both groups experience lower blood pressure levels. Which is the better way to test this drug?
>
> Why it is better to test the drug this way?

All respondents were asked the follow-up probe which proved to be essential in assessing the level of understanding. Most of the 17% of U.S. adults who selected the single-group experiment design did not understand the rationale for establishing a control group, although a small number explained that they understood the logic of control groups, and placebos, but could not ethically withhold medicine from a sick person. Setting aside the ethical argument, it is clear from this response that this small group of respondents, representing approximately 1% of the total sample, did have an adequate level of understanding of experimental logic and they were coded as understanding the nature of scientific inquiry.

Among the 69% of individuals who selected the two-group experiment design, the open-ended probe revealed substantial misunderstanding of the rationale for experimental design. A majority of this group, representing approximately 40% of the total population, indicated that they selected the two-group design so that if the drug "killed a lot of people", it would claim fewer victims since it would have been administered to fewer subjects. This is not the understanding of logic intended by the choice of the two-group experiment design, and illustrates a hazard of closed-ended questions. Approximately 12% of U.S. adults selected the two-group design and were able to explain the logic of establishing control groups. An additional 14% of those interviewed in the 1995 U.S. study selected the two-group design and provided a rationale that included a comparison between the two groups, but that lacked the language or logic of control groups.

A closed-ended question assessing each respondent's understanding of probability was also used in assessing a minimal level of understanding of the nature of scientific inquiry. The question posed a situation in which a doctor "tells a couple that they've got a one-in-four chance of having a child with an inherited illness". Each respondent was asked to indicate whether each of four statements was a correct or an incorrect interpretation of the meaning of *one-in-four chances:*

> If they have only three children, none will have the illness.
>
> If their first child has the illness, the next three will not.
>
> Each of the couple's children has the same risk of suffering from the illness.
>
> If their first three children are healthy, the fourth will have the illness.

Approximately 54% of U.S. adults demonstrated an understanding of *probability* by selecting the third choice as correct and labeling the other three choices incorrect.

Respondents were required to meet two criteria to be classified as having a minimal understanding of the nature of scientific inquiry. First, they had to demonstrate an understanding of the nature of scientific study either by describing the nature of scientific study as theory building and testing or by demonstrating a correct understanding of experimental procedure. Second, they had to demonstrate a correct understanding of *probability*. A total of 21% of U.S. respondents met this standard in the 1995 study.

The 1992 Eurobarometer included three sets of closed-ended process understanding items but no open-ended items. These questions related to an understanding of the nature of scientific inquiry and were loaded on a second factor in a confirmatory factor analysis in a pattern similar to that described above for the United States (see Table 18). The importance of the two-dimension hypothesis to this analysis requires a brief review of these three items.

First, the total Eurobarometer sample was randomly split into two groups. A pair of closed-ended questions asked respondents to think about either a medical example or a machine tool example and determine how they would obtain information to assess the effectiveness of a drug or the likely durability of a metal. Each question offered the respondents three options: asking the opinion of an expert in the field, using their own scientific knowledge, or doing an experiment. The experiment choice was coded as the correct choice. Approximately 38% of European adults provided a correct response.

An additional question assessed the understanding of experiments, utilizing the first part of the question written for the 1993 *U.S. Biomedical Literacy Study*, and presented in the context of the U.S. study quoted above.

Approximately 65% of European respondents selected the two-group model. The Eurobarometer did not use the follow-up probe employed in the United States in 1993 and 1995; thus it is likely that this response overstates the real level of public understanding of the logic of experimentation.

Although neither of these questions utilized an open-ended probe, the combination of the two items into a single indicator improves the quality of the measure. All respondents who selected the experiment option in the first closed-ended question and who selected the two-group model in the second question were classified as having at least a minimally acceptable level of understanding of experimentation. Approximately 28% of European adults were defined as knowledgeable about experimentation in the Eurobarometer.

Second, a split-ballot approach was employed with a question about the scientific or non-scientific basis of astrology. All respondents were asked to rate how scientific a set of disciplines or activities were, using a scale that ranged from 1 for *not at all scientific* to 5 for *very scientific*. The list included biology, astronomy, history, physics, astrology, economics, medicine, and psychology.

A random half of the respondents were given an additional sentence of explanation explaining the formal purpose of each discipline. For example, *astronomy* was defined as the study of the heavenly bodies and *astrology* was defined as the study of occult influence of stars and planets on human affairs. Nearly 40% of European adults indicated that astrology was not at all scientific, but 52% thought there was at least some scientific content in astrology.

Third, a closed-ended question assessed each respondent's understanding of *probability*. Parallel to the question used in the U.S. study, this Eurobarometer question posed a situation in which a doctor "tells a couple that they've got a one-in-four chance of having a child with an inherited illness". Each respondent was then shown a card with the same four choices used in the U.S. study. Approximately 71% of European adults selected the correct equal probability choice.

A simple typology was constructed, based on the framework employed in the analysis of the U.S. data set, to estimate the proportion of Europeans with an understanding of the nature of scientific inquiry. All respondents who satisfied the condition of demonstrating a minimally acceptable level of understanding of *experimentation*, who recognized that astrology is not at all scientific, and who demonstrated a correct response to the probability question were coded as understanding the nature of scientific inquiry. Approximately 12% of European adults in the Eurobarometer study met this standard.

The Japanese study included two items relevant to understanding the nature of scientific inquiry. Each respondent in the study was asked the meaning of *scientific study*, the same question used in the other countries' studies. The Japanese study did not include an open-ended probe. When asked how well they understood what it means to study something scientifically, 4% of Japanese adults claimed a clear understanding and 36% said that they understood, but at a level below clear understanding. Nearly half of Japanese adults said they hardly understood, and 12% said that they did not understand at all. While it would have been desirable to have had a confirmatory open-ended probe, the literature on Japanese public opinion and culture suggests that most respondents would be reluctant to exaggerate their level of understanding, which supports this self-reported response as one indicator of the understanding of scientific study among Japanese adults (Carll and Bowman 1996).

Then each respondent was asked a closed-ended question about a hypothetical drug-testing issue. Respondents were told that medical researchers want to determine the efficacy of a given drug, and they were asked to determine whether the best information would be obtained by asking the patient, using the biochemical knowledge of the physicians, or conducting an experiment. The experiment response was coded as correct, and 38% of Japanese adults provided a correct response.

To build a single indicator of the understanding of the logic of an experiment, respondents who reported clear understanding or some understanding of the meaning of a scientific study and selected the experiment option in the drug-assessment question were recorded as having at least a minimally acceptable understanding of experimentation. Approximately 18% of Japanese adults qualified in the 1991 study.

The second item loaded on the understanding of the scientific inquiry factor was an item concerning probability. The Japanese study designers modified the probability question on inherited illness which was used in Europe and the United States to a plant genetics question, using an example concerning red and white flowers. It was felt that younger Japanese respondents who finished school in the last 20 years were more likely to encounter probability concepts in the context of plant genetics than drug testing. The question used four probes that were structured similarly to the probability question in the U.S. studies. Approximately 20% of Japanese adults in the 1991 study were able to provide the equal probability response and to reject the three incorrect responses.

Following the same procedure utilized in the other analyses, a simple typology was constructed to categorize the level of understanding of the nature of scientific inquiry. Japanese respondents who qualified as understanding both experimentation and probability were classified as understanding the nature of scientific inquiry. Only 5% of Japanese adults met this standard in 1991. This is a surprisingly low result since 18% understood experimentation and 20% understood probability. The polychoric [10] correlation coefficient for the relationship between the two variables is .21. It is unclear from the limited Japanese data set whether this second dimension would have been estimated differently if additional process-oriented questions or open-ended items had been used.

The 1989 Canadian study included an open-ended question concerning the meaning of *scientific study* identical to the question used

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[10] A polychoric correlation coefficient reflects the relationship between two ordinal variables, assuming that each ordinal variable is a crude measurement of an underlying continuous variable (Jöreskog and Sörbom 1993).

in U.S. surveys, as well as Miller's question on the scientific or non-scientific basis of astrology used in his earlier estimates of civic scientific literacy. The coding utilized categories that could be collapsed into a metric comparable to that used in the U.S. Respondents who were able to provide an acceptable explanation of scientific study and who understood that astrology is not at all scientific were classified as having a minimally acceptable understanding of the nature of scientific inquiry. Approximately 8% of Canadians met this standard.

Confirming the Basic Structure

The relationship between the construct vocabulary and the process understanding dimensions indicates that these two measures should be positively correlated. The essential issue is whether sufficient differentiation exists to merit treatment as two dimensions. A set of confirmatory factor analyses examined the item loadings on construct vocabulary and the process understanding dimensions as well as the relationship between the two factors.

A confirmatory factor analysis for the European Union found two clear factors in the 1992 data. Nine construct vocabulary items loaded on one factor, and three process understanding variables loaded on a second factor (see Table 18). The two factors were correlated at .87, indicating that they are related, but separable for analytic purposes.

A confirmatory factor analysis of the U.S. data found two clear factors, with nine items loading on a construct vocabulary dimension and three items loading on a process understanding factor (see Table 19). The two factors were correlated at .86, virtually identical to the European Union pattern.

Despite differences in both wording and format, a confirmatory factor analysis of the 1991 Japanese data found a similar two-factor structure (see Table 20). One factor was composed of five construct vocabulary items, and the second factor included two process understanding items. The two factors were correlated at .88, identical to the European and the U.S. results.

A confirmatory factor analysis of the 1989 Canadian data found the same two-factor pattern (see Table 21). Nine construct vocabulary items defined one factor; two process understanding items composed the second factor. The two factors were correlated at .90, virtually indistinguishable from the three previous patterns.

These four sets of factor patterns suggest that a common structure to civic scientific literacy exists in industrialized countries. Despite differences in the number of items, the use of open-ended and close-ended items, and some variation in wording, a nearly identical structure emerged in each analysis. The evidence for two correlated, but analytically separable, factors is strong.

Computing the Results

It is useful to create a single estimator of the level of civic scientific literacy based on the two-dimensional model, having found a common factor structure. Individuals who demonstrate a high level of understanding on both the vocabulary and process dimensions are assumed to be the most capable of acquiring and comprehending information about a science or technology policy controversy. These individuals are referred to as well informed, or civic scientifically literate.

Individuals who either demonstrate an adequate vocabulary of scientific constructs or display an acceptable level of understanding of the nature of scientific inquiry, but not both, are assumed to be somewhat less capable of understanding information about a science or technology policy dispute. They are referred to as moderately well informed or partially civic scientifically literate.

European respondents who earned a score of 67 or more and who demonstrated at least a minimally acceptable level of understanding of the nature of scientific inquiry were classified as well informed. Individuals who qualified on one dimension, but not the other, were classified as moderately well informed. Five percent of European adults qualified as well informed while an additional 22% were moderately well informed. Interestingly, within Europe, the percentage of civic scientifically literate adults ranged from 10% in Britain to 1% in Portugal. In contrast, 12% of U.S. adults qualified as well informed and approximately 25% qualified as moderately well informed (see Table 23).

Japanese adults with a score of 60 or higher and with a minimal understanding of the nature of scientific inquiry were classified as well informed. Approximately 3% of Japanese adults were well informed and an additional 22% were classified as moderately well informed.

Canadian respondents who scored 67 or higher and who were able to demonstrate a minimal understanding of the nature of scientific inquiry were classified as well informed. Only 4% of

TABLE 23
Percentage of Adults Estimated to be Civic Scientifically Literate by Education, Gender, and Age

Civic Scientifically Literate Adults	European Union	United States	Japan	Canada
All Adults 18 and Over	$5/22_{(12,147)}$	$12/25_{(2,006)}$	$3/22_{(1,457)}$	$4/17_{(2,000)}$
LEVEL OF EDUCATION				
Less than Secondary School	$1/10_{(3,324)}$	$1/8_{(387)}$	$2/11_{(433)}$	$1/9_{(1,143)}$
Secondary School Graduate	$4/22_{(6,103)}$	$8/28_{(1,228)}$	$2/25_{(701)}$	$4/23_{(651)}$
University Graduate	$11/37_{(2,712)}$	$35/33_{(392)}$	$7/30_{(323)}$	$21/40_{(206)}$
GENDER				
Female	$3/17_{(6,372)}$	$8/20_{(1,053)}$	$1/15_{(746)}$	$2/11_{(1,024)}$
Male	$7/27_{(5,775)}$	$16/30_{(953)}$	$6/29_{(711)}$	$6/23_{(976)}$
AGE				
18 to 29 years	$6/27_{(3,028)}$	$12/32_{(479)}$	$5/26_{(330)}$	$5/20_{(582)}$
30 to 39 years	$7/26_{(2,317)}$	$15/30_{(479)}$	$6/24_{(252)}$	$6/25_{(445)}$
40 to 49 years	$6/24_{(1,837)}$	$17/23_{(383)}$	$3/18_{(302)}$	$4/17_{(339)}$
50 to 64 years	$3/20_{(2,734)}$	$8/20_{(340)}$	$1/26_{(243)}$	$2/9_{(364)}$
65 years and over	$2/11_{(2,231)}$	$3/13_{(321)}$	$2/18_{(331)}$	$1/8_{(245)}$

% well informed or civic scientifically literate/% moderately well informed or partially civic scientifically literate
Number of Cases = ( )

Canadian adults were classified as well informed and an additional 17% were classified as moderately well informed.

Distribution of Civic Scientific Literacy

Having defined and measured civic scientific literacy, it is appropriate to examine its distribution according to education, gender, and age. An initial examination of the basic patterns of distribution indicates that the percentages of adults who qualified as moderately well informed, or partially civic scientifically literate, are similar in these four societies. The distribution pattern of those who were well informed, or civic scientifically literate, was different with the U.S. differential advantage clearly marked (more than twice the number of adults in Europe, more than three times those in Canada and four times those in Japan). A substantial variation exists, however, in the estimated levels of scientific literacy within education, gender, and age classifications and across the four sociopolitical systems (see Table 23).

University graduates are significantly more likely to qualify as civic scientifically literate in all four sociopolitical systems than individuals with fewer years of formal education. The university advantage is greatest in the United States and smallest in Japan (see Table 23).

This difference may be attributed to the structure of higher education. In the United States, universities generally require students to complete a core of liberal education courses, regardless of the intended academic major. An U.S. university graduate with a baccalaureate degree in history or literature would have completed college-level course work in science or mathematics as well as in social science. In contrast, many European systems and Japanese universities encourage students to focus course work in a single discipline or a narrow band of courses.

Men were at least twice as likely to qualify as civic scientifically literate than were women. The similarity of this difference across all four sociopolitical systems and cultures is striking.

Individuals 50 years old or older were significantly less likely to be scientifically literate than younger individuals. It is likely that this reflects differences in educational attainment within the four different sociopolitical systems.

It is important to recognize that the education, gender, and age factors are significantly related to each other. Traditionally, a smaller proportion of women have completed a university education than men, although the proportion is narrowing in all four societies, and women have been the majority of university graduates in the United States for nearly 20 years. In all four societies, a higher proportion of more recent generations have completed secondary education or entered a university than the proportion in earlier generations.

Structural equation models [11] were constructed and analyzed to assess the relative influence of each of these factors on the distribution of civic scientific literacy (see Appendix B). In these simple models, gender and age are treated as background variables that may influence the level of education attained (see Figures 2, 3, 4, and 5 and Table 24). Gender, age, and educational attainment are assumed to influence the level of an individual's civic scientific literacy. The path coefficients and the total effects may be compared

[11] A structural equation model is a set of regression equations that provides the best estimate for a set of relationships among several independent variables and one or more dependent variables. The program LISREL was used for all of the structural analyses presented in this monograph. This program allows the simultaneous examination of structural relationships and the modeling of measurement errors. For a more comprehensive discussion of structural equation models, see Hayduk (1987) and Jöreskog and Sörbom (1993).

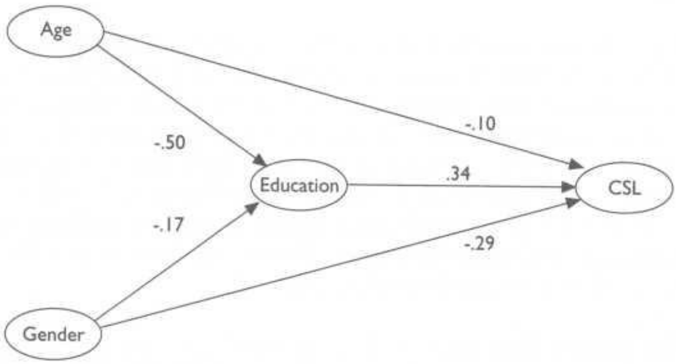

FIGURE 2:
A Path Model to Predict Civic Scientific Literary, European Union, 1992

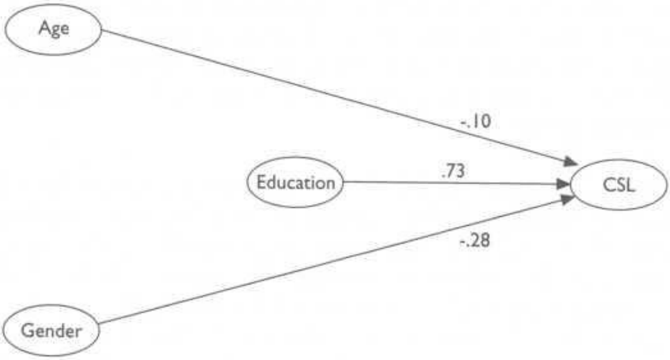

FIGURE 3:
A Path Model to Predict Civic Scientific Literary, United States, 1995

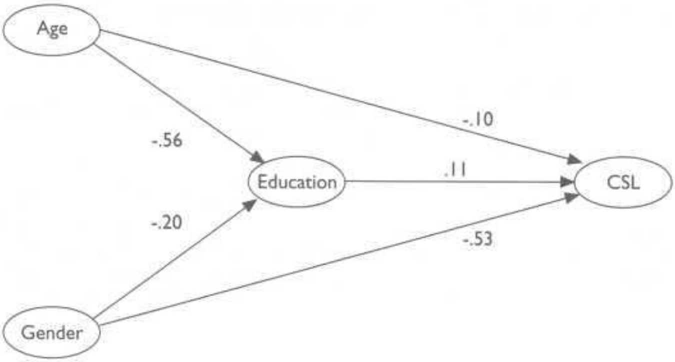

FIGURE 4:
A Path Model to Predict Civic Scientific Literary, Japan, 1991

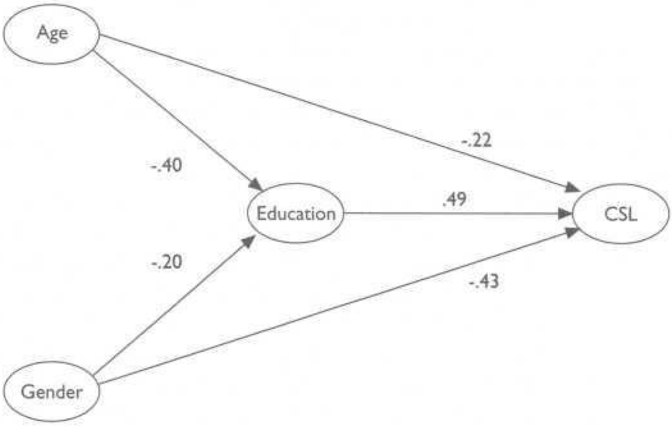

FIGURE 5:
A Path Model to Predict Civic Scientific Literary, Canada, 1989

TABLE 24
Total Effects of Age, Education, and Gender on the Prediction of Civic Scientific Literacy

Variable	Estimated Total Effect			
	Europe	United States	Japan	Canada
Level of Formal Education . . .	.34	.73	.11	.49
Gender (Female is Positive) . .	–.35	–.28	–.55	–.53
Age	–.27	–.10	–.16	–.42
Multiple R^2	.28	.64	.36	.63
Number of Cases	6,122	2,006	1,457	2,000

across the national models since these models were analyzed as four groups with a pooled variance and a common metric.

These models provide useful structural information about the distribution of education in these four societies. Education in the United States does not differ significantly by age, but negative paths exist from age to education in Europe, Japan, and Canada, holding constant differences due to gender. This pattern reflects the differential effect of World War II on the educational systems of Europe and Japan. Although the war interrupted and delayed formal education for young men in the United States, the educational infrastructure was not damaged, and post-war educational benefits for veterans opened doors of universities to a generation whose pre-war economic status would have made study at a university unlikely. The initiation of massive U.S. educational benefit programs 50 years ago impacted the educational opportunities of two generations of Americans. In contrast, the destruction of major cities in Europe and Japan had a substantial impact on the educational infrastructure, and neither Japan nor any European country offered a national program of post-war educational benefits comparable to the U.S. program. By the 1950's, the educational infrastructure and its teachers were fully restored, allowing most European countries and Japan to place a high priority on educational opportunities for that school-aged generation, in contrast to the previous generation, which contributes to the relatively strong negative path coefficients in Europe and Japan.

In the European, Japanese, and Canadian models, a negative path from gender to education indicates that men have been significantly more likely than women to attain higher levels of education, reflecting different educational expectations for women in these countries compared with U.S. expectations.

The absence of a significant path between gender and educational attainment in the United States indicates an increasingly strong commitment to equal access to post-secondary education for males and females in the post-war years. A slightly higher proportion of young women than young men have enrolled in and completed a baccalaureate degree program in the past 20 years. While the proportion of U.S. women enrolling in and completing college was markedly lower than men in the older age cohorts, the elimination of this differential in recent decades appears to have fully offset the disadvantage of earlier generations. It is surprising that no significant gender differentiation appeared in the U.S. model, given the strong focus of the post-war educational programs in the U.S. on male veterans.

The path coefficients are informative, but the strongest indictor of the influence of each of these variables is its estimated total effect. The total effect is computed by multiplying the coefficients in each path from an independent variable to the predicted variable. If multiple paths from an independent variable exist to the predicted variable, the effects of the separate paths are summed into a single estimate of the total effect (Hayduk 1987; Jöreskog and Sörbom 1993).

In the United States, educational attainment is the strongest predictor of civic scientific literacy, but gender is the strongest predictor in Europe, Japan, and Canada (see Table 24). It appears that the scope of student exposure to college-level science courses in the United States compensates for weaker pre-collegiate programs, and may provide an advantage relative to the other national groups included in this analysis. This is surprising, given the performance of U.S. students in international science assessments over the last 30 years.

The influence of age and gender on scientific literacy differs by society. In all four models, a residual negative path from gender to scientific literacy indicates that men were significantly more likely to be scientifically literate than women, holding constant differences in age and education. This is consistent with research indicating that women have traditionally taken fewer science and mathematics courses and have been less likely to pursue scientific and engineering careers (Ormerod and Duckworth 1975; Tobias 1978; Harding 1981; Weis 1988; Chipman, Brush and Wilson 1985; Fennema and Leder 1990).

A small, but significant, residual negative path from age to scientific literacy exists in all four models. These paths reflect that individuals who had not studied science for a number of years were less likely to retain a sufficient level of understanding to qualify as civic scientifically literate, or that recent generations of students have been exposed to more science, and more current science, than earlier generations. It is likely that this result reflects a combination of these factors.

In Europe, Japan, and Canada, the combined total effects of age and gender are greater than the total effect attributable to education. In the United States, the total effect of educational attainment is substantially greater than the combined effects of age and gender. It appears that the post-war emphasis on expanding educational opportunities in the United States, ranging from the veterans-educational programs in the 1940's and 1950's through the gender equity provisions of Title IX, combined to generate real structural change.

It is useful to conclude with a review of the fit of the combined model and its four component national models. In terms of fit, the total model met all of the required parameters (see Table 24). The amount of variance in scientific literacy explained by each of the four models differed significantly, with the multiple R^2 ranging from .64 for the U.S. model and .63 for the Canadian model to .28 for the European model. The multiple R^2 for the Japanese model was .36. The fit in the European and Japanese models may have been reduced for methodological reasons. The absence of open-ended knowledge questions in the European and Japanese studies reduced the quality of the measure of civic scientific literacy. The practice of using a respondent's age at end of full-time study as the measure of educational attainment in the Eurobarometer reduces the quality of that indicator. This result emphasizes that high-quality cross-national research requires a commitment to measurement accuracy in both independent and dependent variables.

CHAPTER IV

PUBLIC PARTICIPATION IN FORMULATING SCIENCE POLICY

The low proportion of civic scientific literacy in Europe, the U.S., Japan, and Canada raises the question of how the public participates in formulating science and technology policy. If the number of civic scientifically literate citizens increased, what changes might be expected in the public's role in formulating policy and resolving disputes in science and technology policy? An exploration of citizen participation in the political systems in modern industrial societies over the last 50 years and the growing impact of political specialization in these systems provide a useful framework for understanding the formulation of science policy in democratic political systems.

Political Specialization

Politics and public affairs compete with demands from work, family, friends, and other social and political activities for citizens in industrialized nations. These pressures continue to increase, as discussed in Chapter I. The evidence suggests that interest in politics, measured by the proportion of adults who take the time to vote in national and local elections, has declined in many countries (Kaase and Nelson 1995; Verba, Schlozman and Brady 1995).

However, scientific and technological issues compete relatively well for the attention of citizens in Europe, the United States, and Canada, and slightly less well among Japanese adults. Economic issues are often viewed as the central focus of public concerns, although the analysis in Chapter II revealed that a higher proportion of citizens in the United States, Japan, and Canada reported interest in environmental and health issues than economic issues (see Table 16). This is reflected in the popularity of science television shows, science magazines, and health and environmental reporting in newspapers.

Interest in an issue is a prerequisite for effective citizen participation, but only one consideration. A landmark study of public participation in formulating U.S. foreign policy argues that it is necessary for citizens to feel that they are reasonably well informed and that they are continuing consumers of relevant news and information (Almond 1950). Citizens are significantly more likely to act by voting, contacting a legislator or government official, or engaging in political meetings or activities in pursuit of a particular policy when they have a high level of interest in an issue, feel reasonably well informed, and follow the issues in the news (Rosenau 1974).

The proportion of adults in every country who report interest in a public policy issue is far greater than the proportion who report that they are well informed about the issue. Adults who feel well informed are more inclined to participate in public policy debates. This conclusion is based on national studies in Europe, the U.S., Japan, and Canada in which respondents assessed their knowledge as *very well informed, moderately well informed* or *poorly informed.* The perception of not being well informed appears to deter individuals from engaging in overt efforts to influence public policy through writing a letter to, or personally contacting, a public official. The actual level of knowledge, which may differ from an individual's self-assessment, also contributes to the likelihood of overt efforts, especially during non-crisis periods (Ressmeyer 1994).

In this stratified model, citizens with a high level of interest in an issue and a sense of being well informed about that issue are referred to as the *attentive public.* Most citizens who follow public policy issues tend to become attentive to two or three issues, creating an attentive public for almost every issue. Citizens who are attentive to a particular area tend to acquire information and stay informed about that issue on a continuing basis. Attentive citizens tend to understand policy issues and are better able to receive and process new information, although it is a rare for a citizen to be attentive to four or more issues.

A Stratified Model of Formulating Public Policy

Scientific and technological issues, to a large extent, are resolved outside the electoral process. Few candidates for national office win or lose on an issue of science or technology policy. Elected officials have the final authority to make binding decisions, but they are rarely elected on the basis of a commitment to a specific science or technology policy. How, then, does the specialization process affect formulating public policy and resolving disputes?

A pyramidal structure illustrates the types of public participation that are likely to occur under conditions of issue specialization in the policy formulation process on issues at the federal government level of the United States (Almond 1950). In this stratified model, decision-makers are at the pinnacle of the system with the power to make binding decisions on policy matters (see Figure 6). For science and technology policy in the U.S., this group includes a mix of federal-level executive, legislative, and judicial officials. In the unitary parliamentary systems common in Europe, Japan, and Canada, the decision-makers include the Prime Minister, relevant cabinet officials, and relevant committee chairs and members, when a substantive legislative committee structure exists.

FIGURE 6:
A Stratified Model of Policy Formation

The second level of the system consists of a group of non-governmental policy leaders. This group includes leading scientists and engineers, leaders of major corporations active in science and engineering, leaders of scientific and professional societies, the presidents and deans of major research universities, the members of the national academies of science or engineering and various business and academic leaders interested in science and technology matters, as well as leaders of consumer and labor organizations and leaders of the Green political parties and associations in Europe. Policy leaders move into decision-making positions and decision-makers move into policy leadership from time-to-time (Rosenau 1961, 1963, 1974).

When decision-makers and policy leaders concur, policy is formed, and little public participation is sought. At least 90% of all science and technology policy decisions in industrial societies are made through this concurrence system. A division of views within the policy leadership group, or between the policy leaders and the decision-makers, often results in appeals to the attentive public to influence decision-makers primarily by direct contact and personal persuasion, but sometimes employing other forms of communication, including demonstrations and boycotts. Traditionally, policy making has been a legislative process. However, in recent decades some private organizations have gained access to the elaboration and implementation process of specific policies, in return for ensuring the compliance with these policies among their members. As the neocorporatist literature has pointed out, organized interest groups, mainly business associations and labor unions, and more recently consumer and Green organizations, have increased their involvement in this kind of policy-making (Lehmbruch and Schmitter, 1982; Streeck and Schmitter, 1985). The development of science and technology policies, particularly in sensitive areas, might be a candidate for the formal participation of diverse interest groups.

The attentive public, the third level of the model, is composed of individuals who are interested in an issue area, report that they are very well informed, and are regular readers of daily newspapers or magazines. The attentive public in the United States, Britain, and Canada is composed of better educated citizens who have completed some courses in science and who may have a professional or occupational relationship to science and technology policy while in France, Germany, and other European countries, the attentive public includes many of the same characteristics, but also includes individuals motivated by consumer or Green interests. While Green party members have entered electoral contests and won legislative seats in several European countries and in the European Parliament, these citizens appear less comfortable with traditional lobbying approaches. It will be important to study how new entrants into the attentive public for science and technology policy seek to influence decision-makers in the early decades of the 21^{st} century and whether these newer approaches have an impact on the lobbying activities of other interest groups.

It appears that most policy leaders appeal to the attentive public through professional organizations, newspapers, television news talk and discussion shows, specialized magazines and journals, and employment-related institutions, although the process by which the leadership group mobilizes the attentive public has not been well studied except in foreign policy. The attentive public contacts public officials through letter-writing, telephone calls, and personal visits. The growth of e-mail use and communication on the Web suggests that the Internet may become another important method, particularly among better-educated citizens. These new technologies may be especially appealing to younger consumers and environmental activists.

Citizens with a high level of interest in a issue area, but who do not think they are well informed, are classified as the *interested public*. Persons in this group display a high level of information consumption on an issue but are less likely to participate in the political process due to their perception that they are not well informed. Individuals may become attentive during a particular controversy, such as a local siting dispute, if they become convinced that they know enough about the issue. However, in the case of the explosion of the shuttle *Challenger*, few members of the interested public for space exploration became members of the attentive public despite six months of hearings and investigations and extensive media coverage (Miller 1987b).

At the bottom of the pyramid is the non-attentive, or residual, public. Individuals in this group display a low level of interest in, or knowledge about, a specific policy area. Two points about this group are important. First, those in this population retain a political veto if they disagree with the policies fostered by decision-makers, policy leaders, and the attentive public. The American public's role in ending the wars in Korea and Vietnam illustrates the power of this veto. Second, non-attentiveness to a specific policy area should not be equated with ignorance or a lack of intellectual activity. Many people who are not attentive to one issue area may be interested in and knowledgeable about other issues.

Important commonalties exist among sociopolitical systems, including the need to develop science and technology policies that support and sustain a competitive position in the global economy and that help to protect the natural environment. This stratified model of policy formulation primarily reflects the U.S. political system. Substantial differences exist between the U.S. and the parliamentary political systems as well as among national political systems in regard to political parties, selection of legislators, and roles of legislative committees (Copeland and Patterson 1994; Lane and Ersson 1996).

The Attentive Public for Science and Technology Policy

The Almond model was used by Miller and others to define and describe an attentive public for science and technology policy in the United States (Miller 1983a, 1983b). The Miller and Prewitt measure of attentiveness to science and technology policy was based on respondent reports, beginning in 1979, of interest in, and self-assessed knowledge about, issues about new scientific discoveries and issues about the use of new inventions and technologies as well as a measure of persistence in consuming relevant information (Miller, Prewitt and Pearson 1980). An assessment of the attentive public in various sociopolitical systems can be made because identical, or comparable, items were asked in the Eurobarometer, and Japanese and Canadian studies.

Approximately one in 10 adults in Europe, the United States, and Canada qualified as attentive to science and technology policy, compared with about 7% in Japan (see Table 25). Science and technology policy decisions may be influenced by interested, informed, and concerned citizens and groups in all sociopolitical systems. The ability for attentive citizens to influence policy may be greater in competitive multi-party systems than in *de facto* one-party systems.

The Structure and Distribution of Attentiveness

The aggregate proportion of citizens attentive to science and technology policy in each of these four sociopolitical systems is important. In Europe, one in 10 adults were attentive to the issues. Better-educated citizens were more likely to qualify as attentive to science and technology policy issues than less well-educated citizens. The ordinal measure of association *gamma* (a proportional reduction in error statistic) for the relationship between the level of education and attentiveness to science and technology policy was .32, indicating that this bivariate relationship accounts for approximately 32% of the total variation between the two (Goodman and Kruskal 1954; Costner 1965). Civic scientifically literate Europeans were more likely to be attentive to science and techology policy than other citizens (gamma between civic scientific literacy and attentiveness = .36). In contrast to the United States and Canada, younger Europeans were slightly more likely to be attentive to science and technology issues than older citizens (gamma between age and attentiveness = –.13).

In the United States, which has a weak party system and strong legislative committees, the results from the 1995 study indicate that approximately 10% of American adults were attentive to science and technology policy, and that an additional 47% were interested in science and technology issues. Individuals in the U.S. with more years of formal schooling were significantly more likely to be attentive to science and technology policy, with one in five college graduates qualifying as attentive and an additional 53% reporting a high level of interest in these issues (gamma between

TABLE 25
Percentage of Adults Attentive to, or Interested in, Science and Technology Policy

Variable	% Adults Attentive to, or Interested in, Science and Technology Policy							
	Europe		United States		Japan		Canada	
	A*	I*	A	I	A	I	A	I
All Adults	10	33	10	47	7	12	11	40
EDUCATION								
Less than High School	5	25	4	37	1	8	9	37
High School Graduate	9	33	8	48	7	13	11	45
Baccalaureate	18	40	21	53	14	15	19	46
GAMMA =	.32		.37		.38		.22	
GENDER								
Female	7	30	8	45	2	10	7	47
Male	13	36	12	49	12	15	14	44
GAMMA =	-.23		-.17		-.48		-.28	
AGE								
18 through 29 Years	13	35	7	52	8	13	8	38
30 through 39 Years	10	36	12	48	12	11	14	41
40 through 49 Years	10	35	11	47	7	13	10	46
50 through 64 Years	9	32	9	47	7	16	11	46
65 Years or More	8	25	10	40	2	9	10	28
GAMMA =	-.13		-.05		-.14		.02	
CIVIC SCIENTIFIC LITERACY								
Well Informed	18	45	29	55	40	26	26	42
Moderately Well Informed	14	39	14	51	12	21	16	44
Not Well Informed	7	27	7	45	4	9	8	40
GAMMA =	.36		.36		.56		.27	
Number of Cases =	1,226	3,971	195	946	101	177	209	809

* A = Attentive to; I = Interested in

education and attentiveness = .32). The level of civic scientifically literacy displayed the second strongest bivariate relationship with attentiveness in the U.S. data (gamma = .36), with 29% of civic scientific literate Americans qualifying as attentive to science and technology policy. Men in the U.S. were more likely to be attentive than women, although no pattern of attentiveness is related to age. The gamma for the relationship between gender and attentiveness was –.17, indicating that men were slightly more likely to be attentive to science and technology policy issues than women. The gamma for the relationship between age and attentiveness to science and technology policy was –.05, which indicates that these two variables are essentially unrelated in this bivariate relationship.

In Japan, 7% of adults qualified as attentive to science and technology policy. An additional 12% of Japanese adults met the criteria for the interested public for science and technology policy. This lower level of attentiveness appears to be a reflection of Japanese political and social systems rather than a measurement problem. As discussed in Chapter II, a modified scale was used in response to the four-level response in the 1991 study. For similar reasons, Japanese respondents who indicated that they were very knowledgeable or moderately knowledgeable about new scientific discoveries or new inventions and technologies were classified as meeting the criterion for feeling adequately informed about an issue. There may be a methodological bias resulting in a slight overestimate of the level of attentiveness to science and technology policy among Japanese respondents.

In Canada, the pattern of attentiveness to science and technology policy was similar to that found for the United States. Approximately 19% of college graduates were attentive to science and technology policy (gamma between education and attentiveness = .22). In the 1989 study, 25% of Canadians who qualified as civic scientifically literate were attentive to science and technology policy (gamma between civic scientific literacy and attentiveness = .27). Canadian men were twice as likely to be attentive to science and technology policy (gamma between gender and attentiveness = –.28). Although there was no association between age and attentiveness in Canada, it is interesting to note that the lowest rates of attentiveness to science and technology policy in both Canada and the United States were among citizens from 18 to 29 years old.

A Structural Analysis of Attentiveness

It is useful to examine the structure of the relationship of age, education, gender, and civic scientific literacy to attentiveness. Historic patterns of association among age, education, and gender demonstrate variation across political and social systems. The structural location of attentiveness is important when examining overall and policy attitudes in Chapter V.

The basic structural model for the United States has a multiple R^2 of only .37, indicating that variables not included in this model are needed to understand the development and distribution of attentiveness to science and technology policy (see Table 26). Measures of an individual's sense of political efficacy, prior experience with the political system, and competing time demands contribute to the predictive power of the system (Almond and Verba 1963, 1980; Verba and Nie 1972; Rosenau 1974; Verba, Nie and Kim 1978; Miller 1983a; Verba, Schlozman and Brady 1995). For that portion of the variance in attentiveness predicted by this model, the levels of education and civic scientific literacy are the strongest predictors, with total effects of .49 and .58 respectively, suggesting that issue attentiveness is content driven (see Figure 7 and Table 26). Holding constant age, education, and civic scientific literacy, men in the U.S. were slightly more likely to be attentive to science and technology policy than women (total effect = –.08).

TABLE 26
Effect of Age, Education, Gender, and Civic Scientific Literacy on Prediction of Attentiveness to Science and Technology Policy

Variable	Estimated total Effect			
	United States	Europe	Japan	Canada
Age	.22	–.26	–.16	.35
Gender (Female is Positive) . . .	–.08	–.25	–.41	–.16
Education	.49	.13	.29	.38
Civic Scientific Literacy	.58	.26	.40	.48
Multiple R^2	.37	.20	.39	.32
Number of Cases	2,006	6,122	1,451	1,974
χ^2 = 42.4/43 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .00; Upper limit of the 90% confidence interval of RMSEA = .011				

In the European Union, the structural model accounted for only 20% of the total variance in attentiveness, indicating that important explanatory factors were omitted from this demographic model. For that portion of the variance predicted by the model, attentiveness among Europeans was moderately associated with gender, education, and the level of civic scientific literacy (see Figure 8 and Table 26). Holding the other components of the model constant, younger Europeans were slightly more likely to be attentive to science and technology policy than older respondents (total effect = –.26), and men were more likely to be attentive than women (total effect = –.23). As in the United States, the combined total effects of education and civic scientific literacy suggest that issue attentiveness is rooted in substantive concerns.

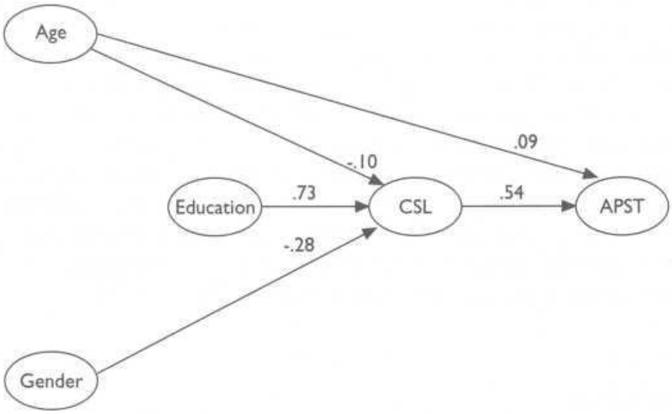

FIGURE 7:
A Path Model to Predict Attentiveness to Science and Technology Policy, European Union, 1992

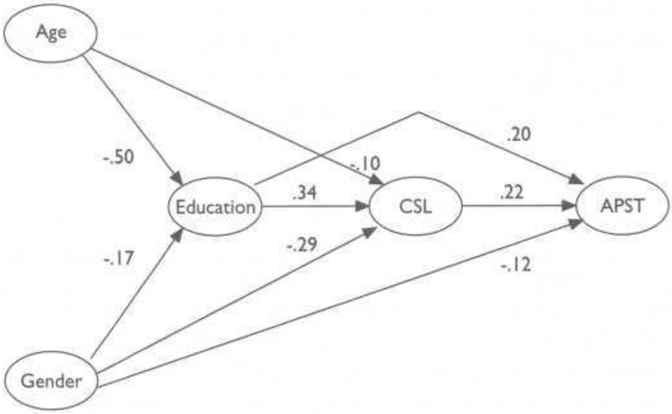

FIGURE 8:
A Path Model to Predict Attentiveness to Science and Technology Policy, United States, 1995

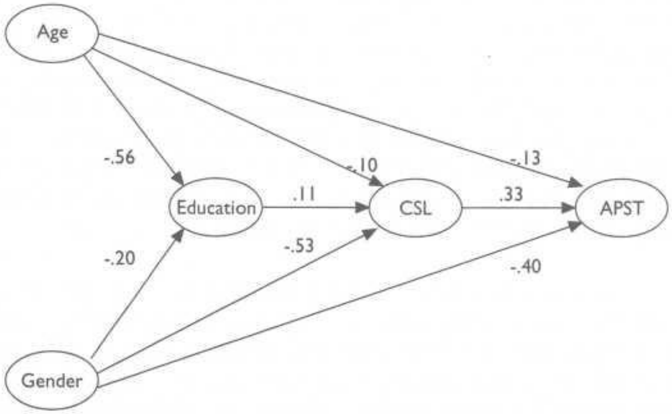

FIGURE 9:
A Path Model to Predict Attentiveness to Science and Technology Policy, Japan, 1991

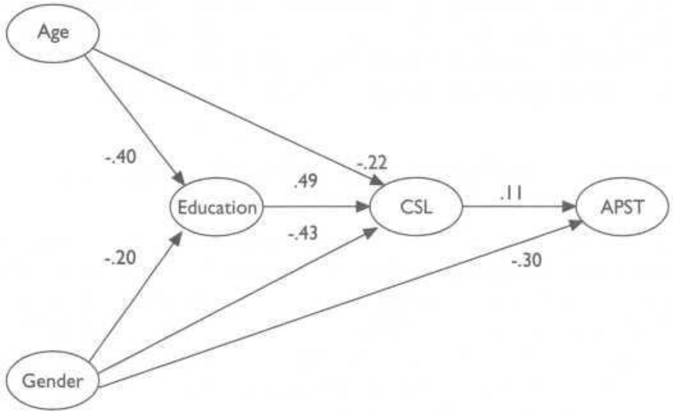

FIGURE 10:
A Path Model to Predict Attentiveness to Science and Technology Policy, Canada, 1989

The structural model for Japan was the best fitting model of the four analyses, accounting for 39% of the total variance in attentiveness (see Table 26). Even with this fit, variables associated with the development of attentiveness to science and technology policy were obviously omitted from this basic demographic model. For that portion of the variance accounted for by the model, the strongest total effects were associated with gender (total effect = –.41) and the level of civic scientific literacy (total effect = .40), holding constant the other factors in the model (see Figure 9 and Table 26). Younger Japanese citizens were somewhat more likely to be attentive than older individuals (total effect = –.16).

In Canada, the structural model accounted for only 32% of the total variance in attentiveness to science and technology policy (see Table 26), indicating that this simple demographic model excluded the major factors associated with the development of attentiveness to science and technology policy. Within the portion of variance explained, civic scientific literacy was the dominant factor (total effect = .48), indicating that Canadians who have a better understanding of science are more likely to be attentive to science and technology issues than citizens with a weaker scientific understanding (see Figure 10 and Table 26).

Comparing these structural models, the level of civic scientific literacy is positively associated with attentiveness to science and technology policy in the analysis of all four sociopolitical systems, although this relationship is weakest in Europe. Interestingly, all the studies showed that men were significantly more likely to be attentive to science and technology policy than women, indicating a pervasive social stereotyping of science and technology.

The Role and Importance of Attentive Publics

At the end of the 20th century, people encounter science and technology in multiple contexts, from work to entertainment, from health care to information-seeking and education. Usually the presence of science and technology in these domains is taken for granted, and the individuals are able to formulate demands or to support programs and policies in their roles as workers, consumers, parents, and citizens. They do not need to pay explicit attention to science and technology, much less to specific policies and decisions regarding science and technology.

Not even the segment of the public we have labeled attentive to science and technology formulates the national policy agenda or plays a significant role in the daily negotiation of public policy relevant to science and technology. But, from time to time, crises, breakdowns, and conflicts in the system emerge, and in those situations, one of whose central characteristics is open controversy between leaders or decision-makers, the public can gain a voice. Different leaders seek to enhance the support for their positions by appealing to the public attentive to the issue at hand and by attempting to mobilize public opinion. Like wars, these conflicts do not happen often, but when they do, they are likely to revolve around the most important issues in the science and technology arena, and certainly the most difficult and controversial. Almond has compared the role of an attentive public to reserve units in the military (Miller 1983a).

When an issue or controversy cannot be resolved at the leadership level, it is essential that there be a sufficient number of citizens attentive to the area and able to comprehend the debates among the leaders about the issue. While it appears that attentive citizens need to think of themselves as well informed in order to intervene in a policy debate via letters, direct contact, or other forms of political action, it is important that these citizens are familiar with science and technology, are civic scientifically literate, and can follow and evaluate the major competing arguments about an issue and contribute to shaping the decision-making process.

In addition, in virtually all advanced and pluralistic societies, a growing number of single-issue groups related to general dimensions of science and technological practices and impacts have emerged in recent decades, from environmentalists to animal rights groups, consumer associations, and individuals with life-threatening medical conditions. The enhancement of the quality and substance of democracy in the complex societies of the last part of the 20th century requires that such groups of concerned citizens gain a voice in the policy-making process of science and technology, instead of opting for a confrontational or an alienated position (Hirschman 1970). This emphasizes the importance of a scientifically literate attentive public for science and technology policy.

CHAPTER V

PUBLIC ATTITUDES TOWARD SCIENCE AND TECHNOLOGY

The attitudes of citizens toward science and technology are an important dimension of advanced democratic societies. While citizens are rarely asked to make decisions on scientific or technological issues, an increasing number of public policies involving scientific or technological issues are decided by governments. In some political systems, these decisions may be made entirely within a cabinet or parliamentary committee, with moderate media coverage and virtually no public discussion. In other political systems, legislative committees may hold public hearings on issues, with extensive media coverage of the policy discussions. This chapter focuses primarily on the substantive attitudes held by citizens toward science and technology and secondarily on the specific issue of public support for government spending on basic research within the sociopolitical systems.

The Search for Structure

It is important to determine whether a structure exists for the attitudes reflected in the national studies and whether sets of questions form statistically consistent scales, or indices, to facilitate and enhance comparative attitude analysis. A description of the general approach to the analysis of these data will assist readers who have varying statistical and quantitative backgrounds.

It is important to utilize cognitive science and social psychology literature for building the theoretical framework used in the analysis of public attitudes toward science and technology. Cognitive science research shows that individuals, when faced with a daily barrage of complex information of different types and from different sources, rely on schemas to filter, structure, and interpret the meaning of that information.

Many of the schemas are learned and transmitted through everyday influences such as family, school, business, and the media. Other schemas are embedded in the culture of a society or are considered common sense. Specialized schemas are specific to professional problem solving (medical doctors, lawyers, engineers). All individuals develop and adapt the received schemas of their particular society to their own personal circumstances, experiences, and social relations network.

Schemas are important because people tend to organize information neither in a logically deductive manner nor in an atomistic (bit-by-bit) way, but in large frames of information (Minsky 1986). Focused frames of information about objects, issues, or situations contain slots that accommodate individual pieces of information. The connections between these do not follow the classical logical principles. Common-sense knowledge in a culture consists of a large number of such frames. Scripts fulfill a similar function for dealing with stereotypical situations and actions in everyday life (Schank 1977; Minsky 1986; Lau and Sears 1986; Milburn 1991; Pick, van den Droek and Knill 1992).

Schemas are latent constructs referring to coupled sets of attitudes and understandings of science and technology. Schemas articulate a cognitive and an affective or evaluative dimension of the activities, content, outputs, and symbols associated with science and technology. Consistency in observed social behavior is a function of the presence of the schemas people apply in their decision-making: therefore, predicting behavior can be achieved by determining the presence or absence of certain schemas. Some individuals have developed schemas about science and technology reflected in their interests and civic scientific literacy while most people in a modern society have basic schemas for scientific and technological matters. Schemas are equivalent to attitudes, but assign more weight to the cognitive and structural dimensions. Accordingly, it is important to identify general schemas that may serve as a framework for choices when interpreting attitudes toward scientific or technological issues. An important aspect is the nature of the relationship between an individual's schema and his or her more specific policy preferences.

Confirmatory factor analyses are used to explore these structures. Cross-system comparisons of the four studies will determine whether it is possible to identify sets of attitudinal scales that can be meaningfully compared across political systems.

Ultimately, the analysis looks at the substantive content of those attitude scales that are comparable across political systems and seeks to explain the commonalties and differences found. A set of structural equation models helps in understanding relationships between attitudes and the relevant social and demographic characteristics of individual respondents.

European Union

Respondents were asked a wide array of attitudinal questions about science and technology policy issues in the Eurobarometer. An initial set of 14 attitude questions was selected to identify the questions that might comprise a schema for scientific and technological information. A series of confirmatory factor analyses demonstrated that a set of six items formed a unidimensional factor that identified a general attitude toward the promise for science and technology. The same series of confirmatory analyses revealed that a second factor of three items focused on reservations, or concerns, about the impact of science and technology (see Table 27).

The six attitude items, all offered in an agree-disagree format [12], appear to reflect a general attitude toward the promise for science and technology among European adults. These are:

> Thanks to science and technology, there will be more opportunities for the future generations.
>
> Science and technology are making our lives healthier, easier, and more comfortable.
>
> The benefits of science are greater than any harmful effects it may have.
>
> Most scientists want to work on things that will make life better for the average person.
>
> Scientific and technological progress will help to cure illnesses such as AIDS and cancer.
>
> The application of science and new technology will make work more interesting.

---

[12] In the Eurobarometer, a methodological study was conducted on the effect of two alternative sets of response categories. A random half of the respondents were shown a card that included as choices *strongly agree, agree, neither agree nor disagree, disagree*, or *strongly disagree*. The other random half were shown a card that included as choices *strongly agree, agree, disagree*, or *strongly disagree*, which is the format used in studies in the United States since 1979. A response of *unsure* or *neither agree nor disagree* was recorded in this format, but not offered. For this analysis, the second set of choices (Form B) was used to assure greater comparability between the European Union and the United States, reducing the total number of cases included in the analysis to 6,122.

TABLE 27
Confirmatory Factor Analysis of Attitudes, European Union, 1992

Attitudes	Promise of Science Dimension	Reservation About Science Dimension	Proportion of Variance Explained
Thanks to science and technology, there will be more opportunities for the future generations . .	.61	–	.37
Science and technology are making our lives healthier, easier, and more comfortable	.58	–	.33
The benefits of science are greater than any harmful effects it may have	.57	–	.32
Most scientists want to work on things that will make life better for the average person	.51	–	.26
Scientific and technological progress will help to cure illnesses such as AIDS and cancer . . .	.51	–	.26
The application of science and new technology will make work more interesting	.51	–	.26
Science makes our way of life change too fast	–	.67	.45
We depend too much on science and not enough on faith . . .	–	.47	.22
Because of their knowledge, scientific researchers have a power that makes them dangerous .	–	.43	.19

χ^2 = 46.9/16 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .02;
Upper limit of the 90% confidence interval for RMSEA = .024; Factor 1 and Factor 2 are correlated at –.11;
Number of Cases = 6,122

The item was "I would like to read you some statements that people have made about science, technology, or the environment. For each statement, please tell me how much you agree or disagree (Show Card)".

These items, listed in the order of their loadings on the factor (see Table 27), reflect a mixture of current assessment and future promise. An individual who agrees with all six of these statements holds a positive attitude, or schema, toward the promise for science and technology. Likewise, an individual who disagrees with all or most of these statements holds a significantly less optimistic view, or schema, of the promise for science and technology.

Three items form a second dimension that is nearly independent of the first factor. The second factor includes items that expressed reservations about the impact of science and technology on individuals and on society. The three items loading on this factor are:

> Science makes our way of life change too fast.
>
> We depend too much on science and not enough on faith.
>
> Because of their knowledge, scientific researchers have a power that makes them dangerous.

An individual who agrees with all three statements holds reservations about the impact of science and technology on life and, perhaps, on personal or societal values.

Since the two factors are only weakly correlated, with a correlation of –.11, it is almost equally possible that individuals who score high on one dimension would score high or low on the other dimension. A larger negative correlation might have been expected, given the substantive content of the items on the two dimensions. This degree of independence suggests that many European adults believe in the promise of science and technology for themselves and their children, while expressing personal concerns about potential negative impacts of science and technology on traditional and religious values.

United States

Many of the items in the Eurobarometer have their roots in the Science Indicators studies. For 20 years, the National Science Foundation has posed attitudinal questions about science and technology policy issues and about people's perceptions of the impact of science and technology on their lives and on society. Recent Science Indicators studies incorporated items from the Eurobarometer and other studies.

A series of confirmatory factor analyses of the 1995 *Science and Engineering Indicators* data identified a two-factor structure similar to the European data pattern. The first factor included four items, each virtually identical to four of the six items found on the first European factor (see Tables 27 and 28). The four items are:

> Because of science and technology, there will be more opportunities for the next generations.
>
> Science and technology are making our lives healthier, easier, and more comfortable.
>
> Most scientists want to work on things that will make life better for the average person.
>
> With the application of science and new technology, work will become more interesting.

TABLE 28
Confirmatory Factor Analysis of Attitudes, United States, 1995

Attitudes	Promise of Science Dimension	Reservation About Science Dimension	Proportion of Variance Explained
Because of science and technology, there will be more opportunities for the next generation	.68	–	.47
Science and technology are making our lives healthier, easier, and more comfortable	.62	–	.38
Most scientists want to work on things that will make life better for the average person	.54	–	.29
With the application of science and new technology, work will become more interesting . . .	.53	–	.28
Science makes our way of life change too fast	–	.66	.44
On balance, the benefits of scientific research have outweighed the harmful results	–	–.60	.36
We depend too much on science and not enough on faith . . .	–	.51	.26
It is not important for me to know about science in my daily life .	–	.41	.17

χ^2 = 30.7/15 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .02;
Upper limit of the 90% confidence interval for RMSEA = .034; Factor 1 and Factor 2 are correlated at –.64;
Number of Cases = 2,006

The item was "I'm going to read you some statements such as those you might find in a newspaper or magazine article. For each statement, please tell me if you generally agree or generally disagree. If you feel especially strongly about a statement, please tell me that you strongly agree or strongly disagree".

The second factor was defined by four items, including a negative loading for one of the items. The four items included on this factor are

> Science makes our way of life change too fast.
>
> On balance, the benefits of scientific research have outweighed the harmful results (negatively correlated).
>
> We depend too much on science and not enough on faith.
>
> It is not important for me to know about science in my daily life.

Three of the four items included on this second factor form an Attitude Toward Organized Science Scale (ATOSS) used by Miller with results reported in *Science and Engineering Indicators* and other papers (U.S. National Science Board 1988, 1990, 1992, 1994, 1996; Miller 1995).

The pattern found in the 1995 United States data is consistent with the results from the 1992 Eurobarometer, with the first factor reflecting a belief in the promise of science and technology and a second factor reflecting concern with, or reservations about, potentially negative impacts from science and technology. In contrast to the European result, however, these two factors are strongly and negatively correlated in the U.S., with a correlation of –.64. This means that an individual with a high score on the first dimension is likely to have a low score on the second factor, and vice versa. Americans who believe in the promise of science and technology are less likely to have reservations or concerns about possible impacts, while individuals who have strong concerns about science and technology are less likely to recognize contemporary benefits or to have optimistic views for the promise of science and technology. This pattern points to a polarized attitude structure compared with Europe.

Japan

A series of confirmatory factor analyses of the Japanese study identified a two-factor structure similar to that found in Europe and the United States. The first factor included four items that expressed a belief in the promise of science, similar in content to the attitude factors found in the European Union and the U.S. (see Table 29). The four items are:

> With the application of science and new technology, work will become more interesting.
>
> Computers and factory automation will create more jobs than they will eliminate.
>
> Scientists are seeking to benefit human beings.
>
> The benefits of scientific research have outweighed any harmful results.

The context of three of the four items is similar although the question wording differs from the European and U.S. studies (the remaining item was not included in these studies). The common factor reflects respect for the intentions of scientists and a sense that scientists provide useful results and products for society. A strength of structural analysis is that it looks at attitudinal dimen-

TABLE 29
Confirmatory Factor Analysis of Attitudes, Japan, 1991

Attitudes	Promise of Science Dimension	Reservation About Science Dimension	Proportion of Variance Explained
With the application of science and new technology, work will become more interesting	.67	–	.45
Computers and factory automation will create more jobs than they will eliminate	.45	–	.21
Scientists are seeking to benefit human beings	.44	–	.19
The benefits of scientific research have outweighed any harmful results	.36	–.24	.15
Science makes our way of life change too fast	–	.76	.58
We depend too much on science and not enough on faith . . .	–	.64	.42
Because of their knowledge, scientific researchers have a power that makes them dangerous .	–	.26	.07

χ^2 = 13.5/9 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .02;
Upper limit of the 90% confidence interval for RMSEA = .038; Factor 1 and Factor 2 are correlated at –.22;
Number of Cases = 1,427

The item was "For each statement, please tell me if you strongly agree, agree, disagree, or strongly disagree".

sions that may be similar regardless of variations in the wording of the questions.

A second factor was defined by four items, including a negative loading for one of the items that loaded on the first dimension. This second dimension included items expressing concern about science and technology. The four items are:

> The benefits of scientific research have outweighed any harmful results (negatively correlated).
>
> Science makes our way of life change too fast.
>
> We depend too much on science and not enough on faith.
>
> Because of their knowledge, scientific researchers have a power that makes them dangerous.

The pattern found in the data is consistent with the results from Europe and the U.S. The first factor reflects a set of items worded in positive or optimistic terms and the second factor includes a set of items expressing concern with, or reservations about, science and technology. These two factors were weakly and negatively correlated in the Japanese data, with a correlation of –.22. This relationship means that an individual with a high score on the first dimension has an almost equal probability of having a low or a high score on the second factor, and vice versa.

Canada

In comparison with the other studies, the Canadian study included fewer attitude items. A series of confirmatory factor analyses found two dimensions in the Canadian data. Only two items loaded on a dimension reflecting the promise of science and technology (see Table 30) while four items loaded on a dimension reflecting concerns and reservations.

TABLE 30
Confirmatory Factor Analysis of Attitudes, Canada, 1989

Attitudes	Promise of Science Dimension	Reservation about Science Dimension	Proportion of Variance Explained
On balance, the benefits of scientific research have outweighed the harmful results	.68	–	.46
Science and technology are making our lives healthier, easier, and more comfortable	.27	–	.07
Science makes our way of life change too fast	–	.65	.42
We depend too much on science and not enough on faith . . .	–	.64	.41
It is not important for me to know about science in my daily life .	–	.40	.16
Because of their knowledge, scientists have a power that makes them dangerous.	–	.38	.14

χ^2 = 5.3/7 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .00;
Upper limit of the 90% confidence interval for RMSEA = .023; Factor 1 and Factor 2 are correlated at .59;
Number of Cases = 2,000

"For each statement, please tell me if you strongly agree, agree, disagree, or strongly disagree".

The two items reflecting the promise of science are:

> On balance, the benefits of scientific research have outweighed the harmful results.
>
> Science and technology are making our lives healthier, easier, and more comfortable.

The four items reflecting concerns and reservations are:

> Science makes our way of life change too fast.
>
> We depend too much on science and not enough on faith.
>
> It is not important for me to know about science in my daily life.
>
> Because of their knowledge, scientists have a power that makes them dangerous.

The two factors were correlated negatively at –.59, reflecting a polarity of views similar to those found in the United States.

Developing Schemas for Science and Technology

Schemas are essential in each individual's efforts to receive, organize, and make sense of the complex information available daily in the broadcast and print media of modern industrial and scientifically advanced societies. Some individuals are more skillful in constructing networks of concrete and abstract schemas than others. Psychologists often refer to these differences in information processing and utilization as mental ability (Sternberg 1985, 1988).

People have schemas for simple tasks (such as driving an automobile in traffic) and for complex or abstract tasks (such as understanding the impact of science on society). Schemas help individuals to act in normal or recurrent situations by filtering or channeling the information relevant for performing the required task efficiently. For example, when a driver sees lights in the form of an arrow, the driver will turn in that direction and may slow the vehicle to execute a turn safely without engaging in a lengthy, formal reasoning process. The observation of the lighted arrow activates prior experiences and knowledge, bringing into short-term memory a set of alternative explanations and associated behaviors.

Only novices who are in the process of acquiring or reinforcing schemas need to engage in a conscious train of thought before taking action, while experts, in the presence of certain data or a particular situation, activate the corresponding schema and respond immediately. To do otherwise would result in a loss in performance (Dreyfus and Dreyfus 1986). It is mainly in unexpected circumstances, like crises, breakdowns, malfunctions, or the emergence of radical innovations, that individuals are forced to make sense of a situation by engaging in active cognitive processes of problem-solving, and even backtracking to basic schemas.

Similarly, when an individual reads a news report about a new drug being tested on a large number of animals which significantly reduces the development of cancer, the information may be recognized as a scientific study, and one or more schema relevant to this subject may be activated. Although the report involves tests of a drug on animals, the individual may recognize that insights gained from animal studies may lead to studies with more advanced animals or with humans, ultimately resulting in a drug that might be useful to friends or family. If the individual holds a positive schema toward biomedical research, this report may be interpreted optimistically with an expectation of new medications and reinforcement that science produces things that make life healthier, easier, and more comfortable. Conversely, if an individual holds a negative schema toward science, other promising test reports that failed to produce major results may be recalled.

The factor patterns support the view that individuals hold two primary schemas toward science and technology. The first factor found in each study represents the promise of science and technology. Items in the factor reflect the judgment that science and technology have improved the quality of life, with the implicit assumption of continuation, or that future benefits are likely. The exact wording differs from study to study but results in the same attitudinal dimension a belief that science and technology provide, and will continue to provide, benefits to improve the quality of life.

The second factor found in each study represents reservations about science and technology. Items in the factor express concerns about the speed of change in modern life and a sense that science may, at times, pose conflicts with traditional values or belief systems. The wording and sometimes the items differ slightly, but this factor reflects a similar attitudinal reservation.

The cognitive science and social psychology literature on the formation and use of schemas indicates that it is reasonable to expect to find a full array of possible combinations of these two schemas.

Individuals may have a strong promise schema and a weak reservation schema, leading them to react positively to science news. Alternatively, individuals may have a weak promise schema and a strong reservation schema, leading them to react negatively to science news. Additionally, it is possible for an individual to have a strong positive schema and a strong negative schema, recognizing both the substantial promise of science and technology and the opportunities for substantial harm from scientific and, especially, technological activities. It is likely that many people have weak promise and weak reservation schemas, and fuzzy images about them (in the technical sense of fuzzy set theory), reflecting limited experience or information and given their minimal understanding of science and technology (Zadeh 1987).

The four national data sets provide an important opportunity to examine empirically the distribution of these two schemas. To provide a common metric for comparison, a factor score was computed for each schema on each of the four data sets. This score was then converted to a zero to 100 metric [13]. The large number of common items allows this simple conversion to retain the conceptual content of each dimension while expressing the results on a simpler, but comparable, metric.

A Positive Schema for Science and Technology

The mean score on the Index of Scientific Promise was 69 in the European Union, 68 in the United States, 55 in Japan, and 72 in Canada (see Table 31). The markedly lower level of public belief in the promise of science in Japan appears to be a reflection of a lower level of scientific optimism which is consistent with a lower level of optimism and satisfaction on the part of the Japanese in other areas of life rather than the results of measurement issues.

The level of belief in the promise of science and technology, in all four societies, is highest among citizens with a university education and lowest among citizens who did not complete secondary education. The association between belief in the promise of science and technology and the level of formal education was statistically significant only in Canada. The level of civic scientific literacy was positively associated with belief in the promise of science and technology in the U.S. (5 points of difference between the two extremes of civic scientific literacy), Japan (10 points of difference),

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[13] The conversion assigned a score of zero for the factor score reflecting the lowest level of agreement with a dimension and a score of 100 for the highest possible level of agreement with a dimension.

TABLE 31
Mean Scores on the Index of Scientific Promise

Variable	Scientific Promise Index			
	Europe	United States	Japan	Canada
All Adults	69	68	55	72
LEVEL OF FORMAL EDUCATION				
Completed Less than Secondary	68	63	54	68
Completed Secondary	69	68	55	75
Post Secondary	71	71	56	84
GENDER				
Female	68	67	54	68
Male	70	69	55	76
AGE				
18 through 29 Years	69	67	53	70
30 through 39 Years	69	69	53	74
40 through 49 Years	70	69	54	73
50 through 64 Years	71	69	56	75
65 or More Years	68	66	57	69
CIVIC SCIENTIFIC LITERACY				
Well Informed	70	72	64	84
Moderately Well Informed	69	69	58	80
Not Well Informed	69	67	54	69
ATTENTIVENESS TO SCIENCE AND TECHNOLOGY POLICY				
Attentive Public	74	74	56	79
Interested Public	72	69	59	74
Residual Public	67	65	54	69
Number of Cases	6,122	2,006	1,457	2,000

and Canada (15 points of difference). No significant difference existed among Europeans.

The attentive public in Europe, the U.S., and Canada expressed a stronger belief in the promise of science and technology than non-attentive citizens or the residual public. The difference in perceptions of promise between the two extremes of the scale of attentiveness were 7 points in Europe, 9 points in the U.S., and 10 points in Canada.

The European Union and North American results indicate a high level of societal optimism about the achievements and promises of science and technology. The distribution of the positive schema toward science and technology was normal in all four societies.

A Negative Schema for Science and Technology

The mean score on the Index of Scientific Reservation was 58 in the European Union, 39 in the United States, and 56 in Japan and Canada (see Table 32). In contrast to the distribution on the promise schema, this pattern suggests that the citizens of Europe, Japan, and Canada hold moderately high levels of reservation about the present and potential negative consequences of science and technology. The significantly lower level of reservation found in the United States is consistent with a literature pointing to 50 years of high optimism for, and low concern about, science and technology among Americans (Miller 1983a; Barke 1986; Hughes 1989; Teich 1990; U.S. National Science Board 1990, 1992, 1994, 1996).

In all four sociopolitical systems, individuals with the lowest levels of formal education expressed the highest levels of reservation about science and technology. Citizens with higher levels of civic scientific literacy reported significantly lower levels of reservation about science and technology than citizens not well informed about science. These relationships were strongest in the United States as was found with the Index of Scientific Promise. The differences in mean scores on the Index of Scientific Reservation for the two extremes of the scale of educational level were 11 points for Europe, 24 points for the U.S., 12 points for Japan, and 20 points for Canada.

In the U.S. and Canada, citizens who were attentive to science and technology policy reported significantly lower levels of reservation about the impact of science and technology than non-attentive citizens or the residual public (with a difference of 12 points for the U.S. and 14 points for Canada). In Europe and Japan, attentive and interested citizens were only slightly less concerned about the side effects and negative impact of science and technology than the residual public.

In all four societies, women were slightly more likely to hold reservations about science and technology than men. The margins of difference were small and most of these observed differences may be accounted for by differences in educational attainment.

TABLE 32
Mean Scores on the Index of Scientific Reservation

Variable	Scientific Promise Index			
	Europe	United States	Japan	Canada
All Adults	58	39	56	56
LEVEL OF FORMAL EDUCATION				
Completed Less than Secondary	64	51	62	60
Completed Secondary	57	39	55	52
Post Secondary	53	27	50	40
GENDER				
Female	60	40	57	58
Male	57	38	55	53
AGE				
18 through 29 Years	53	30	54	45
30 through 39 Years	55	38	52	54
40 through 49 Years	58	36	56	58
50 through 64 Years	62	39	58	60
65 or More Years	64	45	63	61
CIVIC SCIENTIFIC LITERACY				
Well Informed	46	24	45	39
Moderately Well Informed	55	30	55	45
Not Well Informed	62	42	56	59
ATTENTIVENESS TO SCIENCE AND TECHNOLOGY POLICY				
Attentive Public	57	30	54	45
Interested Public	57	38	52	54
Residual Public	60	42	57	59
Number of Cases	6,122	2,006	1,457	2,000

Links to Specific Policy Preferences

It is reasonable to expect that most people hold simultaneously one schema for the achievements and promise of science and technology and another schema for harmful and politically harmful results from science or technology, although these schemas do not necessarily carry an equal weight in all societies. To explore the role of these schemas in processing information and formulating specific policy attitudes, it is useful to examine the responses of individuals in all four sociopolitical systems to the statement [14] that [government]

[14] In the European, U.S., and Japanese studies, the same statement was used with a varying reference to government. In the U.S. study, the term *Federal Government* was inserted into the question, while a more generic reference to the national government was employed in the European and Japanese studies. In all three of these studies, the respondents were asked if they *strongly agreed, agreed, disagreed,* or *strongly disagreed* with the statement, and *don't know* or *not sure* responses were coded into a middle category, producing a five-category

"should provide support for basic scientific research even if it produces no immediate benefits". An overwhelming majority of adults supported the view that the national government should provide support for basic scientific research. The level of support was highest in Japan and Canada, with 86% and 88% of adults, respectively, indicating that they would like the government to provide, or continue to provide, support for basic scientific research (see Table 33). The support was 80% among Europeans and 78% in the U.S.

The level of formal education and the level of civic scientific literacy were positively associated with support for government funding of basic scientific research in all four societies. Citizens who were not interested in science and technology policy issues were the least supportive in all four sociopolitical systems. Men were slightly more likely to support government spending for basic scientific research than were women.

A set of structural equation models was constructed to explore the impact of the two schemas--promise in science and doubts about science--in developing and maintaining a specific policy preference in regard to government support for basic scientific research (see Figures 11, 12, 13, and 14). It is essential to examine the marginal impact of these schema in a multivariate context, taking into account the configuration of social and educational factors since these two schemas are the product of a complex set of demographic and educational factors.

The intervening relationships between the two schemas and attitudes toward government spending for basic scientific research illustrate important differences in the four societies. In Europe, a strong scientific promise schema was the most significant predictor of citizen approval of government spending for basic scientific research (see Figure 11 and Table 34). European adults favor government spending for research as a means of improving the quality of life. The level of reservation about the impact of science and technology is significantly higher among European adults than U.S. adults, but it is virtually unrelated to attitude toward government spending for scientific research. This is comparable to the

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ordinal variable. In the Canadian study, the question was not asked, but the study did ask Canadians if they thought that their national [federal] government was spending *too little*, *too much*, or *about the right amount* on basic scientific research, producing a three-category ordinal variable. The descriptive results reported in Table 33 include the *strongly agree* and *agree* responses in European, Japanese, and U.S. studies and the *about right* and *too little* responses in the Canadian study. In the structural equation analyses, all five-response categories were retained in the European, Japanese, and U.S. data, and all three categories were utilized in the Canadian data.

TABLE 33
Approval of Government Support for Basic Scientific and Technological Research

Variable	% Strongly Agreeing or Agreeing			
	Europe	United States	Japan	Canada
All Adults	80	78	86	88
LEVEL OF FORMAL EDUCATION				
Completed Less than Secondary	67	67	81	85
Completed Secondary	83	79	86	89
Post Secondary	89	87	93	98
GENDER				
Female	77	77	83	84
Male	83	79	90	91
AGE				
18 through 29 Years	78	86	86	84
30 through 39 Years	85	84	86	90
40 through 49 Years	84	78	88	89
50 through 64 Years	80	72	88	87
65 or More Years	71	65	84	92
CIVIC SCIENTIFIC LITERACY				
Well Informed	91	90	96	98
Moderately Well Informed	87	87	94	93
Not Well Informed	74	75	85	86
ATTENTIVENESS TO SCIENCE AND TECHNOLOGY POLICY				
Attentive Public	91	83	89	92
Interested Public	89	85	96	90
Residual Public	73	70	84	84
Number of Cases =	6,122	2,006	1,457	2,000

individual who has a moderate level of anxiety about flying in an airplane but recognizes the speed and convenience of air transportation and travels by air.

In the United States, the scientific promise and scientific reservation schemas display a clear, but differentiated, relationship with citizens-policy attitude for government support of basic scientific research (see Figure 12 and Table 34). This model indicates that citizens who have a strong belief in the promise of science and technology and relatively little reservation about the impact of science and technology were significantly more likely to approve of government spending for basic scientific research. It reflected the negative correlation between the promise and the reservation schemas in the U.S. data. This model suggests that these two schemas operate separately, but not independently.

TABLE 34
Effect of Age, Education, and Gender on the Prediction of Attitude Toward Support for Basic Research

Variable	Estimated Total Effect			
	Europe	United States	Japan	Canada
Age	−.09	.01	.20	−.06
Gender (Female is Positive)	−.17	−.03	−.54	−.45
Education	.15	.39	.10	.09
Civic Scientific Literacy	.22	.44	.10	.13
Attentiveness to Science & Technology Policy	.38	.13	.15	.18
Science Promise Schema	.56	.49	.46	.00
Science Reservation Schema	.08	−.42	.42	−.25
Multiple R^2	.49	.63	.51	.30
Number of Cases	6,122	2,006	1,451	2,000

χ^2 = 42.4/43 degrees of freedom; Root Mean Square Error of Approximation (RMSEA) = .00;
Upper limit of the 90% confidence interval of RMSEA = .011

In Japan, the two schema illustrate the unique support for science and technology among its citizens. Both the scientific promise schema and the scientific reservation schema are positively related to approval of government spending for scientific research. The mean Japanese score on the Index of Scientific Promise was 55 and the mean score on the Index of Scientific Reservation was 56, but 86% of Japanese adults voiced approval for government spending for scientific research (see Figure 13 and Table 34). The finding that science and technology policy is a low salience issue suggests that Japanese adults do not have strong, crystallized feelings about the promise or the dangers of science and technology. However, they may attribute to science and technology some responsibility for the strong growth of Japanese industry in recent decades. Support for science research may have become a social and socio-political expectation in Japan in the post-war period, but without a clear cognitive foundation of associated schemas. The positive total effect (.20) between age and approval of government spending for scientific research in Japan supports this interpretation.

In Canada, the best predictor of approval of government spending for scientific research was a rejection of concern about science and technology (see Figure 14 and Table 34). It is important to remember that Canadian adults had a higher mean score, 72, on the Index of Scientific Promise than Europe, the U. S., or Japan and that 88% of Canadians approved government spending for scientific research. The model had limited variance to predict, given these

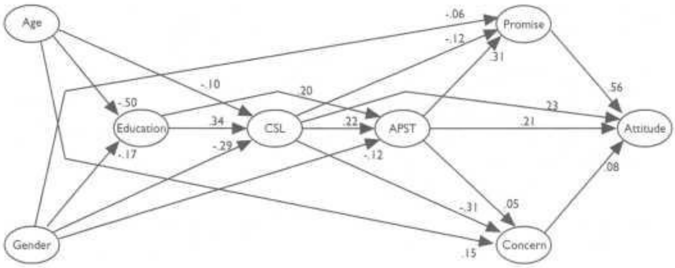

FIGURE 11:
A Path Model to Predict Attitudes toward Government Spending for Basic Scientific Research, European Union, 1992

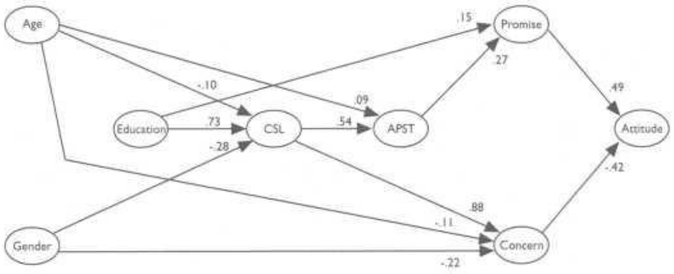

FIGURE 12:
A Path Model to Predict Attitudes toward Government Spending for Basic Scientific Research, United States, 1995

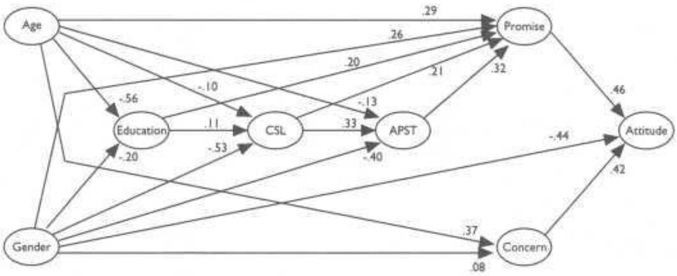

FIGURE 13:
A Path Model to Predict Attitudes toward Governmental Spending for Basic Scientific Research, Japan, 1991

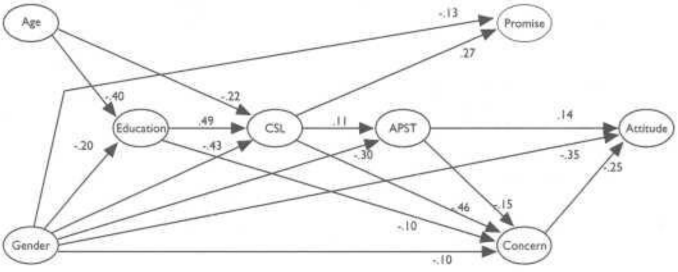

FIGURE 14:
A Path Model to Predict Attitudes toward Government Spending for Basic Scientific Research, Canada, 1989

parameters, so the factor that distinguished approval from disapproval was a low level of reservation, or concern, about the impact of science and technology. Belief in the promise of science was not a good predictor of the spending attitude since it was so pervasive among Canadian adults.

These models provide insights into the social and political context of a specific policy preference. The combined effects of formal education and the development of civic scientific literacy have substantial influence in the United States, but significantly less impact in the other three societies. This appears to reflect some of the differences in access to higher education generally, and to university-level science instruction in particular, in Europe, Japan, and Canada. In Japan and Canada, gender is a major predictor of attitude toward government spending for scientific research, holding constant differences in education and other factors.

The complex, but comprehensible, environment in which policy attitudes are formed and maintained is influenced by selected demographic characteristics and general attitude schemas on specific policy attitudes. The items in these four studies form meaningful dimensions reflecting cognitive and attitudinal schemas that individuals use in forming opinions on science and technology policy issues. These results demonstrate both the feasibility and the value of this kind of research particularly through the analysis of controversial science and technology policy issues.

CHAPTER VI

AN AGENDA FOR FUTURE RESEARCH

This monograph has examined the structure of public interest in science and technology, the level of public understanding of basic scientific concepts, and the structure and content of public attitudes toward science and technology. It is important to review the major substantive findings and outline an agenda for future research.

Principal Findings

The level of public interest in new scientific and medical discoveries, new inventions and technologies, and environmental issues was relatively high in Europe, the United States, and Canada. In the marketplace for time and attention, science and technology competed relatively effectively. The lower level of interest in these issues in Japan appears to reflect a combination of cultural and political factors.

The level of public understanding of basic scientific concepts was relatively low in the four societies studied. Based on the Index of Civic Scientific Literacy, approximately one in 10 adults in the United States and one in 20 European, Japanese, and Canadian citizens were well informed, or civic scientifically literate. This finding raises serious questions about the ability of citizens to comprehend the arguments in major scientific controversies, and argues strongly for renewed efforts to improve the quality and effectiveness of science and technology education in all countries.

It is important to recognize that two distinct schemas, the promise of science and technology and reservations about the impact of science and technology, operate simultaneously in the minds of most individuals in modern industrial societies even with differential weights and combinations in the various social groups and societies. An issue may activate one schema, while another issue may activate another schema. Analysis of these four sociopolitical systems revealed that substantial majorities of adults in Europe, the United States, and Canada believed in the promise of science and technology, which reflects a positive assessment of past achievements. Relatively few Americans had reservations about the impact of science and technology, although a substantial proportion of European, Japanese, and Canadian citizens expressed concerns. These concerns existed alongside high levels of expectation in science and technology development and did not represent an anti-science sentiment so much as wariness. The attitude of the public must be taken into account, or applications of new scientific discoveries and technologies in sensitive areas (biomedical science, genetic engineering, information technologies that intrude into the private sphere, megaprojects of high environmental impact) may be subject to an increase in the level of doubt or in adversarial action from issue groups and movements.

Science and technology policy must compete with other public policy issues and with social and recreational activities for the attention of citizens. Inevitably, a process of political and issue specialization occurs in which individuals allocate relatively little time or attention to political issues, which is reflected in the low rates of voter participation in many democratic political systems. Those citizens who choose to focus their time and attention on public policy matters must inherently choose the issues. One in 10 Europeans, Americans, and Canadians were attentive to science and technology policy issues. Citizens who were attentive to science and technology policy in all four sociopolitical systems generally had stronger beliefs in the promise of science and technology and lower levels of reservation about science and technology than other citizens.

Factors such as age, gender, educational attainment, scientific literacy, and issue attentiveness produce two science-relevant schema which ultimately influence specific policy preferences. A series of structural equation models document the important intermediary role of these educational, knowledge, attentiveness, and attitude variables on individual policy preferences in regard to government spending for basic scientific research in Europe, the United States, Japan, and Canada. Interestingly, the most influential factors are educational and demographic in character, areas not easily influenced by information or advertising campaigns.

Future Research Directions

The experience obtained in conducting this analysis highlights the importance of establishing a consistent methodology for concept and wording of item sets and coordination of information. Additionally, the substantive results of this analysis raise questions and issues indicating where additional research is timely and will be productive.

Methodological Issues

This analysis identified three important methodological issues: time-series data, cross-national comparison, and multivariate analysis. Each is discussed below.

Time-Series Data. This analysis was based on four cross-sectional data sets, each reflecting a single year. This analysis would have been enriched if there had been adequate time-series data available for comparative analysis. The commonalties among advanced industrial nations exceed their differences, and important lessons can be learned from systematic and continuous comparisons among different political, social, and educational systems. The major industrial countries will benefit from a commitment to support national studies of the public understanding of science and technology at regular intervals, with the intention of developing a time-series data set comparable to the *U.S. Science and Engineering Indicators.*

Cross-National Comparison. The value of cross-national comparisons is highlighted in this monograph. To assure reliable comparative estimates, researchers must develop a core set of items as similar as possible in wording and structure. The development of a core set of items should be part of an ongoing discussion by the nations involved in national studies on scientific literacy.

Multivariate Analysis. These results demonstrate the value of using appropriate quantitative techniques in comparative analyses of national survey data. A commitment should be made to using state-of-the-art multivariate analysis, including a preference for scales over single items and reliance on multivariate models to promote understanding of the relative contribution of various factors.

Substantive Issues

An important dimension that merits future examination is the interplay between institutional arrangements and forms of participation by the public in the decision-making process in scientific and technological areas on one hand, and issue attentiveness, attitudes, and actual behavior of the public on the other. While studies have been conducted in the U.S., this research needs to be expanded to other sociopolitical systems, particularly the European Union which is embarking on a path of complex institutional reform that may result in different outcomes (Miller 1983a, 1995, 1996). This transformation may result in a dramatic change in the modes of governance in Europe, which in turn may have a profound impact on the structure and dynamics of citizen involvement in the policy-making processes [15].

The complexity of decision-making in the European Union opens up an opportunity to study the interactions among the institutional dimension and some of the critical topics in the area of public understanding of science, such as issue attentiveness to science and technology or public participation in policy-making. The future research agenda should make room for addressing this critical characteristic of advanced democracies at the turn of the 20th century.

Five substantive issues merit future research: the structure of political systems, the influence of formal education, the influence of continuing and informal education, issue attentiveness, and mobilization to participate. These are discussed below.

The Structure of Political Systems. The results suggest that important systemic differences exist between the congressional system in the United States and the various national parliamentary systems of Europe, Japan, and Canada. The evolution of the governmental structure for the European Union merits careful study.

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[15] "The Maastricht Accord may have changed the trajectory of European political integration and opened up a range of possible (but not ineluctable) outcomes that were not previously apparent to or desired by either national or supranational actors. Instead of the coherent system of *checks and balances* long awaited by Eurofederalists, it could encourage the development of a hybrid arrangement for *presences and absences* in which member states, specific industrial sectors, subnational polities, and supranational organizations will be able initially to pick up and choose the obligations they prefer and only later discover which are compatible with each other. It is as if Europe--having been previously invited by its nation-states to sit down to a light snack of regional cooperation and by its supranational civil servants to a heavy *prix fixe* dinner of centralized governance--suddenly found itself before a *repas á la carte* prepared by several cooks and tempting the invitees with diverse, but unequally appealing, arrangements for managing their common affairs!" (Schmitter 1997).

The separation of powers at the federal level in the United States often pits the legislative branch and its committees against the leadership and bureaucratic expertise of the executive branch, inviting political intervention by interested groups. The single-member district system in the House of Representatives and the Senate and a relatively weak political party system allow an elaborate network of interest groups to form professionally-staffed lobbying operations that offer a combination of endorsements, volunteer workers for campaigns, and cash contributions for advertising and campaign use.

The U.S. political system does not parallel the systems in Japan, Canada, or any of the member states of the European Union. It appears that the emerging government of the European Union may ultimately resemble the U.S. system in several essential aspects. The European Union is beginning to develop federal characteristics, especially with the ratification of the Maastricht Treaty. The European Parliament is based on population and is elected from single-member districts, with a weak political party system. The European Parliament makes extensive use of committees and is building a professional staff structure to support the work of its committees. The European Commission is composed of an equal number of members from each member state, appointed by each national parliament. This parallels the original senate appointments specified in the U.S. Constitution where direct election of senators in the U.S. did not occur until the 1920's. Although the European constitution does not provide for an elected chief executive, the Maastricht Treaty provides for a review of this issue.

The growth and development of the European Union offer an important and unique opportunity to study several important questions. It is important to understand how interest groups organize to influence legislation and policy at the community level, especially as the parliamentary systems at the national level may not encourage an open lobbying system. It will be useful to observe the role of organized interest groups in electoral politics, assuming that the single-member district system continues for election to the European Parliament. It will be interesting to watch whether an open and overt lobbying system subsequently develops or expands at the national parliamentary level.

The Influence of Formal Education. The development of civic scientific literacy, attentiveness to science and technology policy issues, and participation in the formulation of public policy appear to be related to formal education. This analysis suggests that the higher number of Americans qualifying as civic scientifically literate and attentive to science and technology policy issues might be attributed to the higher proportion of students entering post-secondary education and to the widespread use of general education requirements at both the secondary and post-secondary levels. Important opportunities exist throughout Europe for rigorous studies of the impact of formal education on subsequent knowledge and attitudes toward science and technology.

The Influence of Continuing and Informal Education. Informal education in major industrial nations, especially those programs that might broaden or update an individual's understanding of science and technology, has expanded in the last 30 years. A renewed effort exists to expand post-secondary educational opportunities for adults in Japan and throughout Europe. A steady growth in the availability of science television programming in Europe, the United States, Japan, and Canada has followed the example of the British Broadcasting Corporation. The availability of science books and magazines has grown throughout the industrialized world. It is important to study the relationship of these new resources to formal schooling and to attentiveness to science issues.

Issue Attentiveness. It is important to look at the emergence of issue attentiveness in various political systems, given changes in political systems and growing opportunities in formal and informal education. Legislative systems that encourage open lobbying may foster greater interest-group activity and issue attentiveness. This is an empirically testable hypothesis. Research to explore the origins, maintenance, and functioning of issue attentiveness and political specialization should be conducted in many political systems.

Mobilization to Participate. It is important to examine the factors associated with citizen participation in public policy disputes involving science and technology. A democratic system assumes that interested citizens will organize to influence public policy on an issue. This process has been observed for decades on issues which people feel they understand, such as collective bargaining. However, the prospects for meaningful citizen participation in formulating public policy on science and technological issues, such as nuclear power or the thinning of the ozone layer, have been more challenging. The number and complexity of public policy issues involving science and technology will grow substantially during the 21st century. Research must focus on the structures and processes that will facilitate and maximize public participation in resolving issues of science and technology. This analysis should be conducted in cross-national studies that include adequate variation in both structure and process.

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APPENDIX A

CONFIRMATORY FACTOR ANALYSIS

All factor analysis captures concepts of interest to researchers, which cannot be directly observed. For example, social psychologists agree that individuals have an attitude called *self-esteem,* which cannot be ascertained by a single factual question such as used to measure height or weight. Another example is that, when measuring an individual's ability to solve algebra problems, a broad set of items is desirable to assess this skill rather than a one-item test. Constructs such as self-esteem or algebra skill are referred to as *latent variables,* or *factors.*

Latent variables cannot be measured directly, but information about them can be obtained through their effect on observed variables (Kim and Mueller 1978; Long 1983). Latent variables are responsible for covariation among the *observed variables.* In factor analysis, each observed variable, or *indicator,* is a function of the unmeasured *latent construct* and a *unique error* or *disturbance term* (Blalock 1971). In survey research, responses to individual questions are the observed variables while constructs such as scientific literacy and attitudes about the promise of science represent *latent variables.*

Factor analysis encompasses two areas: *exploratory* factor analysis and *confirmatory* factor analysis. Factor analyses conducted in statistical packages such as SPSS are representative of exploratory factor analysis. Exploratory factor analysis is what most people think of when no qualifier is attached to the term *factor analysis* (Loehlin 1987). In contrast, confirming factor analysis is theory-driven.

Exploratory factor analysis measures two approaches: *principal component analysis* and *common factor analysis.* Principal component analysis is used in order to reduce the number of variables, assuming that all variability in an item should be used in the analysis. Common factor analysis aims to detect structure in the data, using only the variability that is shared by the items, or variables. Exploratory factor analysis can be used as an "expedient way of ascertaining the minimum number of hypothetical factors that can account for the observed covariation, and as a means of exploring the data for possible data reduction". Exploratory factor analysis often generates models or hypotheses, rather than being based on prior theory (Kim and Mueller 1978; Jöreskog and Sörbom 1993).

In confirmatory factor analysis, the researcher develops a model to explain the relationships between observed variables and latent constructs. Prior theory or hypotheses form these models. Various measures of fit are used to determine how well the model accounts for the relationships observed in the actual data (Loehlin 1987; Jöreskog and Sörbom 1993). LISREL, EQS, and LISCOMP are statistical packages that can be used for confirmatory factor analysis.

In exploratory factor analysis, all latent factors are either correlated (in the case of an oblique rotation) or uncorrelated (in the case of an orthogonal rotation). The researcher cannot specify that some latent constructs are correlated while others are uncorrelated. In confirmatory factor analysis, the researcher specifies exactly which latent constructs are assumed to be correlated, and constrains those latent constructs which are assumed to be uncorrelated (Long 1983).

Exploratory factor analysis assumes that all observed variables are directly affected by all latent constructs, whether or not a substantive basis exists for this assumption. Confirmatory factor analysis requires a researcher to specify the exact relationship between the latent constructs and the observed variables. The researcher determines whether a given indicator is affected by one latent construct, or more, based on prior theory.

Unique errors are uncorrelated in exploratory factor analysis, even when identical measurement techniques are used. In confirmatory factor analysis, the researcher can specify that some unique factors are correlated, while constraining others to be uncorrelated. This is useful in survey research where the same question format may measure an entire series of items, and allowing the unique factors to correlate may be a reasonable assumption.

A graphic portrayal of these two types of factor analysis illustrates the differences in technique. Figures A-1 and A-2 present the six hypothetical variables: probability, scientific study, experiment, *DNA*, molecule, and radiation. The two examples share the same two principles: scientific process and scientific constructs.

In the model for exploratory factor analysis (see Figure A-1), arrows lead from the latent factors to each observed variable in the diagram, representing the assumption of exploratory factor analysis that all observed variables are directly affected by all latent constructs. If this were a question on *DNA*, the figure would indicate knowledge of scientific constructs and an understanding of the scientific process. This assumption is made "regardless of the substantive appropriateness", even in the case of an orthogonal rotation in which the two latent constructs are assumed to be uncorrelated (Long 1983).

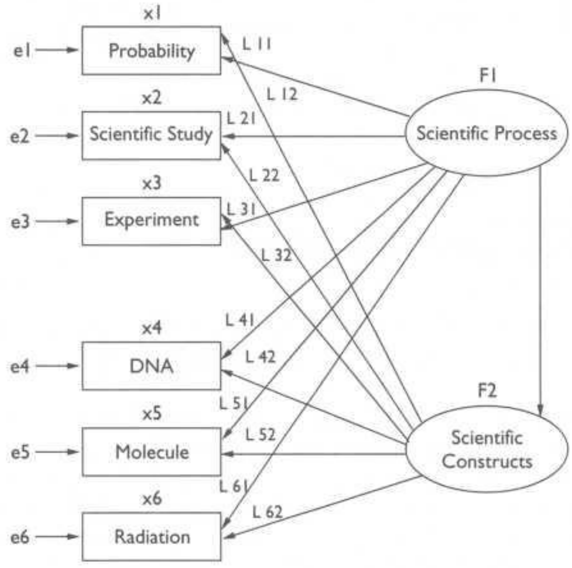

FIGURE A-1:
An Explanatory Factor Analysis

In contrast, the model for confirmatory factor analysis (see Figure A-2) is based on the hypothesis that questions on scientific study, experiment, and probability are indicators of an understanding of the scientific process but may have no relationship with an understanding of scientific constructs. If this were a question on *DNA*, the figure would show molecule and radiation as indicators

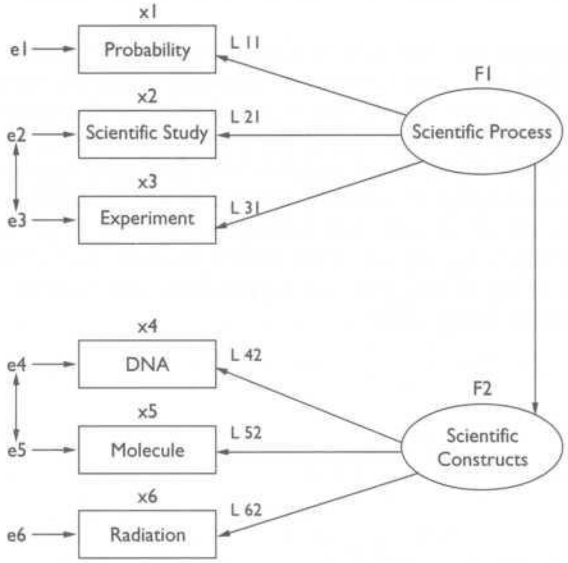

FIGURE A-2:
A Confirmatory Factor Analysis

of an understanding of scientific constructs, and would not have a relationship with an understanding of scientific process.

Exploratory factor analysis assumes that unique factors are uncorrelated, while confirmatory factor analysis allows the researcher to specify correlations. In Figure A-2, the researcher specified that the unique error should correlate between scientific study and experiment, as is depicted by the double-edged arrow between e2 and e3. The error terms have been allowed to correlate between e4 and e5--*DNA* and molecule.

An advantage of confirmatory factor analysis is that statistical tests can be used to determine whether data are consistent with the model assumptions. The statistical measures of fit for structural equation models (and, by extension, confirmatory factor analysis) are discussed extensively by Bollen and Long (1993). Their points of consensus on model fit were used to guide the confirmatory factor analyses conducted for this monograph. These included:

> The model should be consistent with substantive theory.

> Multiple measures should be used in assessing the fit of the model.
>
> The components of the model, such as the magnitude of coefficient estimates and the sign of the estimates, should make sense.

Multiple measures were used to assess the fit of all of the models in this monograph. The Root Mean Square Error of Approximation (RMSEA) is a measure of discrepancy per degree of freedom. Values of .05 or less indicate a close fit. It is generally suggested that the 90% confidence interval for the RMSEA should be less than .08 (Jöreskog and Sörbom 1993). Jöreskog and Sörbom (1988) recommend using the χ^2 as a goodness-of-fit measure. Large χ^2 values indicate a bad fit, and small χ^2 values indicate a good fit. However, the χ^2 is extremely sensitive to large sample sizes. As a result, Jöreskog and Sörbom (1988) recommend dividing the measure by the total degrees of freedom in cases of large sample size. Wheaton, Muthen, Alwin, and Summers (1977) recommend an χ^2 to a degree of freedom ratio of five or less, while Carmines and McIver (1981) suggest a more stringent ratio of two to three.

In the confirmatory factor analyses conducted for this monograph, a large proportion of variables were ordinal. When used to produce a simple covariance or correlation matrix, ordinal variables can result in distorted parameter estimates, incorrect χ^2 measures, and incorrect standard errors. Consequently, the raw data were produced as a matrix of polychoric polyserial correlations along with an asymptotic covariance matrix using PRELIS2. The matrices were then estimated using the WLS method in LISREL (Jöreskog and Sörbom 1993).

APPENDIX B

STRUCTURAL EQUATION MODELS

Research in the social and behavioral sciences is concerned with two broad problems: measurement and causal relationships (Jöreskog and Sörbom 1993).

> The first problem is concerned with the measurement properties--validity and reliability--of the measurement instruments. The second problem concerns the causal relationships among the variables and their rel-ative explanatory power.

Structural equation models combine the two broad concerns of social science research: measurement and causal relationships. Discussions on measurement of the research are conducted separately from other stages of research (Hayduk 1987). Speaking of LISREL, the first structural equation modeling software package, Hayduk notes that:

> LISREL integrates measurement concerns with structural equation modeling by incorporating both latent theoretical concepts and observed or measured indicator variables into a single structural equation model. Furthermore, knowledge of the methodological adequacy of the data gathering process and the quality of particular questionnaire items (measurement instruments) can be directly incorporated into LISREL models by specifying (fixing) a specific proportion of the variance in an indicator to be error variance.

Structural equation models have two parts: measurement and structural equation models. Measurement is used to specify "how the latent variables or hypothetical constructs are measured in terms of the observed variables, and it describes the measurement properties (validity and reliability) of the observed variables" (Jöreskog and Sörbom 1988). Loehlin (1987) has described the measurement portion as a variant of confirmatory factor analysis [16]. The structural equation model "specifies the causal relationships among the latent variables and describes the causal effects and the amount of unexplained variance" (Jöreskog and Sörbom 1988).

A structural equation model is a set of equations that provides an estimate for a set of relationships among independent variables and one or more dependent variables. Jöreskog and Sörbom (1988) define *structural equation modeling* as:

> [It] estimates the unknown coefficients in a set of linear structural equations. Variables in the equation system may be either directly observed variables or unmeasured latent (theoretical) variables that are not observed but relate to observed variables. The model assumes that there is a "causal" structure among a set of latent variables, and that the observed variables are indicators or symptoms of the latent variables.

This is similar to regression analysis which provides estimates of the relationship between a series of independent variables and a dependent variable. Three situations exist in which structural equation models should be used because regression parameters do not give relevant information: when observed variables contain measurement error, when the observed variables are interdependent, and when important explanatory variables have been omitted or not included in the model. These three situations occur on a routine basis in social and behavioral sciences research.

Structural equation models are a theory-driven analytical technique. The analyst develops a hypothetical model specifying the anticipated relationships between a series of constructs based on theory. The theoretical model is tested with actual data. Statistical software packages are available for structural equation modeling, including LISREL, EQS, AMOS, CALIS, and LISCOMP. Each package provides goodness-of-fit measures to determine whether the model theorized by the analyst fits the data.

If the model does not fit the data, a variety of measures may be used to modify the model to better fit the data. However, Jöreskog and Sörbom (1993) caution:

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[16] For a more detailed discussion of the measurement model, or confirmatory factor analysis, see Appendix A.

> If the model *fits* the data, it does not mean that it is *the "correct" model* or *even the "best" model*. In fact, there can be many *equivalent* models, all of which will fit the data equally well as judged by any goodness-of-fit measure. This holds not just for a particular data set but for any data set. The direction of causation and the causal ordering of the constructs cannot be determined by the data. To conclude that the fitted model is the "best", one must be able to exclude all models equivalent to it on a logical or a substantive basis.

Jöreskog and Sörbom (1993) distinguish among three different model tests in structural equation modeling: strictly confirmatory, alternative or competing models, and model generating. In strictly confirmatory models, the researcher develops a model on the basis of theory, tests the model with empirical data, and accepts or rejects the model on the basis of the test. In alternative or competing models, the researcher develops and tests a series of models and selects the model that best fits the data. In the most common situation, model generating, the researcher develops an initial model based on theory and tests the model with empirical data. If the model does not fit the data, the analyst modifies the model and tests it again, using the same data. The goal of model generating "may be to find a model which not only fits the data well from a statistical point of view, but also has the property that every parameter of the model can be given a substantively meaningful interpretation" (Jöreskog and Sörbom 1993).

The path model used (see Figure B-1) was used to predict civic scientific literacy in the United States. The model has two basic background, or *exogenous*, factors. Each respondent's gender and age were taken as being temporally and logically prior to the person's current level of scientific literacy. This does not imply that gender or age causes differences in one's level of civic scientific literacy, but that these variables are associated with civic scientific literacy. The structural equation analysis identifies the intervening variables that account for, or explain, the bivariate correlations between background variables such as gender and age and outcome measures such as scientific literacy.

One intervening variable, the respondent's level of formal education, was placed in the model between the background variables and scientific literacy, which helps explain the relationships between background variables such as gender and age and outcome variables such as scientific literacy.

The numbers above the arrows are the standardized beta coefficients for the paths. Standardized beta coefficients allow for com-

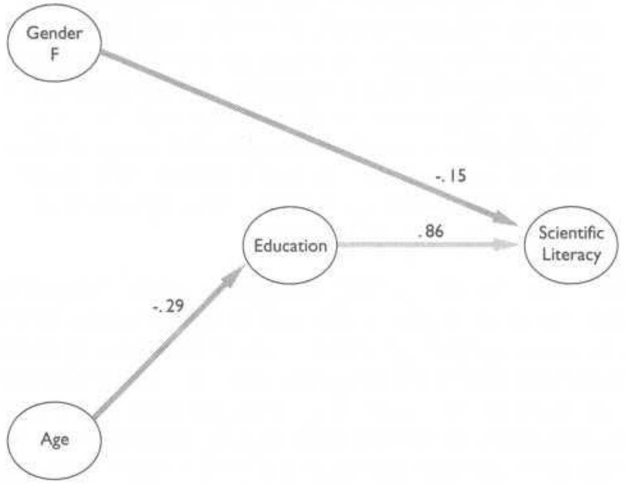

FIGURE B-1:
A Path Model to Predict Civic Scientific Literary

parisons of the relative effects of all of the factors in the model. All beta coefficients presented are significant at the .05 level. Standardized beta coefficients range from -1.0 to +1.0, with values close to zero representing small paths, and values close to -1.0 or +1.0 representing large paths.

An arrow, on the left, from age to education indicates that age has an effect on the respondents' level of education. The number above the arrow, –.29, indicates the sign and size of the effect. The negative sign means that younger respondents tend to have higher levels of education than older respondents. No arrow between gender and education means that once age is taken into account, there is no relationship between gender and education.

The effects of background (or exogenous) variables and intervening variables on outcome factors such as civic scientific literacy are important in structural equation models. The *total effects* of selected factors on various outcome variables are discussed in this monograph. Total effects are comprised of *explained*, or indirect, effects and *residual*, or direct, effects. The total explained and residual effects of gender, age, and education on civic scientific literacy in the United States are shown on Table B-1. Explained effects occur when intervening variables account for part, or all, of the relationship between background variables and outcome variables. Residual effects are represented by paths from any background or intervening variable to the outcome variable. Figure B-1 on civic scientific literacy in the United States explains the differences in these effects.

No direct path leads from age to scientific literacy, indicating that age has no significant residual, or direct, effect on scientific literacy. An explained effect is obtained by analyzing other paths. There is a path of –.29 from age to education and one from education to scientific literacy of .86. These indicate that the level of education mediates, or explains, the relationship between a respondent's age and his level of civic scientific literacy. When the path of –.29 is multiplied by the path of .86, a value of –.25 is obtained, which is the value of the explained, or indirect, effect of age on civic scientific literacy. The total effects of age on civic scientific literacy are obtained by adding the residual effects of age (.00) to the explained effects (–.25) of age.

Gender has a residual effect of –.15 on civic scientific literacy, as is depicted by the arrow from gender to civic scientific literacy (see Figure B-1). Residual paths such as these suggest that other possible explanatory factors have been omitted from the model. No path exists between gender and education. This means that gender has no explained, or indirect, effect on scientific literacy, resulting in a value of .00 for the explained effects of gender on civic scientific literacy (see Table B-1). The total effects of gender on civic scientific literacy are obtained by adding the residual effects of gender (–.15) to the explained effects (.00) of gender.

TABLE B-1
Explained, Residual, and Total Effects of Age, Education, and Gender on Prediction of Civic Scientific Literacy in the United States

Variable	Effects		
	Explained (Indirect)	Residual (Direct)	Total
Gender (Female is Positive) .	.00	–.15	–.15
Age	–.25	.00	–.25
Level of Formal Education .	–	.86	.86

The explained, residual, and total effects of the level of formal education on civic scientific literacy are itemized in the final row on Table B-1. Since no intervening variables were included in this model between the level of formal education and civic scientific literacy, formal education can have no explained, or indirect, effects on civic scientific literacy, and this null case is indicated by a dash.

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This monograph, based on research carried out in collaboration by the BBV Foundation and the Chicago Academy of Sciences, is the first systematic comparative analysis of the public's knowledge, images, and attitudes regarding science in Europe, Japan, the United States, and Canada. It focuses on the development of a set of indicators to explore the relations between interest in scientific issues, level of understanding of substantive and methodological dimensions of science, and patterns of attitudes toward science and technology. This analysis leads to the formulation of hypotheses about the public's role in the frequent controversies that involve science and technology. The statistical techniques of confirmatory factor analysis and structural equation modeling take this study beyond simple data analysis by exposing data structure and advancing explanatory models. These tasks, in the authors' view, should inform a new series of comparative analyses of scientific culture in advanced societies.

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