Science for All Americans
Chapter 1
The Nature of Science

I) The scientific worldview
   1) *The world is understandable*: Science assumes the unity of the universe and the existence of consistent patterns that underlie natural occurrences. Science also assumes that such patterns can be understood through empirical inquiry
   2) *Scientific ideas are subject to change*: Scientific knowledge is tentative
   3) *Scientific knowledge is durable*: Although scientific claims are never absolute, they tend to be durable. These claims tend to survive, get refined and modified, and grow in their accuracy and ability to predict the behavior of natural phenomena
   4) *Science cannot provide complete answers to all questions*: Science can contribute little to answering questions that relate to axiomatic beliefs. And even though science can inform decision making regarding ethical and moral questions, it cannot provide complete answers to such questions

II) Scientific inquiry: "is not easily described apart from the context of particular investigations. There simply is no fixed set of steps that scientists always follow, no one path that leads them unerringly to scientific knowledge" (AAAS, 1990, p. 4)
   1) *Science demands evidence*
      (i) Need to match scientific claims with observations of phenomena
      (ii) Active manipulation (controlling conditions/variables to deduce cause-effect relationships) versus passive observations (need for observations over a wide range of naturally occurring conditions)
      (iii) Controlled versus uncontrolled data gathering (practical and ethical considerations; distortion of phenomena)
      (iv) Need for better instrumentation and sharing of data
   2) *Science is a blend of logic and imagination*
      (i) Scientists use imagination as well as agreed upon logical principles (that connect evidence and assumptions with conclusions) in coming up with hypothesis and theories
      (ii) Working hypotheses guide data collection and ensuing research. Viable hypotheses should suggest what evidence supports them and what evidence refutes them
      (iii) "Scientific concepts do not emerge automatically from data or from any amount of analysis done. Inventing hypotheses and theories to imagine how the world works and then figuring out how they can be put to the test of reality is as creative as writing poetry" (AAAS, 1990, p. 5)
   3) *Science explains and predicts*
      (i) Scientific theories explain huge sets of scientifically valid observations and show relationships between seemingly unrelated sets of observations
      (ii) Theories should have predictive power. Predictions could be related to future or past events
   4) *Scientists try to identify and avoid bias*
      (i) "Scientists nationality, sex, ethnic origin, age, political convictions, and so on" influence "how the data are interpreted, . . . the recording or reporting of

the data, or even . . . the choice of what data to consider" (AAAS, 1990, pp. 6-7)

(ii) Although bias cannot be totally eliminated, scientists try to minimize it by checking on each others' work

5) *Science is not authoritarian*

(i) Scientists do not have privileged access to the truth

(ii) In the short run, scientists may resist accepting new theories even if those theories are well supported. However, in the long run, theories that have more explanatory and predictive power replace previous ones

III) The scientific enterprise

1) *Science is a complex social activity*

(i) Science reflects social values and viewpoints

(ii) The scientific community's subtle social and power structure determines directions of present and future research through tacit or implicit agreement on worthwhile questions and appropriate research methods. Elaborate structures for appropriating funds are often established

(iii) Routes for dissemination of scientific research and information is crucial to the advancement of science

2) *Science is organized into content disciplines and is conducted in various institutions*

(i) Science is a collection of different scientific fields or disciplines that differ in history, subject of investigation, research methods, and desired outcomes. Disciplines organize research and research findings but hinder communication and often create divisions that are not commensurate with the natural world. The boarders of disciplines, however, are always in flux

(ii) Funding agencies as well as social and ethical values influence the directions of scientific research

3) *There are generally accepted ethical principles in the conduct of science*

(i) Openness, replication, critical review. Sometimes violated because of issues of priority

(ii) Research on animals and human subjects (informed consent: full disclosure)

(iii) Personal versus professional ethics: Working on projects that might be harmful to humanity in the long run

4) *Scientists participate in public affairs both as specialists and as citizens*

(i) Scientists can inform public debates but can seldom present definitive answers

(ii) "On issues outside their expertise, the opinions of scientists should enjoy no special credibility" (AAAS, 1990, p. 12)

(iii) "In matters of public interest, scientists, like other people, can be expected to be biased where their own personal, corporate, institutional, or community interests are at stake" (AAAS, 1990, p. 12)

Some Important NOS Aspects

1) *Tentative*

   Scientific knowledge is never absolute or certain. All scientific claims including "facts," laws, and theories are subject to change pending the availability of new data, new conceptual ideas (e.g., hypotheses, theories), or the reinterpretation of old data in light of new conceptual advancements
2) *Empirical*

   Science demands evidence. Eventually scientific knowledge *should* be based on and consistent with observations of the natural world
3) *Creative and imaginative*

   Scientific knowledge is partly a product of human imagination and creativity. It involves the invention of explanations (hypotheses, theories)
4) *Theory-laden*

   Scientists' personal prejudices, perspectives, expectations, beliefs, theoretical commitments, previous knowledge, experiences, and training actually influence their work: Their observations and the inferences they derive from those observations
5) *Socially and culturally embedded*

   Science and scientific knowledge are influenced by the philosophical and economic spheres, and religious, ideological, ethical, and cultural values of societies
6) *The myth of "The Scientific Method"*: There exists no one single way or set of step-wise procedures that scientists always follow to produce scientific knowledge
7) *Observation versus inference*
   a) Observations are descriptive statements about natural phenomena that are "directly" accessible to the senses (or extensions of the senses) and about which several observers can reach consensus with relative ease
   b) Inferences are statements about natural phenomena that are not "directly" accessible to the senses
   c) To be valid inferences should be "consistent" with observations
8) *The difference and relationship between theories and laws*
   a) Laws are statements or descriptions of the relationships among observable phenomena
   b) Theories are inferred explanations for observable phenomena
   c) Scientific theories and laws are different kinds of knowledge and one does not become the other

Some Ideas on Nature of Science

What is Science?

1. Body of knowledge
2. Set of methods/processes
3. A way of knowing: Nature of Science

Nature of Science

The values and assumptions inherent to science, scientific knowledge, and/or the development of scientific knowledge

Phenomena vs. Data

Phenomena: Are relatively stable and general features of the natural world that are amenable to explanation and/or prediction (e.g., phases of the moon, the four seasons, lightning, volcanoes, decay of dead animals and plants, flowering of plants)

Data: Are evidence for claims about phenomena. Data are observations or what registers on measurement or recording devices in forms that are accessible to the human senses and to public inspection (e.g., temperature readings, soil samples, telescopic photos of distant galaxies, records of animal behavior in captivity)

Observation vs. Inference

Observations: Descriptive statements about natural phenomena that are "directly" accessible to the senses (or extensions of the senses) and about which several observers can reach consensus with relative ease. Ex: Objects tend to fall down when released from various heights

Inferences: Statements about natural phenomena that are not "directly" accessible to the senses. Ex: Objects fall down due to gravity

Misconceived Notion of the Relationship of the Categories of Scientific Knowledge

Law

⇑

Theory

⇑

Hypothesis

⇑

Observations

Scientific Theories and Laws

Scientific law: States, identifies, or describes relationships among observable phenomena

Scientific theory: Inferred explanation for observable phenomena