THE SCIENTIFIC METHOD AS PRESENTED IN SCIENCE TEXTBOOKS AND AS DESCRIBED BY EMINENT SCIENTISTS *

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INTRODUCTION

For some time the feeling has existed that textbook authors, who are not at the frontier of scientific investigation, may have presented a distorted concept of the scientific method. If such a distorted interpretation has been presented, a critical, comparative analysis of randomly selected textbooks and appropriately selected writings of eminent scientists should reveal significant differences.

The study being reported deals with the degree of correspondence between two such samples, as described above, and a reference group composed of accepted, authoritative writings on the subject (by such authors as: Campbell, Cohen, Hanson, Hull, Mintague, Nagel, and Wolf.

METHOD

1. The method of the study was descriptive-analytical. Classical sources were investigated to develop a working description of the components *(elements)* of scientific method.

2. A stratified random sample of school science textbooks, in print in 1961, were selected and sub-categorized into these groups: grades seven through nine; grades ten through twelve; and grades thirteen and fourteen. These textbooks were used to identify the authors' viewpoints and definitions of scientific method.

3. A categorized random sample of eminent scientists was chosen and the description(s) of scientific method were isolated from each of their writings. Correspondence (personal letters) from the scientists was used to validate the scientists' current position regarding the interpretation and description of scientific methodology. The differences and similarities between the two sets of descriptions were identified. All of the scientists in the sample are living members of The National Academy of Sciences of the United States of America; six of them are Nobel Prize winners.

The categories of scientists selected were: astronomers, biological scientists, chemists, geologists, and physicists. Forty-one scientists were involved in the study. Thirty-nine of them contri-

*Complete study available from University Microfilms, Inc., Ann Arbor, Michigan.

buted to the study, through personal letters, published writings, personal and telephone interviews, and both structured and unstructured responses to interrogation by the investigator.

Thirty-four months were required for the study.

4. A comparative analysis was effected.

ASSUMPTIONS

The findings were limited to these assumptions: (1) the samples were adequate to be representative of the range of interpretations; (2) critical analysis was an appropriate method for identifying areas of difference and similarity in presentation; and (3) definitions adequate for analysis and comparison could be isolated from the groups under study.

FINDINGS

1. These five characteristics were identified as elements of scientific method in the reference (classical) sources: *causation, classification, consensus, experimentation,* and *observation.*

2. Definitions of the five reference elements were substantially agreed upon in the reference literature.

3. With two exceptions, the "steps-to-follow" procedure (after Pearson), although variously presented, was described in textbooks.

4. Junior high school textbooks most emphasized the attitudes of scientists, rather than descriptions of scientific method *per se.*

5. Specialized books in the senior high school category contained diverse presentations, representing mainly the "steps" approach to scientific discovery. Perhaps, on the order of one-fourth of the textbooks used biography or the description of classical experiments as illustrative material.

6. The textbooks substantially agreed, with respect to definitions of *experimentation* and *observation.* Inferred agreement was contained in the textbooks concerning *concensus* and *classification. Classification* was presented in the sense of the taxonomy of scientific realia, not in the sense of the ordering of ideation and knowledge.

7. The scientists' descriptions were characterized by diversity. More interestingly, the biological scientists, the astronomers, the geologists, and the physical scientists were more alike, than divergent, with respect to within-group interpretations.

8. Scientists' presentations varied from a disclaiming of the existence of a scientific method, to outlining in detail, factors, not steps, in scientific methodology. There was appreciable agreement among scientists, that discovery in science is a personal effort, but the presentation of one's discovery follows definite rules of procedure.

9. Agreement among scientists was substantially strong that *experimentation* and *observation* are important aspects of scientific method.

10. *Classification,* interpreted as the ordering of knowledge, was not specifically listed, but was inferentially suggested by the scientists.

11. Scientists, to the extent of approximately one-half of the sample, emphasized the personal nature of scientific discovery and the public nature of its organization. Textbook writers, by contrast, were not so precise.

12. Neither scientists nor philosopher-scientists gave serious consideration to the importance of *consensus.* It may be that *consensus* is the more proper concern of those who write encyclopedias and treatises.

13. Textbook writers worked for simple causes and effects; the philosopher-scientists and scientists attempted to identify and to differentiate between multiple causes and concomitance. Causation was a strong point of inferred variation between scientists and textbook authors. The life scientists agreed that the problem of citing causes was difficult. Certain astronomers and physical scientists expressed concern with empirically constant relationships, rather than with causation.

14. Textbook authors viewed the outcomes of scientific investigation (experimentation or application of the scientific method) as highly certain and usually precise; the scientists sample, by contrast, described scientific discovery as a flexible, dynamic, and not always certain procedure.

15. Scientists recognized that much experimentation is trial-and-success; textbooks generally gave this topic only very brief treatment.

16. The rigidity of definitions in textbooks contrasted strongly with the descriptions of scientists. The static nature of methodology found in textbook presentations is opposed to the dynamic, evolutionary nature of scientific method as described by scientists.

17. Uniformity of presentation of scientific method was a prime characteristic of textbook writings; diversity of description was abundant in the scientists' writings. Textbooks typically centered around the "steps-to-follow"—those steps being, of course, (a) define a problem, (b) form an hypotheses, (c) test the hypotheses, (d) gather data, and (e) form a conclusion.

18. Textbooks presented more rigidly structured approaches to scientific methodology while scientists argued for flexibility, intuition, serendipity, probability, and luck. However, the writings of the scientists did not communicate the idea that scientific investigation is a haphazardly arranged enterprise, operated by undisciplined researchers. The scientists agreed that the rational processes and ideational organization of the researcher may not be revealed by his experimental *modus operandi*.

UNSOLVED PROBLEMS

Certain questions or problems were raised by the investigation; they suggested a need for further study. Among these problems were:

1. Is scientific method an art of such dimension that it cannot be adequately and simply verbalized for inclusion in school science textbooks?

2. Is the "*logic of the discovered*"—the laws of science—instrumental in forming the *logic of discovery*—scientific method?

3. Can a science curriculum be designed for teaching the *process* of scientific discovery?

If the production of science researchers and the early identification and "training" of scientific talent remains one of the important functions of the schools, it appears reasonable to pursue further investigations of these questions in an effort to determine what is "correct" and "teachable" concerning scientific method.