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REPORT ON
THE RELATIONSHIP
OF THE
SCIENTIFIC METHOD
TO
SCIENTIFICALLY
VALID RESEARCH
AND
EDUCATION RESEARCH



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INTRODUCTION

On January 23, 2002 Congress passed H.R. 3801, the Educational Sciences Reform Act, “to provide for improvement of Federal education research, statistics, evaluation, information, and dissemination, and for other purposes.” The act established the Institute of Education Sciences in the Department of Education, to be administered by a Director. The National Board for Education Sciences was also established to advise and consult with the Director on policies of the Institute. The duties are quite demanding, and the Director and Board Members have sworn to faithfully discharge them. They serve without compensation, making a great sacrifice of time and effort for America.

Their task is made especially difficult because of the little-publicized situation that:

Our top educational leaders and educational researchers follow the claim of Dr. James B. Conant (1893–1978), a powerful and authoritative educator and scientist, that the scientific method does not exist.

The scientific literature on the whole acknowledges the existence of the scientific method. This consensus can easily be confirmed by typing “the scientific method” into Google and Yahoo. On November 11, 2005 each showed more than 1,500,000 hits. From a previous rough sampling I made, I estimate that more than 95% are favorable to the existence of the scientific method. Since the general literature also clearly indicates that science is its method, this difference of opinions makes the task of the Board much harder.

The National Science Foundation and the U.S. Department of Education have never awarded grants to research the scientific method. This has contributed to a shortage of reliable knowledge on the subject. In my second career, I have spent 16 years of full-time research on the scientific method and its relationship to education. I have accumulated more than 3,000 books and 16 file cabinets of data. I decided to prepare a short report for Grover J. Whitehurst, Director of the Institute of Education Sciences, the National Board for Education Sciences, the media, Congress, and the public for all to gain a better understanding of available knowledge on the scientific method.

The National Science Foundation and the U.S. Department of Education have never awarded grants to research the scientific method. This has contributed to a shortage of reliable knowledge on the subject.

At its September 2005 meeting, after public comment, the Board for Education Sciences set four long-term goals. I can be of most help on the fourth goal: “developing systems for delivering research on which policymakers, educators, and the public will come to rely.” The scientific method is the system of obtaining scientifically valid research that can be relied upon. It is also part of the system of science in the accumulation of knowledge, and I have a suggestion in this area.

The Board has been directed by Congress “to solicit and consider the recommendations of education stakeholders, in order to ensure that there is broad and regular public and professional input from the educational field in the planning and carrying out of the Institute’s activities.” I have taken the initiative of preparing this report in an effort to be of assistance to the Board and others in understanding this complex matter.

THE STATUS OF EDUCATION RESEARCH IN 2005

The literature is filled with statements that education research has been highly unreliable. Additional evidence can be found in Congress' dissatisfaction to the extent that it passed H.R. 3801 on January 23, 2002 "to provide for improvement of Federal education research, statistics, evaluation, information, and dissemination and for other purposes."

Basic Cause of the Unreliability of Education Research

The basic cause of the unreliability of education research is the non-use of the scientific method, which is not only for scientists. The scientific method is the complete method of creative problem solving and decision making for all fields. Often education researchers

- Do not go through all the mental activity stages of the scientific method.
- Ignore or do not search enough for contrary evidence.
- Fail to attempt to falsify their hypotheses before reaching a conclusion.
- Do not acknowledge or realize that they are subject to the same code of ethics as those in the natural sciences in terms of government grants.

Brief History of the Scientific Method in the Field of Education

John Dewey's book *Sources of a Science of Education* (1929) discusses education as a science. I quote from the 60th anniversary edition of Dewey's book *Experience and Education* (1938):

It is argued that science and its method must be subordinated; that we must return to the logic of ultimate first principles expressed in the logic of Aristotle and St. Thomas, in order that the young may have sure anchorage in their intellectual and moral life, and not be at the mercy of every passing breeze that blows.

For a number of years after 1938 educators were interested in the scientific method to the extent that it became one of the primary aims of modern education.

I see at bottom but two alternatives between which education must choose if it is not to drift aimlessly. One of them is expressed by the attempt to induce educators to return to the intellectual methods and ideals that arose centuries before the scientific method was developed. The appeal may be temporarily successful in a period when general insecurity, emotional and intellectual as well as economic, is rife. For under these conditions the desire to lean on fixed authority is active. Nevertheless, it is so out of touch with all the conditions of modern life that I believe it is folly to seek salvation in this direction.

The other alternative is systematic utilization of *scientific method* as the pattern and ideal of intelligent exploration and exploitation of the potentialities inherent in experience. [emphasis mine]

For a number of years after 1938 educators were interested in the scientific method to the extent that it became one of the primary aims of modern education (Conant, 1947).

Unfortunately, after the publication of *On Understanding Science* (Conant, 1947), the situation changed dramatically. In a number of his books, Conant erroneously claimed that the scientific method does not exist.

Professor Jack Easley (1922–1994) wrote as his doctoral thesis a 30-page essay entitled *Is the Teaching of Scientific Method a Significant Educational Objective?* He challenged and, I believe, falsified Conant’s views and contrasted Dewey’s, Schwab’s, Conant’s, and his own views on scientific method. The essay was published in *Philosophy and Education: Modern Readings* (1958). Easley also wrote “Scientific Method as an Educational Objective” (in *Encyclopedia of Education*, 1971). Unfortunately, his research was ignored.

...national education reform programs from 1957 to the present do not include the teaching of the scientific method

An example of the change is the fact that national education reform programs from 1957 to the present do not include the teaching of the scientific method and a formula for its stages.

In contrast to the non-inclusion of the scientific method in national education reform programs, about 65% of science textbooks used in K–12 and universities have continued to cover the scientific method in discussions of 1 to 30 pages and often included a formula for it.

For a while, some books on education research continued to stress the use of the scientific method in education research; *The Art and Science of Investigation* (Mouly, 1978) and *Educational Research – An Introduction* (Borg and Gall, 1971) are two examples. Although I have not made a survey, I believe that current books on education research do not include the scientific method.

What happened in the educational field and the other social sciences is described by Steve Fuller in *Thomas Kuhn: A Philosophical History of Our Times* (2000). He states:

All of these revelations induced a collective sigh of relief from practitioners of the humanities and the social sciences, who had a hard enough time making sense of each other, let alone agreeing on a common method. They quickly latched on to Kuhn's ideas and declared that they too were respectable knowledge producers laboring under paradigms.

Operating under paradigms is not an efficient procedure. It is the scientific method that is the greatest quality control method ever recognized and developed.

In his book *Of One Mind: The Collectivization of Science* (1995), John Ziman, whose work was cited by the U.S. Supreme Court in the *Daubert* decision, says, “This principle can be stated quite easily: the goal of science is a consensus of rational opinion over the widest possible field.” A Google search for “scientific method” results in more than 1.5 million hits. Google searches for “scientific method does not exist,” “scientific method alleged method,” “scientific method no one method” result in a very low number of hits. This is an indication that the use of the scientific method by educational researchers deserves serious consideration.

THE RELATIONSHIP OF THE SCIENTIFIC METHOD TO SCIENTIFICALLY VALID RESEARCH

Considerations in Defining Scientifically Valid Research

In the Reading Excellence Act of 1998 and the No Child Left Behind Act of 2001 scientifically based research is specified many times. H.R. 3801 calls for scientifically valid research.

In *The Scientific Approach – Basic Principles of the Scientific Method* (1967) psychologist Carlo Lastrucci states:

I.1. In spite of the tremendous influence of science upon modern civilization, there exists as yet no standardized definition of science. Laymen, scholars, and scientists themselves define the term in varying ways and employ it in a variety of contexts . . .

I.2 Checking the definition of the adjective “scientific” does not help very much to determine its essential features. According to a standard source, the word “scientific” is derived from the Latin word *scientia*, meaning knowledge, plus the term *facere*, meaning to make; both terms were originally employed as a translation from the Greek term *episthemonikos*, or making knowledge (from which the modern term *epistemology* is derived, meaning the study or theory of the origin, essence, methods, and limits of knowledge.

Based on my 16 years of specialized research of the scientific method, I will define “scientifically valid research.”

What Is Research?

The *American Heritage Dictionary* defines the noun research as:

- (1) Scholarly or scientific investigation or inquiry. (2) Close, careful study.

Let us examine the dictionary definition.

“Scholarly” – The method of scholars is another name for the scientific method. Time and scholarly study have shown the scientific method to be the best method of obtaining reliable knowledge. Thus, “scholarly” means using the scientific method.

“Scientific investigation” –Back in 1863, T.H. Huxley told us:

The method of scientific investigation is nothing but the expression of the necessary mode of working of the human mind. It is simply the mode at which all phenomena are reasoned about, rendered precise and exact.

Please note that Huxley stated “the mode [method] at which all phenomena are reasoned about, rendered precise and exact.” Research is far from simply using common sense. It requires disciplined inquiry.

So again, research basically means using the method of investigation, which is the scientific method.

“Inquiry” – Inquiry is necessary in research, but just inquiry can result in aimless wandering unless the method of inquiry, which is the scientific method, is followed.

“Close, careful study” – To conduct close, careful study, you must follow, in complex matters, the method of study, the scientific method. Centuries of research have established this as reliable knowledge.

Conclusion. An accurate interpretation or definition of the word “research” is research based on and following the method of research, also called the scientific method.

The word “research” has often been carelessly or broadly used and interpreted. In addition, any time someone conducts research, he/she does not have to go through all the stages of the process. An accurate definition has generally not been understood. Thus, Congress added descriptive words to ensure that the “research” called for was the correct type and “scientifically valid.”

The Meaning of “Valid”

In H.R. 3801 the term scientifically valid research is used. The definition of valid is:

well grounded, produces the desired results, having legal force

In *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993), the U.S. Supreme Court ruled:

“But, in order to qualify as ‘scientific knowledge’ an inference or assertion must be derived by the scientific method. Proposed testimony must be supported by appropriate validation – i.e., ‘good grounds,’ based on what is known.” [emphasis added]

Conclusion. Research must be based on or validated by use of the scientific method. It must thus be well grounded and based on our body of reliable knowledge but at the same time viewed skeptically because of its changing nature.

Here is a review of some of the things science and scientific method (SM-14) are based on or valid and a comparison with the opposite, unscientific base, or not scientifically valid.

Base of SM-14 Formula for the Scientific Method	Unscientific Base Not Scientifically Valid
<u>Eleven stages of mental activity.</u> Used in a flexible manner to originate, refine, extend, and apply knowledge.	<u>Proceeding haphazardly.</u> Going ahead without a guide or without following a complete act of thought.
<u>Creative, non-logical, logical, and technical methods</u> are applied following the scientific method guide at each stage to accomplish results.	<u>Techniques (often called methods)</u> are used but there is no quality control as to how they are used.
<u>Procedural principles and theories.</u> Provide fundamentals of good and ethical procedures to follow at various stages.	<u>No quality or ethics.</u> Proceeding unregulated usually produces unreliable results.
<u>Attributes and thinking skills.</u> Provide quality guidance.	<u>No personal quality standards.</u> Often results in poor work.

H.R. 3801-5 defines scientifically valid research as: “(20) Scientifically Valid Research. – The term ‘scientifically valid research’ includes applied research, basic research, and field-initiated research in which the rationale, design, and interpretation are soundly developed in accordance with scientifically based research standards.” The scientific method as it has been used and described in the literature covers all of these.

What Is Scientifically Valid Research?

Scientifically (or science)

- Practitioners, including teams, doing scientifically valid research must then utilize the accumulated body of reliable knowledge, but considering the usual skepticism afforded any knowledge by the procedural principles of the scientific method.
- Since science is fundamentally method, its method must be used – the scientific method.

Valid

The foundation must be on science, which is fundamentally method – the scientific method. The validity of the scientific method has been established by the U.S. Supreme Court.

Research

Research in the strict and correct meaning of the word means research following the scientific method.

Conclusion. The total meaning of the phrase “scientifically valid research” means and emphasizes research following the scientific method.

SUMMARY OF THE MISUNDERSTANDINGS AND ERRONEOUS CLAIMS ABOUT THE SCIENTIFIC METHOD

A definite pattern can be found as to why the false claims against the scientific method are erroneous. These reasons are illustrated by Claude Bernard in *An Introduction to the Study of Experimental Medicine* (1865, trans. 1957):

The art of investigation is the cornerstone of all the experimental sciences. If the facts used as a basis for reasoning are ill-established or erroneous, everything will crumble or be falsified; and it is thus that errors in scientific theories most often originate in errors of fact.

False Claims Against the Scientific Method	Explanation and Falsification of These Misinterpretations
<p>“Alleged” scientific method. No one method. No such thing. No one method for all fields.</p>	<p>This is a clear case of getting the “facts” wrong by misinterpreting the word “method.” In this case method is not a technique which, if applied, will actually solve a problem. Instead, it is a collective term for the types of mental activity that define the stages of the scientific method.</p>
<p>Science is a culture.</p>	<p>Yes, but one that the literature shows is best described as the scientific method.</p>
<p>There are many different forms of observation, measurement, and study design.</p>	<p>Yes, but centuries of study and experience have shown that there is a general pattern to the mental activity stages of the research process. They have most commonly been termed the scientific method or scientific method.</p>
<p>It is a myth, a fallacy, an artificial method.</p>	<p>Misinterpretation of the scientific method leads to claims that it is a myth, a fallacy, or an artificial method. Getting the facts wrong falsifies these claims.</p>
<p>It is a rigid method of steps. Mindless adherence to a rigid series of steps.</p>	<p>In actual use, the scientific method is very flexible and allows one to backtrack, loop, skip, detour to sub-problems, and interplay. Stages is a better word than steps for the phases.</p>
<p>It is only a rational method. One set of logical rules.</p>	<p>Karl Pearson (in <i>The Grammar of Science</i> [1892]) and John Dewey (1910) long ago explained that imagination and creativity are essential ingredients of the scientific method.</p>
<p>It is only a textbook method.</p>	<p>Formulas in textbooks are usually condensed, but many are good enough to get the concept across.</p>

False Claims Against the Scientific Method	Explanation and Falsification of These Misinterpretations
Nobody has successfully abstracted the pattern of the scientific method. It is best learned by working alongside an experimenting scientist.	Ross (1930), Crooks (1958), Cope (1978), and other authors have shown a reasonably good general pattern for the stages of the scientific method
Advances in scientific knowledge are achieved by the self-regulating norms of the scientific community over time, not, as sometimes alleged, by the mechanistic application of a particular method to a static set of questions.	True, as far as being one description of the way scientific knowledge is achieved. However, the self-regulating norms are the scientific method system. This description attempts to discredit the scientific method by describing it (incorrectly).
It is the method only scientists use.	Wrong. Many authors point out that it is a universal problem solving method used in all fields.

To the best of my knowledge, my library and files constitute the best collection of information on the scientific method in a concentrated or easily accessible area. They are available for use by the Department of Education, the National Board for Education Sciences and its staff, and the media.

THE SCIENTIFIC METHOD GAINS LEGAL STATUS

A historic event occurred in 1993. In the *Daubert v. Merrell Dow Pharmaceuticals, Inc.* [(509 U.S. 579 (1993))] decision, the U.S. Supreme Court ruled:

But, in order to qualify as “scientific knowledge” an inference or assertion must be derived *by the scientific method*. Proposed testimony must be supported by appropriate validation – i.e., “*good grounds*,” based on what is known. [emphasis mine]

The American Association for the Advancement of Science and the National Academy of Sciences filed a joint brief. These are two of our most prestigious organizations, so it is readily understood why the Court would pay special attention to their brief. The following are some statements from the joint brief.

Science thus involves far more than the mere observation. Valid science must also explain and clarify relationships. The key to valid science is a convergence of well reasoned explanation with supporting observations or experimental results. No discrete set of experiments can establish that an hypothesis is true in all situations. Rather, scientists conduct rigorous experimental testing in an attempt to falsify hypotheses. An hypothesis is accepted as generally valid to the extent that it has survived repeated attempts at falsification. “Observation, reason, and experiment make up what we call the scientific method.” n8

n8 R. FEYNMAN, R. LEIGHTON & M. SANDS,
THE FEYNMAN LECTURES ON PHYSICS 2-1 (1963)

To avoid lawsuits in the future, the attorneys for government agencies, universities awarded government grants, and others should study whether educational researchers holding government grants are required under this decision to follow the scientific method.

A direct reference by the Court to the scientific method:

A new theory or explanation must generally survive a period of testing, review, and refinement before achieving scientific acceptance. This process does not merely reflect the scientific method, it is the scientific method. n15

n15 See J ZIMAN, RELIABLE KNOWLEDGE: AN EXPLORATION OF THE GROUNDS FOR BELIEF IN SCIENCE 130-32 (1978); Relman & Angell, How Good Is Peer Review? 321 NEW ENGL. J. MED. 827, 828 (1989).

To avoid lawsuits in the future, the attorneys for government agencies, universities awarded government grants, and others should study whether educational researchers holding government grants are required under this decision to follow the scientific method. H.R. 3801 specifies scientifically valid research, which is really research following the scientific method. Again, are they not required under this act to follow the scientific method?

TRANSFORMATION OF EDUCATION INTO AN EVIDENCE-BASED FIELD BASED ON THE SCIENTIFIC METHOD

The aim of transforming education into an evidence-based field is a great goal. After so many years of fads based on researchers' personal experiences and untested ideas, the change to education based on evidence would be a significant advance.

The tool to use in this transformation is the scientific method, which is the basic method of research for all fields.

Here is why the scientific method should be the method used:

- “Evidence-based” is a little too vague. The scientific method has a more complete existing base. It is well established.
- The program for which evidence is provided may not be the best. It may not have gone through all the stages of the scientific method and thus could be defective, even if there is evidence to support it. For example, in the past, fad after fad has been promoted. The promoters provide “evidence” to support their programs but also ignore contrary evidence. In addition, no falsification attempt may have been made.
- I remind you that, of all the quality control methods ever recognized and developed, the scientific method has been found to be the best. It is a method, a guide, and a system.

Many authors claim that the aim of science and the scientific method is to find the truth. Because “the truth” can mean so many things, others claim it should be “the truth as near as it can be determined.” Even better is “On the evidence available today, the balance of probability favors the view that . . .” (V. Gordon Childe, 1936).

Randomized Controlled Trials

Randomized controlled trials are a technique or method used widely. They fall under ingredient 12 of SM-14, Creative, Non-logical, Logical, and Technical Methods.

There is no question that the application of randomized controlled trials following the scientific method will improve results in many cases. However, the programs that reach this stage must first have been designed following the beginning stages of the scientific method.

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AN ANALYSIS OF “EDUCATIONAL RESEARCH SHOULD FOLLOW THE MEDICAL MODEL”

Recently there have been hundreds of comments that education should follow the medical mode.

What Is the Medical Model?

If you analyze the medical field, you quickly find that this field made little progress until its practitioners and researchers began to follow our natural scientists and use the scientific method. Two influential and well-known books in the medical field are *An Introduction to the Study of Experimental Medicine* (1865) by Claude Bernard and *The Way of an Investigator – A Scientist’s Experience in Medical Research* (1945) by Walter B. Cannon.

Dr. Bernard wrote:

Reasoning is always the same, whether in the sciences that study living beings or in those concerned with inorganic bodies. But each kind of science presents different phenomena and complexities and difficulties of investigation peculiarly its own.

Here is what Harvard professor Cannon wrote in 1945:

The chief grievance which the popularizer expresses is that the teaching of science in grade schools, high schools, and even colleges does not result in a public with a sufficient background of knowledge to allow understanding of the simplest account of new advances. This is a deplorable situation. For a hundred years scientific investigators have been transforming the civilized world. The progress of knowledge in recent times is **chiefly progress in knowledge of science and the scientific method**. The investigators in physics, in chemistry, and in the medical sciences have brought about conditions, within the life span of many now living, that would seem to their fathers nothing short of miraculous. [emphasis mine]

*The progress of
knowledge in recent
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scientific method.*

Thus the real story is that education should follow the natural science model – the scientific method, not the so-called medical model, which is really the scientific model. Those promoting the medical model often refer to the other method as the “physics model.” The literature seldom uses the term. The term used is the natural science model. Many point out that the natural science model is a general method for use by all domains. The scientific method is the idea that has most changed the world for the better.

STAGE 4 OF THE SM-14 FORMULA FOR THE SCIENTIFIC METHOD IS GENERATE CREATIVE AND LOGICAL ALTERNATIVE SOLUTIONS

Here are possible solutions to the meaning of scientifically valid research, along with my opinions of them.

Some of the leading solutions include:

1. Educational research is research following the scientific method. Education is a social science and should follow the natural sciences, which historically have followed the scientific method.
2. Research based on evidence. This is good but not complete enough. Any complete definition of “evidence” will lead you back to the scientific method.
3. Research following the medical model. The medical model came from the natural sciences and thus leads us back to the scientific method.
4. Research is to use randomized trials. Although randomized trials are one of the established techniques or methods used at stages of the scientific method, it is not a complete system of research.
5. Research is the culture of science. A Google search on November 18, 2005 showed 66,600 hits for “culture of science” and more than 1.5 million for “the scientific method.” The culture of science is merely a general term and does not have a full historical base in the literature as does the scientific method.
6. Research is the norms of science. In *Scientific Research in Education* (2002) by the Center for Education of the National Research Council under the heading Nature of Science a claim is made that advances are made in scientific knowledge by the self-regulating norms of the scientific community over time and that six guiding principles underlie all scientific inquiry, including educational research:
 - Pose significant questions that can be investigated empirically.
 - Link research to relevant theory.
 - Use methods that permit direct investigation of the question.
 - Provide a coherent and explicit chain of reasoning.
 - Replicate and generalize across studies.
 - Disclose research to encourage professional scrutiny and critique.

These are descriptions of some of the stages of the scientific method. Compare them to SM-14. They do not constitute a complete description of the research process, are not a good teaching formula for all grades, and in general are not a good analysis.

7. Research is the hypothetical-deductive method. This normally starts with the hypothesis and is not as complete as the scientific method.

8. Research is paradigms of education. Some educational researchers in recent years have claimed that they follow paradigms. Since educational research has been so unreliable, this should not be an alternative. Paradigms have no substantiated base in the literature as a method of research.

9. Research is . . . (develop a new definition). Considering the complexity of the subject, this would be a highly impractical approach.

In evaluations of possible solutions, the scientific method is by far the most likely solution, as long as it is properly defined. It can be challenged, but I believe it is not fruitful to do so, as it has survived so many challenges already.

10. Others I may have overlooked.

IMPORTANT POINT

In preparing H.R. 3801 and the definition of scientifically valid research and scientifically based research, Congress and its staff consulted many educational leaders and educational researchers. Indications are that these people did not provide information on the existence of the scientific method and its extensive descriptions in the literature.

Instead they furnished various definitions that are about some of the features, techniques, methods, procedural principles, and theories of the scientific method. This has resulted in vague and confusing definitions of these important terms Congress wants followed.

As H.R. 3801 specifies that the Institute conform to high standards, I believe it has the duty to go outside the group ignoring the scientific method for knowledge of the scientific method. My extensive research indicates that scientifically valid research will never be achieved without the use of the scientific method (SM-14 type or similar).

THE ACCUMULATION AND DISSEMINATION OF KNOWLEDGE

One of the principles of science is that reliable knowledge is accumulated and built up to enable further refinement, extension, and application.

Another principle is that there should be dissemination of knowledge. H.R. 3801 specifically calls for the dissemination of scientifically valid research.

In the past and at present in the educational field there have been educational research centers. My observations are:

- A single center often covers much too large a subject area to fulfill the country's needs.
- Some such centers are really advocacy centers for unreliable or biased views.
- They try but do not follow a proper vision statement and the scientific method (SM-14 or similar).
- A few may produce reliable knowledge, but they do not gain recognition for the quality of their work for a variety of reasons.

Need for a System of Permanent Specialized SM-14 Type National Research Centers

In this era of great increases in research and knowledge, there is an ever-increasing need for specialization. These centers should be accumulators, evaluators, originators, refiners, extenders, and disseminators of reliable knowledge in specialized areas. They would earn the reputation for being the recognized authority in their specialty. They would usually be located at colleges and universities, and permanently financed by government, foundations, etc. There would have to be a large number of "mini specialized institutes."

At the present time educational researchers have the heavy burden of having to search for and depend upon individual grants from the National Science Foundation, the U.S. Department of Education, other government agencies, foundations, etc. This is not a productive or efficient method of doing educational research or a productive or efficient use of researchers' time and effort.

This change would help end the situation we have today of so much unreliable knowledge being produced and researchers simply writing for one another. This is not productive and a waste of taxpayers' funds.

THE SCIENTIFIC METHOD

A Well-Researched Description of the Problem Solving and Research Process

The SM-14 Formula for the General Pattern of the Scientific Method

- | | |
|---|---|
| 1. Curious observation | 7. Make the educated guess (hypothesis) |
| 2. Is there a problem? | 8. Challenge the hypothesis |
| 3. Goals and planning | 9. Reach a conclusion |
| 4. Search, explore, and gather the evidence | 10. Suspend judgment |
| 5. Generate creative and logical alternatives | 11. Take action |
| 6. Evaluate the evidence | |

Supporting Ingredients:

12. Creative, non-logical, logical, and technical methods
13. Procedural principles and theories
14. Attributes and thinking skills

The research process is not just a collection of miscellaneous “scientific methods.” Scientists and other researchers do not proceed in a haphazard fashion. Centuries of trial and error, research, discussions, and debates have led to a realization of the general pattern of the scientific method. The pattern represents the major stages of how we originate, refine, extend, and apply knowledge in all fields. The method of science has been called by many names, most commonly the scientific method. It is also a complete method of creative problem solving and decision making for all fields.

There Are 11 Major Stages (1–11) of the Scientific Method

Each stage (1–11) represents a different type of mental activity (usually aided by physical actions). The method is subject neutral.

Flexible order of use. While the stages are listed in the usual order of use, in actual practice they will be used in a very flexible manner, as progress on complex problems is seldom smooth. There will be backtracking, skipping, false starts, looping, sub-problems, and other diversions.

The Supporting Ingredients (12–14) of the Scientific Method

These are included in the SM-14 formula as ingredients rather than stages to help people understand “the method” and as an aid to teaching it to students and others. Presenting only the stages does not give a complete picture of the overall system. The scientific method is the master method of all methods. The word “method” in the term “the scientific method” is a collective term for the stages. “Scientific” qualifies how scientists and others have historically used the stages to accomplish results.

The Complete System of Science and Problem Solving

The SM-14 formula embodies the complete method of science – its stages, techniques, procedural principles and theories, and attributes and thinking skills needed.

[Abstracted from *The Scientific Method Today* by Norman W. Edmund. It may be viewed at www.scientificmethod.com.]

SUMMARY OF THE ADVANTAGES OF THE SCIENTIFIC METHOD

It Is the Most Reliable of All Methods of Knowledge

The literature indicates that, after centuries of experience, the scientific method is the most reliable of all research methods for originating, refining, extending, and applying knowledge. It provides a base for a profession to become a science. It is a self-correcting method. It requires that the problem be properly defined, that a complete search and evaluation of all possible solutions be made, that the hypothesis be challenged, and that the final conclusion be peer reviewed if required.

Creative, Non-logical, Logical, and Technical Methods or Techniques

These are used at every stage of the scientific method. New ones are developed every day, but there is a whole body of existing ones that have been well developed, such as statistics, surveying, randomized trials, and many others.

There Is a Code of Ethics for the Use of the Scientific Method

Natural scientists have established a code of ethics for researchers, and there are government regulations for enforcement in government contracts. Human nature and competitive practices make an enforceable code of ethics a necessity.

Standard Formula for the Scientific Method

For centuries a variety of formulas were available for the mental activity stages of the method. The SM-14 formula is now suitable to be a standard.

The Scientific Method Has a Legal Basis

The *Daubert v. Merrell Dow Pharmaceuticals* decision by the U.S. Supreme Court provided a legal basis and recognition for the scientific method.

In the Event of Disputes

There is an existing body of knowledge, literature, and experience regarding the scientific method to which we can refer.

One Method or Guide Covers All Fields of Endeavor

Since the scientific method is a universal method or guide, it can be taught across the curriculum. It covers research in all areas, scientific management, entrepreneurship, medical practice, teaching, vocational and technology trades, all professions, etc. Some of these require special creative, non-logical, logical, and technical methods or techniques as well as standard ones to be used at the various stages of the scientific method. However, the basic mental activity stages are universal.

THE IMPORTANCE OF THE DECISIONS MADE BY THE NATIONAL BOARD FOR EDUCATION SCIENCES

Education and training constitute America's largest industry, with expenditures estimated to range from \$750 billion to \$1 trillion per year.

If the Board makes a correct decision about the scientific method, the effectiveness of educators' expenditures and efforts will increase dramatically.

If the scientific method is recognized and taught in kindergarten through college and across the curricula, all domains will benefit greatly because the scientific method is the complete method of creative problem solving and decision making for all fields, including our personal lives.

The Board's decisions will affect not only education but also

- America's future prosperity
- Our world competitiveness
- Our world leadership in science and technology
- The future of business and industry
- Our health and safety

If the Board does not recognize the scientific method, the misunderstandings about it may continue longer than they otherwise would.

Standards and testing in science under the No Child Left Behind Act are supposed to begin in the 2007–2008 school year. If the Board does not approve the scientific method, these standards and tests will probably not include the scientific method.

