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Science & Technology in Education:
What Kind of a Marriage Is This?

By FRANKLIN G. FISK

In the 1890's a group of American schoolmen returned from Europe with degrees of Doctor of Philosophy earned studying with the disciples of Johann Friedrich Herbart. Herbart in a preceding generation had made one of the first attempts at a systematic psychology involving a theory of learning which had obvious pedagogical applications. The increase in the number of common schools in both Germany and the United States in the 19th Century had created many problems. A large number of teachers needed to be trained and new techniques and strategies of teaching became worthy of serious study. Herbartianism, with its systematic theory and practical method, seemed ideally suited to meet the needs of schools and teachers of that time. The returning American schoolmen, Charles DeGarmo, the McMurray Brothers and C. C. Van Liew had wholeheartedly adopted Herbartianism as taught by Zille rand Zein. Upon returning to the United States these schoolmen began immediately to proselyte in favor of Herbartianism as a scientific approach to the problems of education. Among their many activities was the establishment of the National Herbartian Society which in 1902 became the NSSSE, the National Society for the Scientific Study of Education. This organization a few years later became the NSSE, the National Society for the Study of Education. The NSSE, based at the University of Chicago, is still active today publishing each year two volumes studying in great detail a part of American education. These American Herbartians were also responsible for the translation and American publication
of Herbart's *The Science of Education*.\(^1\) Herbartianism with its teacher proof technology—the five step method of the recitation involving preparation, presentation, association, generalization and application and the curriculum doctrines of concentration and correlation—was promoted as *the scientific solution* to the problems of education.

Why did educators turn to science? One reason was not knowing the answer to many completely novel and pressing problems. Rising enrollments and a changing composition in the school population had created intense pressures for change. Moreover, the turn to science by educators, was also due to the great success of the sciences of physics, chemistry and biology in the 19th century. The sure knowledge gained through science in these subjects was being used to create a whole system of scientific technologies, technologies which were responsible for an improved existence. Science was so successful in supporting technology that to this day most people consider inventors such as Edison and Morse as scientists. So educators turned to science to help establish valid technologies for the schools.

Herbartians were not the only ones who wanted to put education on a scientific basis. The relation of psychology to education was obvious, in fact, psychology soon came to be considered the key for a scientific basis for adequate technologies in education. Edward L. Thorndike, who received one of America's first Ph.D.'s was a leading proponent of the scientific approach to the study of psychology and education. He has been influential, perhaps more than any other single person, in affecting American Education from 1910 to the present. The results of his psychological research revealed many of the inadequacies of the speculative psychologies of Herbartians, formal disciplinarians, and those believing in faculties residing in the mind. It was Thorndike who created the oft-quoted educational aphorism, "We learn to do by doing"—rather than John Dewey—Dewey stated that we learn *from* doing, but not from doing alone. Learning by doing as a pedagogical principle was a direct deduction from the psychological principles of Thorndike. According to Thorndike these principles had been established through scientific experimentation. It is more than coincidental that the Scottish sensationist, Alexander Bain, under whom Thorndike had studied had published a book in the 1890's entitled, *Education as a Science*.\(^2\)

The Education-as-a-Science movement became more respectable when early in this century the American Association for the Advancement of Science established a section called, Education as a Science. Today this is Section Q. This section was to be a group for those

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who were interested in studying education in a scientific manner. At present Section Q has developed into a science-teacher or science-education group and devotes most of its symposia to the problems of teaching science and not scientific teaching. Many other examples are available which would show the intense interest during the early part of the 20th century in making education scientific—in getting valid technologies—such as the correct answers to what should be taught and how it should be taught.

What has been accomplished in the past 70 years as a result of this scientific movement in education to create an adequate technology of education? Whatever the results, there was far less accomplished than had ever been claimed as possible. Why the discrepancy between rhetoric and realization? It is my contention that the claims for what could be accomplished from a scientific approach to education have been much greater than what has been accomplished because the scientific approach to education has not been and is still not scientific.

Reducing pedagogical problems to scientific problems is possible if one, they are first the type of problem that can undergo a scientific reductionism, and, two, if the person doing the reduction has an adequate understanding of scientific epistemology and ontology. It is my contention that most people have not had such an adequate understanding. In supporting my contention I would like to concentrate my attention upon educational measurement and educational research.

In the past 70 years the Education-as-a-Science movement had its greatest impact in testing and evaluation, educational research, and teaching techniques based on psychologies of learning. The failure of Education-as-a-Science to accomplish all that was claimed comes from equating measurement with science, collecting facts and analyzing them into patterns as scientific research, and confusing classroom environments with those in the laboratory. There are to be sure other mitigating factors which hindered innovation, but if the innovation was based on misconstrued premises it will surely be handicapped in its realization. Additionally, part of the present reluctance to innovate can also be traced to the appearance of one fool-proof panacea after another with the results being that they were neither fool-proof nor panaceas. Most of the fool-proof and revolutionary innovations in education in the past 70 years have been failures. True, there has always been some question as to how wholeheartedly innovations have been accepted by the schools, e.g., say progressive educational technologies, but yet many innovations were ill-conceived or else failed to recognize the complexities of the educational environment. That present innovations are meeting with about the same rate of failure is not so apparent. The United States Office of Education recently listed 10 educational innovations in the last decade that were failures. Among these were team teaching and the nationwide revision of a
physics course. There are, of course, more than these ten that have been either thwarted or aborted. Read only the perceptive and knowledgeable essays by Anthony Oettinger titled *Run, Computer, Run* and *The Mythology of Educational Innovation.*3 Oettinger in his final chapter quotes from John Gardner's *No Easy Victories.*4 The quote is:

The roller coaster of aspiration and disillusionment is amusing to the extreme conservative, who thought the aspirations were silly in the first place. It gives satisfaction to the left-wing nihilist, who thinks the whole system should be brought down. It is a gold mine for mountebanks willing to promise anything and exploit any emotion. But it is a devastating whip-saw for serious and responsible leaders.

Oettinger follows this quote writing:5

We have seen that educational technology has not re-formed—much less revolutionized—education as dispensed in our schools . . . . Numerous economic, institutional, intellectual, and technical barriers account for this failure. The formal educational system is bound to society in a way that is almost ideally designed to thwart change. Little substantive technological change is therefore to be expected in the next decade (the '70's) . . . .

The schools haven’t got any money. Universities, non-profit creatures of the government, and private industry haven’t got any ideas save the present innovation fad, which favors highly visible quickie approaches creating the illusion of progress. No one is able or willing to take time and risks.

Let us now return to the technology called educational measurement. Since physics was considered to be the most successful of sciences—it followed that research should then be modeled after physics. Since accurate and careful measurement was essential to the progress of physics, then if you wished to be scientific you must be able to measure carefully and accurately. It is easy to see how accurate measurement could be equated with being scientific. For some early commentators in the 20th century, measurement was the only process by which you know something—if you could not measure it, it was impossible to know it. Following this line of reasoning, knowing means being scientific.

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5 Ibid., p. 215.
Perhaps the person most responsible, if responsibility can be assigned, for this truncated view of science was Karl Pearson. His *Grammar of Science* presented an inadequate view of the nature of science and was unfortunately very influential in the Education-as-a-Science movement. Since essay examinations were difficult to convert to scaled measurements—the short-answer examination with its objective scoring and essential quantification rapidly took its place in the schools. A new technology entered American education—a technology purportedly based upon science. I wish to emphasize that this new technology did not represent any fall from a previous Golden Age—far from it. But it did not necessarily improve schooling. The introduction of short-answer examinations may also represent more than an attempt to be scientific since necessity is frequently the “mother of invention.” With rising enrollments and larger classes it was becoming impossible to check essay examinations—so why not use short-answer examinations! With short-answer examinations you could get both a numerical score (a quantification) and you could do it quickly. How could anyone lose—you were being both scientific and efficient at the same time. Who cared if it was not known what was measured or what were the essential characteristics of a valid measuring device.

Physics does involve measurement, very careful measurement, but physical measurement is constructed with great care so it is seldom ambiguous on what it is measuring. But accurate measurement is, of course, not all there is to physics. Nevertheless, a clear operational definition of what is measured, a careful determination of whether or not the measurement scale is linear and a careful determination of the amount of error in the measurement has for the most part been totally neglected in educational measurement in the schools. Test scores may be numbers but they are not necessarily measurements. Confusing number with measurement is an all pervading myth in our society. Teaching that a measurement is an absolute entity, a point on a scale rather than a fuzzy indeterminancy with an estimated boundary, borders on the criminal when you start to use test scores as measurements in making important decisions. When mathematics instructors start to realize that a table which measures 12 inches by 12 inches has an area of 140 inches\(^2\) and not 144 inches\(^2\) we might be able to make some progress on this pervasive confusion. Every measurement carries with it an error and this error is an inseparable part of the measurement. With no knowledge of the error in a measurement it cannot be considered a measurement. I remember well a class taken as an undergraduate. In this class you needed exactly 263 points to receive a grade of A, no more and certainly no less. I was awarded 263 points, a good friend,

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262 points—I received an A, he a B. All the points were received from scores on short-answer examinations. These scores were obviously considered accurate measurements. Yet no one even raised the possibility that these scores did have an error. How much error?—It was probably of the order of + or − 15 points. This meant that by using these total scores and this error one could see a difference in performance only when the difference in scores was 30 points. It is only incidental, but poignant, that the department which could see a difference in 1 point where only a difference existed for 30 points was a department of physics. I have found that the many textbooks in educational measurements that I have examined concerning how test scores are used in the classroom that instructions concerning the proper handling of error in a measurement is completely absent. My own standardized test which took over two years to produce and was tried on some 8,000 students before being revised and published has an estimated standard error of + or − five points.7 This means that if two people have a difference of 10 points in scores on my examination there is a 2/3 chance that this is a real difference but there is a 1/3 chance that this difference could have happened by chance alone. One cannot discriminate where a difference does not exist. Banesh Hoffman, a persistent and sometimes off-base critic of short-answer examination has not even begun to see the problem associated with error in the treating of test scores as measurements.8 If test scores are measurements, then the errors must be known. If the error cannot be determined then you are not measuring but playing with numbers—a professional numerologist. Kepler and the Platonic tradition to the contrary, science is not numerology even if much educational measurement approaches it. When teachers fully understand how measurements must be interpreted when the error is considered along with the test score many want to give up educational measurement altogether. This is indeed unfortunate. An article written within this past year and published in a British science teaching journal discussed the problem associated with teachers realizing that their test scores have an error, in many cases mostly indeterminate.9 What was the writer’s solution: it was to keep the teachers uninformed for the present because if the word was out the teacher would then lose confidence.

This intense need for any technology, however defective, because of the immediacy of the problems facing teaching at all levels may well be the most destructive influence we have operating in our schools

today. Rather than say we do not know, we keep up the facade that we are knowledgeable. How can there be improvement sharpening our technologies when we completely ignore their inadequacies. That many technologies are inadequate as used in the schools is seldom recognized. Failure to achieve stated goals is usually blamed on the practitioner’s deficiencies or else on some innate or adopted disposition of the pupil.

Measurement is a tricky process and it is especially tricky when it is being used to measure something that has not yet been measured. The objectivity of short answer examinations, therefore, is misleading, especially if the scores are not treated as measurement. Many people label short answer examinations objective examinations. Since objectivity is one of the characteristics of being scientific then short answer examinations labeled objective begin to take on the appearance of being scientific. Even if the classroom teacher considers the error of measurement, the kind of scale used, the identity of what is being measured, he is not necessarily being scientific, only careful and systematic.

Another measurement technology presented as having a scientific basis has been the use of the Gaussian Distribution as a model for deciding the distribution of grades from a set of test scores. In the language of the student this is known as “curving it.” Just why this unjustifiable procedure should still be in existence today is one of the many small mysteries of our times. Using short answer examinations and treating the scores as a Gaussian distribution for purposes of assigning grades is still considered to be a completely fair, objective, and scientific way of testing and evaluating in the schools. I can certainly think of very few more invidious practices than this technique. It is possible that a large number of test scores could arrange themselves in a pattern approximating a Gaussian distribution—but so what if they do! This only tells you more about the kind of test used rather than how well the students have learned. If test scores are distributed in a Gaussian manner there is still no rational justification that forces one to decide that the grades have to have a Gaussian distribution. The failure to carefully think about the nature of a measurement, and an evaluation of that measurement is surely a contributing factor to the continued existence of a procedure that creates so much despair in the students. If this is a scientific procedure, then no wonder science has an image problem. Science appears as deterministic, mechanical and unfeeling.

Please know that my criticism of educational measurement is not an attack on the idea that capabilities and performance cannot be measured. They can, but the problems associated with educational measurement, putting it on a sound scientific basis are much more numerous and complicated than most of us have recognized. The failure to recognize the complexity and difficulty of educational measurement-

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ment has certainly contributed to oversimplifying it to the point of uselessness.

Contributing to the failure of the Education-as-a-Science movement to bring forth a set of valid educational technologies was confusion on what was the nature of the process called science. This confusion took two forms, both of which are related. On the one hand science is considered to be a strictly inductive process where general laws appear if one only looks at enough data. One must, of course, look at this data objectively, look at it unbiased. According to inductive methodology the observed data may exist either in nature or else in a laboratory. The laboratory exists solely to simplify, to eliminate variables, so that the order existing in nature will be more readily apparent. Considering science as induction, once the natural law appears in the data you have a near absolute truth—not completely absolute—because you may have made a mistake in your observations or you may have approached the data trying to read into the data certain preconceived patterns rather than letting the data speak to you—letting the facts speak for themselves. However, if certain safeguards are established you can very closely approximate the already existing natural relationship, the natural law. In letting the facts speak for themselves it is permissible, however, if one considers science to be strictly inductive, to use aids. Such aids are the use of least-square analysis, the plotting of non-linear data on a log-log graph, the use of analysis of variance and covariance, and factor analysis. For those who consider scientific research to be strictly an inductive process, a statistical analysis of data uncovering the relationships that already exist in the data is a necessary technique. In this mode, statistical analysis of data becomes a contemporary representation of the Baconian Inductive Method. Those holding that science employs only an inductive methodology are distinctly unhappy with the use of theory. Theory, to them, is a speculative intervention used only when the data are not sufficiently clear to speak for themselves. The great majority of researchers in pedagogy and psychology consider science to employ exclusively an inductive methodology. This has been amply documented in a valuable dissertation by Dr. Kenneth E. Lake, entitled *Inductive Methodology versus Hypothetico-Deductive Methodology in Educational Research.*

Lake shows that almost all educational research is cast in the inductive mold with the intense use of statistical analysis to uncover the relationships existing in the data. In his study Lake is very careful to establish what would be the main features of an inductive methodology, what would be emphasized in such studies, and what would be considered to be quasi-scientific procedures. Using this

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established frame of reference Lake shows that the epitome of the scientific procedure as held in pedagogical and psychological research is that science is an inductive process. Now one might ask, so what!! Since science is considered an inductive process and it is found that educational and psychological research is primarily in the inductive mode, is this any great discovery? It is if you consider that science does not employ a strict inductive methodology. Most contemporary philosophers of science are in almost total agreement that there is no such thing as an inductive methodology—at least a methodology that uncovers natural relationships existing in the natural or experimental data. William Whewell in the 19th century was one of the first to show that induction—a process by which one proceeded directly from the particular data to a general law did not in fact exist.\footnote{Whewell, William, \textit{The Philosophy of the Inductive Sciences}, vol. 1. (London, John W. Parker, 1847.) pp. 16-46.} This was 300 years after Bacon had proposed a systematic inductive methodology. Whewell in his criticism of induction asks an essential question—if you are to look at data, which data are you going to look at? There is a lot to observe in this world and that you pick out one set of data to gather or record over another shows you have some hypothesis or inference as to which is best. This analysis by Whewell has since been called the “Problem of Induction.” There exists no formal straightforward inductive logic. Whewell called the general relationship, the law, an abductive inference, an abduction from or among the data. To a certain degree you force the data to speak in a certain manner. This is certainly apparent in the work of Galileo and many contemporary scientists. Careful accurate data is still important but for a different reason.

According to Whewell and most contemporary philosophers of science, generalizations, laws, explanations, are all hypothetications—which in order to establish their validity must be subjected to continued testing, testing which attempts to falsify the hypothetication. Failure to falsify a given hypothetication does not render it true—it only makes it more acceptable. Just as science is not measurement alone neither is it only blank minded data sifting for relationships existing only in the sensate data of the world. Statistical techniques of analysis create possible, that is, hypothetical relations among the data. A searching analysis of scientific methodologies show that science does not employ a strict inductive methodology—if it ever did—it is not even inductive-deductive, but in fact hypothetico-deductive. A hypothetico-deductive methodology places emphasis on the use of theory, explanations, and hypotheses in addition to generalizations, laws and accurate data.

If the scientific process does give answers to questions, if the process is a human-operated, human-constructed one, if it is hypothetico-
deductive in establishing valid relationships, then anything short of this process cannot give adequate answers. Lake in his dissertation documented that up to 1961 most pedagogical research and those who write about such research conceive of it as an inductive methodology. If this is so, and if it is granted that the inductive methodology is a faulty methodology then the answers from this approach would be of limited value. That the technologies we are using in the classrooms, some of which have been established by research, are less than useful is obvious. What is not so obvious is that failure of these technologies may be in some part attributed to faulty science. This is indeed unfortunate.

In closing, let me say that I do not think that new and adequate technologies will automatically appear once all educational research becomes hypothetico-deductive. Pedagogical and psychological questions are very complex: pedagogical research is perhaps the most difficult kind of research to conduct we have today. Answers will never be easy to come by—but they will never come in a scientific manner unless a proper appreciation of the nature of science is realized. False models eventually create a lack of faith in the whole enterprise. Science as a human activity can help give us answers to adequate technologies in the classroom, but only if the nature of the scientific enterprise is properly recognized for what it is: A human approach to the world of sense experience with certain definite but necessary biases involving the creative use of hypothesis and theory in conjunction with valid generalizations and accurate data. All this is science, man is a part of it, and I firmly believe that science is one of man's most successful attempts to understand the world in which he lives.