NAS 501 Research Methods and Scientific Ethics

Chapter 5: Scientific Method of Research

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- Science is that activity which aims to further our understanding of why things happen as they do in the natural world. It accomplishes this goal by applications of scientific method—the process of observing nature, isolating a facet that is not well understood and then proposing and testing possible explanations.
- Observing the nature
- Proposing Explanations
- Testing Explanations

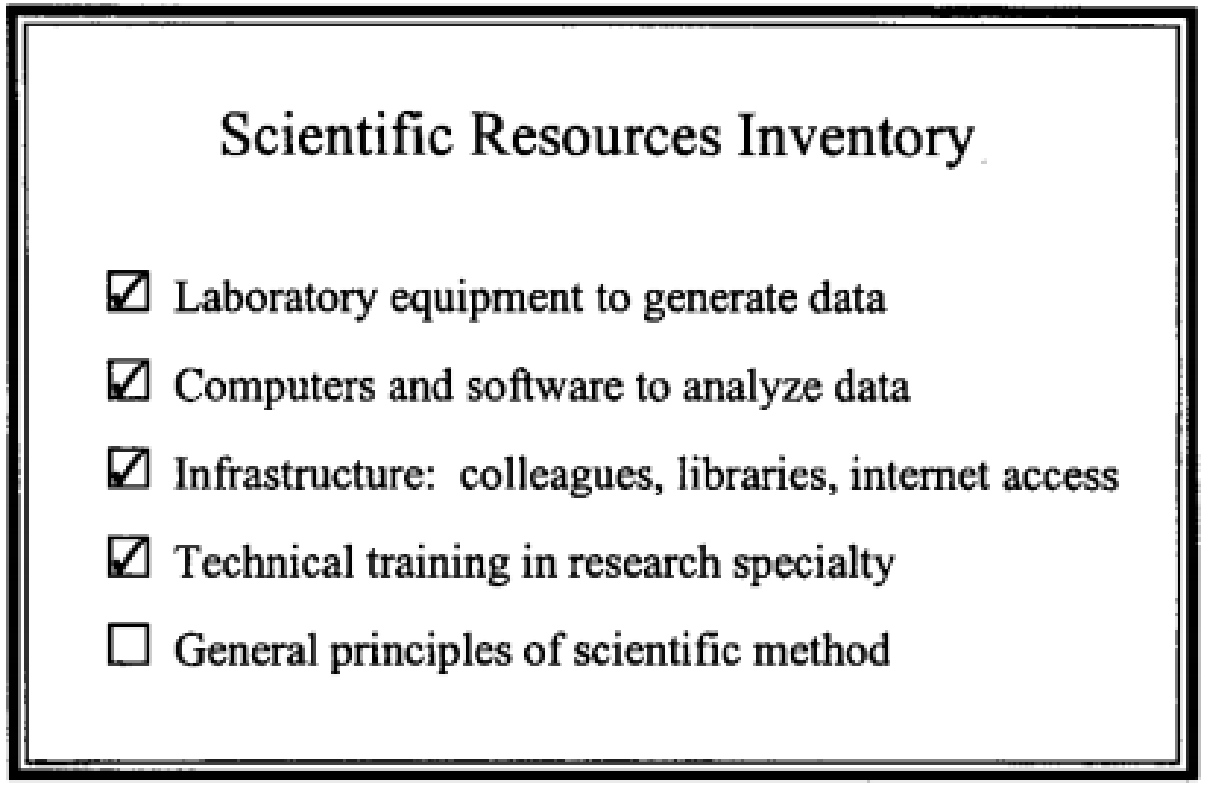


Figure 1.3. A typical resources inventory for a research group. The scientists in a given research group often have excellent laboratory equipment, computers, infrastructure, and technical training, but inadequate understanding of the general principles of scientific method is the weakest link. Ideally, a research group will be able to check off all five boxes in this inventory, and there will be no weak link.

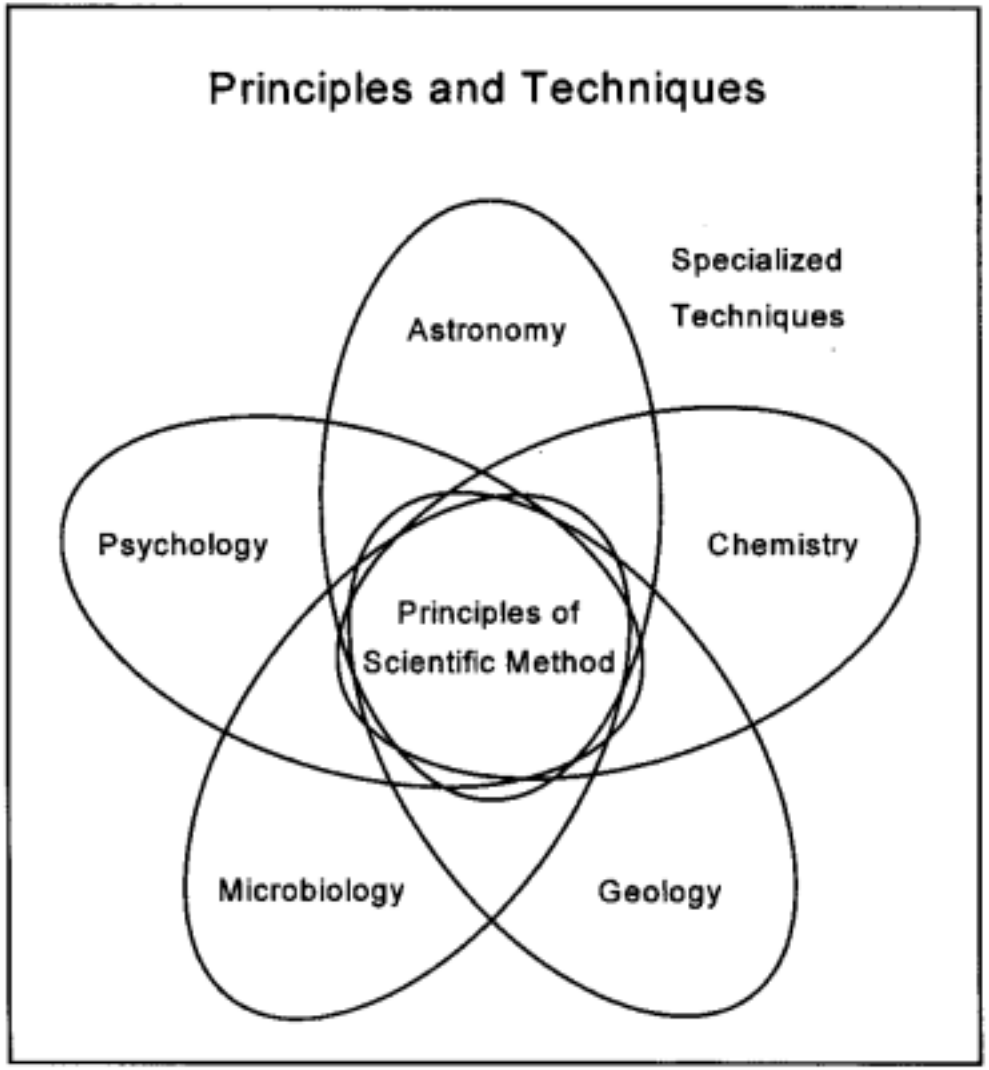


Figure 1.1. Science's methodology depicted for five representative scientific disciplines, which are partly similar and partly dissimilar. Accordingly, scientific methodology has two components. The general principles of scientific method pervade the entire scientific enterprise, whereas specialized techniques are confined to particular disciplines or subdisciplines.

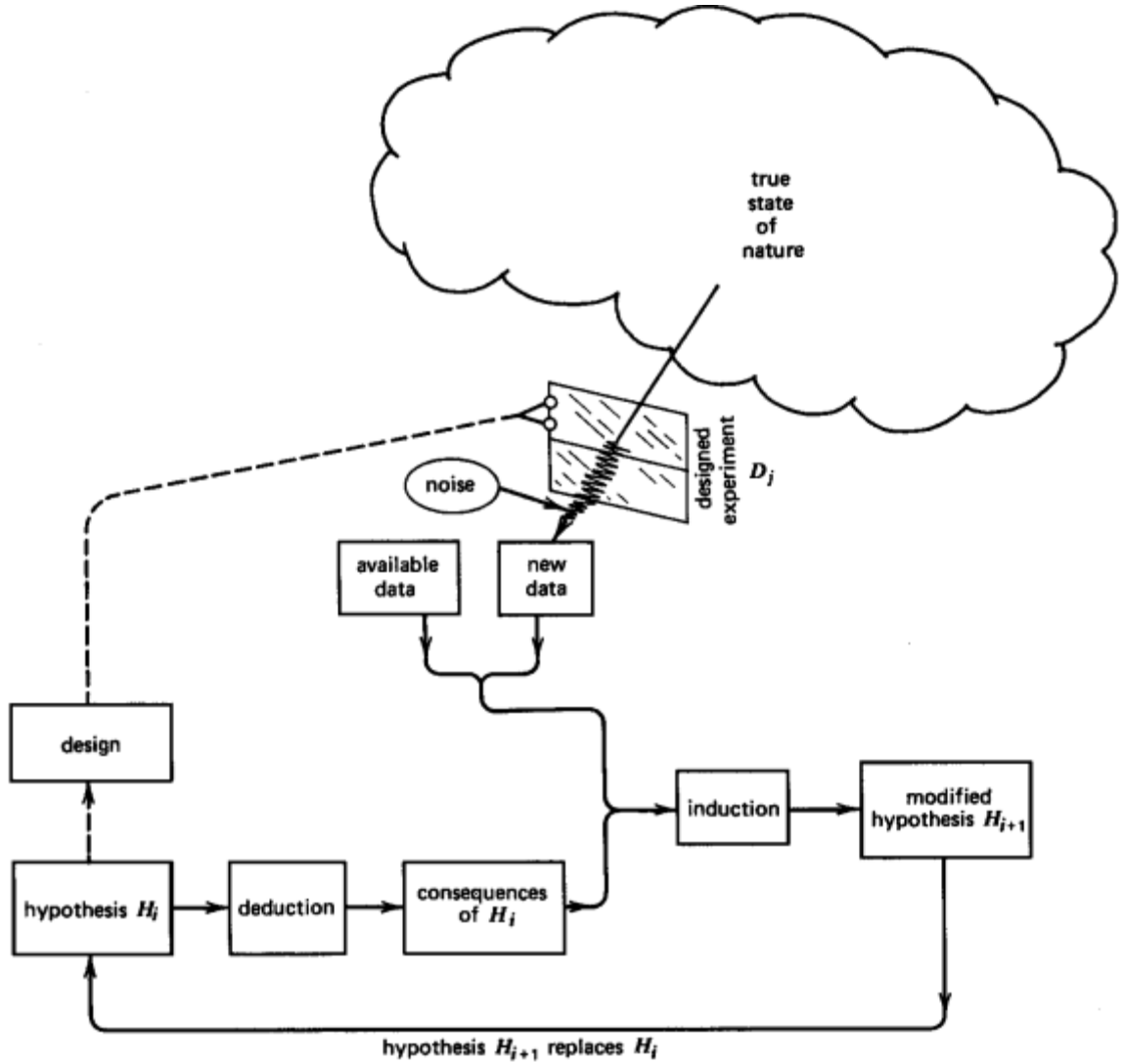
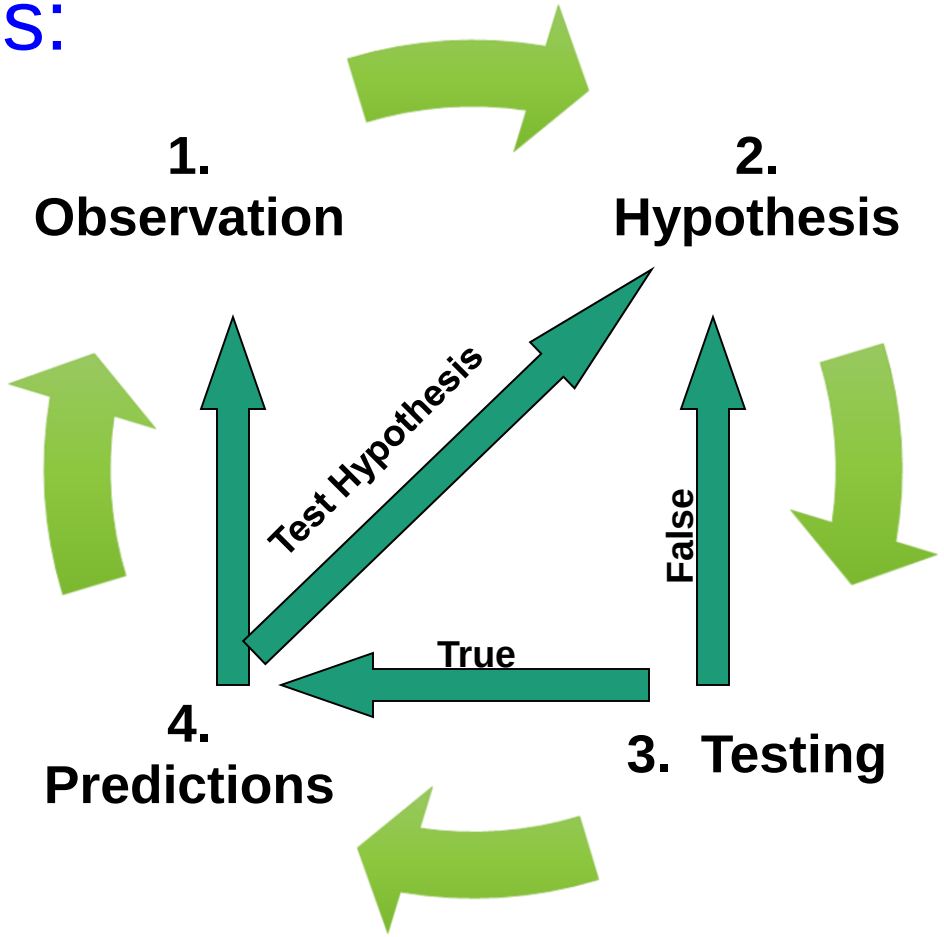


Figure 12.1. An overview of the scientific method. Deduction and induction are used to bring data to bear on theory choice. The goal is for theory choice to converge on the true state of nature. (Reproduced from Box et al., 1978:4, with kind permission from John Wiley & Sons.)

Scientific Method of Research

Four Steps:



- If the experiments prove the **hypothesis** to be true, it becomes a **theory** or **law** of nature. If the experiments prove the hypothesis to be false, the hypothesis must be rejected or modified. The scientific method used properly should give us **predictive power** (to understand phenomena which have not been tested).

Some significant milestones along the way

- Edwin Smith papyrus

The origin of the scientific method can be traced back to approximately 2600 BC. Ancient surgical methods were documented in the Edwin Smith papyrus.

The papyrus contains the essential elements of the scientific method: examination, diagnosis, treatment, and prognosis.

Some significant milestones along the way

- Greek philosophy (4 th century BC)

Greek philosopher, Aristotle (384–322 BC)

While both Plato and Aristotle supported deductive reasoning, only Aristotle championed inductive reasoning

some significant milestones along the way

- Islamic philosophy (8-15th century AD)
- Muslim scientists played a significant role in the development of the scientific method in the modern form. They placed more emphasis on experiments than the Greeks. Guided by Islamic philosophy and religion, the Muslim's empirical studies of nature were based on systematic observation and experimentation.

some significant milestones along the way

- European Science (12–16 th century AD)

In the 14th century, an English logician, William of Ockham (1285–1349) introduced the principle of parsimony, which is now known as the **Ockham's Razor**.

The principle states that an explanation or a theory should be as simple as possible and contains just enough terms to explain the facts.

The term "razor" is used to mean that unnecessary assumptions need to be shaved away to obtain the simplest explanation.

The Razor is sometimes stated as "entities are not to be multiplied beyond necessity".

It parallels what Einstein wrote in the 20th century, "Theories should be as simple as possible, but not simpler".

some significant milestones along the way

- Scientific Revolution (1543 AD–18th century AD)

The Scientific Revolution was based upon the learning of the universities in Europe. It can be dated as having begun in 1543, the year when Copernicus published On the Revolutions of the Heavenly Spheres.

At the end of the Scientific Revolution, knowledge was no longer dictated by authorities, but accumulated painstakingly by experimental research. All these have been made possible through the introduction of philosophical ideation in humanism and empiricism for the past centuries.

Basic Elements of the Scientific Method

- Empiricism: the notion that enquiry is conducted through observation and knowledge verified through evidence
- Determinism: the notion that events occur according to regular laws and causes. The goal of research is to discover these
- Scepticism: the notion that any proposition is open to analysis and critique

Good research practice is something that can be required of research of every kind. It is applicable to every discipline and field of research, both in the natural sciences, engineering and medicine and in the social sciences and humanities.

There is no such thing as “intellectual property”, owned by the researcher.

1 Tell the truth about your research
2 Openly report your methods and results
3 Openly disclose any commercial interests and other ties
4 Consciously examine and present the basic assumptions underlying your studies
5 Do not steal research results from others (e.g. from younger colleagues)
6 Conduct your research in an orderly manner (e.g. by maintaining documentation and retaining data)
7 Do not conduct your research in a way that could harm other people (e.g. subjects)
8 Be fair in your assessment of other people’s research

The Scientific Method involves a series of steps that are used to investigate a natural occurrence.

Steps of the Scientific Method

1. **Problem/Question**: Develop a question or problem that can be solved through experimentation.
2. **Observation/Research**: Make observations and research your topic of interest.

Steps of the Scientific Method

3. Formulate a Hypothesis: Predict a possible answer to the problem or question.

4. Experiment: Develop and follow a procedure. Include a detailed materials list.The outcome must be measurable (quantifiable).

Steps of the Scientific Method

5. **Collect and Analyze Results**: Modify the procedure if needed. Confirm the results by retesting. Include tables, graphs, and photographs.
6. **Conclusion**: Include a statement that accepts or rejects the hypothesis. Make recommendations for further study and possible improvements to the procedure.

Steps of the Scientific Method

7. **Communicate the Results**: Be prepared to present the project to an audience. Expect questions from the audience.

Hypothesis Framing

Traditionally…..

H_0: "Null" hypothesis (assumed)

H_1: "Alternative" hypothesis

Variables

A variable is any factor, trait, or condition that can exist in differing amounts or types.

1.Independent
2.Dependent
3.Controlled

The **independent variable** is the one that is changed by the scientist. As the scientist changes the independent variable, he or she **observes** what happens.

The scientist focuses his or her observations on the **dependent variable** to see how it responds to the change made to the independent variable.

Experiments also have **controlled variables**. Controlled variables are quantities that a scientist wants to remain constant, and he must observe them as carefully as the dependent variables.

Once a scientist completes an experiment, they often repeat it using the exact same materials and procedure to see if they get the same findings and results.

verification, or checking things out to make sure everything was valid and will happen again and again.

Scientists share their experiments and findings with others.

- Accumulation: scientists can learn from each other and often use someone else’s experiences to help them with what they are studying or doing.

- Know what has been done by others. Do not reinvent the wheel unnecessarily!!!
- Understand your field. This qualifies you to make reasonable hypothesis about fundamental advances in the field.
- Do not strive to solve all problems in the field, look for small advances in your field.
- Small advancements lead to critical developments.
- Prepare to report results even if hypothesis fails. False hypothesis are also advancements in science (and will save others time and money on repeating these experiments). Failed hypothesis should also be used to make suggestions for future directions (making you and EXPERT since you can suggest new directions in your field!!!).

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