The Difference Between the Abstract Concepts of Science and the General Concepts of Empirical Educational Research

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It is argued here that one key reason for the limited results so far achieved by empirical educational research may be that there is a fundamental difference between the general concepts used therein and the abstract concepts used in the natural sciences. To make clear the contrast between generalization and abstraction, the work of Galileo and Newton is discussed. It is shown how success is achieved through their ability to penetrate behind the flux of observable empirical phenomena to reach universal conceptual abstractions and relations between these. As well, two pieces of modern empirical educational research are discussed. It is argued that such studies make use of general concepts rather than abstract concepts of the scientific sort, general concepts which lack the possibility of the precise manipulation used in science as demonstrated in the work of Galileo and Newton.

La recherche empirique en éducation ne tient pas suffisamment compte de la distinction entre, d'une part les concepts abstraits de la connaissance de type scientifique et, d'autre part les concepts généraux de la connaissance pratique. Avec Galilée et Newton, la physique a réussi à dépasser le flux des phénomènes empiriques pour saisir d'abord des concepts abstraits puis les liens entre ces abstractions. De son côté, la recherche la mieux connue en éducation illustre encore des concepts généraux; c'est pourquoi, on dit, de l'éducation, qu'elle n'a pas encore trouvé son Galilée ou son Newton. Cet article pose la question: la recherche empirique en éducation peut-elle ou doit-elle, étant donné l'objet qui est le sien, viser à l'abstraction propre à la connaissance de type scientifique?

The claim made in this paper is basic and succinct. There is a fundamental difference between the abstract concepts upon which natural science rests and the general concepts made use of in empirical educational research. Many researchers seem to be unaware of this difference. Yet the practice of conceptual generalization rather than of conceptual abstraction may be preventing educational researchers from producing the kinds of results achieved in the natural sciences.

One fundamental reason why the natural sciences have been so successful has been that their concepts have been *abstracted from* the empirical world and relationships have been formed between these abstractions. Interrelationships of abstract concepts are a crucial, perhaps *the* crucial, aspect of scientific theory. It is not merely from the meanings that they themselves carry, but also from their complex interrelationships within the scientific theory that such abstracted scientific concepts gain their power. Such abstract concepts and their relationships can then be applied back deductively into the empirical world of diverse and changing phenomena.

Abstraction Versus Generalization

It is easy to confuse abstract concepts and general concepts. This may be because, throughout most of history, our practical knowledge has been empiricist (i.e., based upon general concepts), rather than scientific and based upon abstract concepts. (The word "empiric*ist*" is used in this paper to contrast with the word "scientific." Both empiricist activity and research and scientific activity and research are empiric*al*. That is, both attempt to deal with and to explain the world of empirical phenomena.)

Greek and Roman builders, for instance, were empiricist not scientific. The same is true of the Chinese discoverers of the magnet, gunpowder, and rockets. These people worked with general concepts and their explanations were generalizations which involved these general concepts, being derived by trial and error from their observations and experience. But they did not imaginatively create abstract concepts abstracted from their experience and link these in universal laws and theories. In medieval Europe, masons and builders had a sort of "empiricist technology" which used general concepts and was again built up through trial and error, but they had no abstract concepts — the kind of concepts involved in science and in the modern scientific technology which is based upon such science. They had craft wisdom and rule of thumb. Thus, while most of the arches and vaults in their Gothic cathedrals held successfully, some, such as those of Beauvais, did not. But the only explanations such masons and builders had were *empiricist* generalizations: for example, that this sort of arch at this approximate height and at about this width had been observed generally to hold in the past.

The powerful theories of mechanics, statics, and dynamics with their interrelated laws, which would explain why the arches and vaults of medieval cathedrals held, which are applied in modern architecture and engineering, and which allow new and creative extensions of architectural and engineering achievement, were not worked out until the interrelated conceptual abstractions were produced within the scientific theory of the scientific revolution of the 17th and 18th centuries. This was the work of Kepler, Galileo, Newton, Hooke, and other scientific giants. Until such times, the knowledge upon which construction was based was necessarily empiricist not scientific.

It is true that abstract scientific concepts are in some manner suggested by happenings in the empirical world and they must be capable of connection or application in some manner to that world, but they are not themselves empiricist notions. Scientific concepts and explanations, unlike empiricist concepts and explanations, are not defined by reference to observation; they do not consist of descriptions of observable facts. On the contrary, observation in science is defined by reference to the abstract scientific concepts, theories, and explanations. Scientific concepts and the laws and theories which relate them are concatenations of abstractions and unobservables, idealized and commonly held together by the equally pure abstractions of mathematics. To put it another way, scientific statements are statements involving symbols and the connections between them, from which statements about observable facts can then be derived and by which the scientific statements can be tested.

Thus, an important reason why science has been successful has not been because the phenomena are any simpler, but because it has worked with abstractions *from* empirical phenomena, rather than with generalizations *about* it. Such abstractions (unlike such generalizations) can then be related to seemingly quite diverse empirical phenomena. Falling apples, the moon, Halley's Comet, baseballs, bullets, and space shuttles do not look alike, but all can be construed under Newton's three laws of motion and his law of gravity. Rainbows, magnetic compasses, generators, and television sets ostensibly do not appear to have anything in common, but they can all be understood through electro-magnetic theory. The explanation of success is not that scientific phenomena are any simpler than social or pedagogical phenomena, but that brilliant conceptual insight has been able to abstract concepts and relationships which when used make the phenomena seem more simple.

Scientific laws and claims involving abstract concepts are thus not the same as generalizations which involve general concepts. As Judith and David Willer so succinctly put it in their perceptive book, "abstraction does not proceed by summarizing observations, but by generating a nonobservational structure which deliberately does not summarize" (1972, p. 24). Whereas empiricist generalization (both the general concepts and the claims which relate them) gradually builds as more and more approximately similar cases are observed, abstraction immediately and precisely defines a potentially infinite universe involving that conceptual framework.

It is sometimes suggested that empirical educational research has yet to find its Galileo or Newton. In view of this sentiment and to make clear the contrast between general empiricist concepts and abstract scientific concepts, some of the work of Galileo and Newton will be briefly considered.

The Scientific Achievement of Galileo and Newton

Let us look at the nature of Newton's laws. (Similar points could be made about Galileo's laws.)

Newton's First Law of Motion specifies the behavior of bodies which are free from impressed forces. But *empirically* there are no such bodies. And if by some celestial sleight-of-hand such a body could exist, no Newton could have any empirical knowledge of it because such knowledge would require somewhere in the universe the presence of an observer or his apparatus. This would mean the presence of impressed forces. In any case, the empirical existence of such a body conflicts with Newton's own Law of Universal Gravitation. Consequently, as Losee (1980) says, "the [Newtonian] law of inertia is not a generalization about the observed motions of particular bodies. It is, rather, an abstraction from such motions" (p. 84).

A similar point pertains to the Second Law of Motion. As Nagel indicates, this law says that the direction of change of motion (i.e., direction of acceleration) of a body acting under a force, is along "the right line in which the force is impressed" (1961, p. 160). But actual bodies have spatial dimensions, and therefore, "if the force acts upon the whole of it, there is no *unique* straight line that determines the direction of the acceleration—for the different parts of the body are then accelerated along distinct straight lines (1961, p. 160). So the law must therefore refer theoretically to the abstract concept called a "point-mass" (i.e., to a body whose mass in theory is concentrated at a "point"). Thus, any application of the Second Law "assumes an extension of the fundamental theory to cover the motions of systems of point-masses that are subject to more or less rigid mutual constraints" (Nagel, 1961, p. 160). This extension requires complex mathematics, but it does not need to introduce any new theoretical ideas. (And the 18th and 19th century progress in the theoretical mechanics of solids, liquids, and gases was developed on the abstract assumption that actual bodies are construed as systems of large numbers of point masses.) Similar points can be made about Newton's Third Law.

Let us be clear what the methods of Galileo and Newton involved. Ideas of empiricist observational concepts and of generalization from numerous empirically observed cases are clearly inadequate to describe their approach. Both savants demonstrated and insisted upon the importance of abstraction from the empirical world. They extrapolated conceptually and then tested their conceptualizations.

But the common confusion even in the minds of some natural scientists between abstract concepts and empiricist general concepts is easy to understand. As Einstein said in a famous lecture: "To the discoverer in that field, the constructions of his imagination appear so necessary and so natural that he is apt to treat them not as the creations of his thoughts but as given realities" (1980, p. 143).

Galileo and Newton did not make that mistake. Galileo continually made use of abstract concepts such as frictionless planes, free fall in a vacuum, ideal pendulums. These are not entities exemplified directly in empirical phenomena. A frictionless plane is a concept arrived at by abstraction from, not generalization from, observed behavior of bodies on real surfaces. Free fall in a vacuum is an idealization suggested by the observed behavior of bodies dropped in a series of fluids of decreasing density. (Galileo's analysis of acceleration in a vacuum was at a time in history when such a physical state was assumed by the scientific community to be an impossibility.) An ideal pendulum is a bob on a string without mass, moving through a vacuum, there being in the string no frictional forces. Newton made use of abstract concepts such as invisible centripetal forces, point masses, interplanetary attractions, centers of gravity. By using such explanatory principles and abstractions Galileo and Newton were then able to prescribe mathematically the behavior of bodies in motion in the empirical world of changing phenomena and to test these mathematical prescriptions in various ways. The laws of Galileo and Newton are better science than Aristotle's claims, or the claims of the medieval impetus theorists, not because they represent experience more perfectly, but because they penetrate behind the superficial regularity disclosed by empiricist observation to the more essential, but hidden, aspects of motion. I am here discussing specifically the work of Galileo and Newton, but the points made apply equally well throughout the history of science.

Furthermore, in using abstract concepts and their interrelationships, and thus making possible the development of real scientific theory, Galileo and Newton enabled their concepts to remain stable in meaning, and also (though conceptually related by their rational connection within the theory) conceptually distinct. Moreover, the abstract concepts, because of their abstraction and because of their conceptual distinctness, were able to be rationally connected by way of mathematics, and thus that quality of precision for which most of established science has become so noted became possible.

Imprecision of Empiricist Educational Concepts

In contrast to the above, empirical research in education is merely empiricist (though sophisticatedly empiricist because it makes use of very subtle statistics). There would seem to be at least two kinds of empiricist concepts involved in such research. First, there are general concepts drawn from observable empirical phenomena and social life, such as rules, frequent praise, formal style, mixed style, reacting group, interesting assignments. Second, there are ambiguous, pseudo-theoretical concepts which mix empirical aspects and value aspects, such as academic needs, random response, adjusted achievement scores. Both kinds refer to context-affected, general empiricist notions, and/or value categories built up from individual observed cases. They are not embedded in interrelated scientific theory. Neither are they ontologically separated from the empirical world in the way in which such common scientific concepts as force, mass, electron, light ray, specific heat, density, and the thousand others are separated.

In such educational research, there is thus not the precision of the abstractions of established science, but the empiricist generalizations of always partly disputable, more or less ambiguous categories. In being general rather than abstract, such concepts necessarily lack precision in meaning. This fact is of immense significance, for it helps to explain why the concepts of such educational research cannot be related through the precision of mathematics, but can merely be related by the imprecision of statistics. What is more, (as shown later in the discussion of Bennett's 1976 study), because they lack precision, the concepts used in the same piece of research commonly overlap in meaning. In such cases, not only can they not be related by the precision of mathematics, but it must follow that the results of all such statistical manipulation are equivocal. To emphasize these points, two pieces of empirical educational research will now be considered. They are both representative and widely reported in the literature of research.

Gage in "The Scientific Basis of the Art of Teaching"

Some of the more usable (though still rather commonsensical) results of the study of teaching (in this instance, process-product research) are listed by Gage in his book, *The Scientific Basis of the Art of Teaching* (1978). Gage says that he and his co-workers:

> carefully sifted ... the detailed information for several hundred variables in teacher behavior and classroom activity. From this sifting we developed a set of inferences as to how third-grade teachers should work if they wish to maximize achievement in reading and, we think, also in mathematics. (1978, p. 38)

He lists seven *teacher should* findings. The first three are typical:

1. Teachers should have a system of rules that allows pupils to attend to their personal and procedural needs without having to check with the teacher.
2. Teachers should move around the room a lot, monitoring pupils' seatwork and communicating to their pupils an awareness of their behavior, while also attending to their academic needs.
3. When pupils work independently, teachers should insure that the assignments are interesting and worthwhile yet still easy enough to be completed by each third grader working without teacher direction. (1978, p. 39).

Gage is also careful to claim that such results are "the joint yield, the convergence, the common general finding of years of careful classroom observation, reliable and valid measurement, and sophisticated statistical work"

(1978, p. 40). If such commonsense findings are the result of such massive amounts of hard work, this is surely good empirical evidence that something is amiss with the enterprise. (This is not so much a criticism of Gage and his co-workers, or of all the other educational researchers who adopt his or similar research modes, as it is a comment upon the tragically misleading paradigm in which such capable and hard-working researchers find themselves enmeshed.)

In order to shore up the case for his kind of process-product research and its admitted limitations, Gage points to the complexity of the "interactions" between variables in teaching. He rejects the possibility that the interactions in teaching are so complex that practical applications are not possible, saying that research on teaching is no more complicated in this respect than in a science such as physics. He claims that in physics:

> many relationships are about as firm as anyone could wish. *Yet considered one at a time, these relationships hold only under laboratory conditions and not in real life.* When it comes to real-life phenomena, physical scientists must apply many of these laws in combination ... even the apparently simple laws of mechanics interact with a host of other laws. But physical scientists do not denigrate their main effects simply because interaction effects also occur. They simply take more laws into account. (1978, p. 19) [italics added]

What has been missed here is that the laws of physics relate *abstract* concepts by way of *theory*. In that sense they do not apply in real life. But they are quickly shown to apply in real life by way of deductive empirical inferences combined with mathematical calculation. And it is true that scientists "do not denigrate their main effects simply because interaction effects also occur. They simply take more laws into account" (Gage, 1978, p. 19). But the reason they do not denigrate their main effects (i.e., laws) is that they do indeed have them. Moreover they can indeed, where judged necessary, simply take more laws into account because they have so many established laws which relate abstract concepts. But the nearest equivalent to laws which have come out of process-product or any other kind of empirical research on education remain the kind of statistical correlations (usually low) upon which Gage bases the *teacher should* statements quoted above.

The main point for the present paper is that the limitations of such research may well derive from the fact that Gage's research does not make use of abstract concepts. The terms used: pupils, communicating, rules, procedural needs, monitoring, worthwhile, etc., refer as already indicated to general empiricist and value notions or to pseudo-theoretical concepts, rather than to precise conceptual abstractions. The concept, *pupils*, refers to John and Jane and Tom and Tammy considered as a whole despite their manifest differences. The concept *communicating* refers to facial expressions, to bodily movements, to complex sentences, to part-sentences, to leading questions, to exclamations, and so on.

This seems all very different from the abstract concepts of Galileo and Newton.

Bennett's "Teaching Styles and Pupil Progress"

Bennett et al.'s book, *Teaching Styles and Pupil Progress* (1976) is chosen not because it is specially good or bad, but because it is a typical large-scale statistical study, representative of a multitude which over the decades have attempted to draw conclusions about methods of teaching. There are of course other deficiencies in such studies besides their failure to use abstraction. But the burden of this paper rests upon the latter. Bennett et al. attempt to compare three teaching styles: *formal*, *mixed*, and *informal*. In so doing they divide the myriad of relevant features such as teaching practices and tasks, the values, habits, and so on, into merely three empirically-based styles.

Given the imprecision involved here, any research which attempts to distinguish clearly the comparative efficacy of these three styles of teaching is necessarily going to have problematic results. As Barrow puts it: "If one operates with very broad categories, such that many facets of performance are contained within each one ... then it is almost certain that there will in practice be no clear instances of any category" (1984, p. 192). The problem is that, with such general concepts, many of the above tasks, values, and so forth will fit in each of the three styles. But there are thousands of different features and dimensions involved, many of which could be particularly significant but will find equal representation in each of the three concepts. This results in the antithesis of the precision of conceptual abstraction.

To make the point, let us consider just 10 features. The similar use of sessions of critical questioning by teachers can fall into any of the three styles. So can their use of praise. So can an unusual ability to work an overhead projector effectively. So can a propensity to mark all written work immediately. So can a teacher's moral belief in the abiding worth of each individual pupil. So can a teacher's charismatic personality. So can his/her patience with children. So can a pleasantly modulated voice. So can a depth of knowledge of the subject, history or mathematics or whatever. So can his/her ability to make things clear to learners. All of these features and thousands of others may have great significance in any particular teacher's success. Thus, we have here the necessary imprecision of immense conceptual overlap between and among the three categories. Any supposed causal relationships derived from such categories will be about as useful as (to adapt Barrow's example) would be such relationships derived from dividing teachers into three hair color categories: those with red, blond, and black hair. So why practice sophisticated statistical analysis with these three general empiricist concepts as a basis?

Thus, the very concepts which the study seeks to relate are themselves ambiguous and overlapping in meaning. As Bennett himself agreed recently:

> The major problem with this approach was that the styles themselves were composed of groups or bundles of teacher behaviors and activities, making it impossible to ascertain the impact of any individual teacher behavior on pupil outcomes ... as such, the notion of teaching styles, in itself, cannot provide an adequate explanation of differences in pupil outcomes. (1988, p. 21)

What should be carefully noted is that such vagueness and overlap in meaning are not just problems for the teaching styles approach, but because of the nature of its empiricist concepts are also problems of empirical educational research generally.

Conclusion

The laws and theories of science guide, explain, and predict. They also give us new and unexpected information about the world. Empirical educational research, because it is merely empiricist, does none of these things. Because empirical research in education uses general concepts it may be irrelevant how sophisticated the statistical procedures may become, or how rapid the computers. If they are ever to have a chance of achieving the scientific results which have been achieved in the established sciences, educational researchers may have to shift to a quite different initial ontological level of analysis: one which makes use of abstract concepts.

It may of course be easier to point to the lack of abstract concepts in educational research than to show how they can be produced. There is no attempt in this paper to do the latter.

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