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Teaching: A Study in Evidence

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This paper outlines the way in which the adoption of a particular "world view" and its conception of evidence might influence teaching. Building on a view of teaching which takes the presentation of reasons and evidence to be central, Pepper's four world hypotheses are used to demonstrate how four different conceptions of evidence can each lead to a different teaching strategy. Particular attention is paid to some of the inherent weaknesses of the approach provided by each world hypothesis, and to the confusion that can arise when there is a mismatch between the teacher's and students' concepts of evidence.

In spite of intensive efforts to improve the quality of schooling, it would appear that numerous students still find school a less than successful experience. Some researchers have focused attention on the "cultural gap" between groups of students and the school, and attributed their relative educational failure to a mutual failure in communication between teacher and students (see for example Barnes, 1976; Becker, 1952). Others have investigated the differences in "learning style" among students and drawn attention to the need for a match between learning style and learning environment (Hunt, 1977-78).

In this paper I would like to explore a concept which is philosophical rather than sociological or psychological, and which if given the same kind of explicit attention would appear to have the potential for improving productive communication between teachers and students. This characteristic is part of what has been called an individual's "world view," i.e., the individual's set of assumptions and beliefs about the nature of reality (Kilbourn, 1980-81). In particular I will concern myself with the view an individual holds as to the nature of evidence and how it is verified.

In a recent article in *Science*, Holden notes that

> psychiatrist Rima Laibow [states] that the gifted child often suffers from isolation and feelings of "invalidation" of internal perceptions. Children need to grow up with a feeling of "rightness" she says—that "what is there is real and right. Yet what they get is continual invalidation". (1980, p. 880)

What Laibow is referring to is the invalidation of a personal "world view." Any student whose personal world view differed substantially from that

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habitually assumed in the classroom, would appear to be susceptible to such invalidation.

Teaching: A Matter of Evidence

Evidence plays a particularly important role in intellectual endeavours in the classroom. Philosophical analysis of teaching has drawn attention to the centrality of a concept of teaching which makes provision for students to understand the reasons and evidence warranting knowledge claims. Scheffler (1968) sees that "teaching, in this way, requires us to reveal our reasons to the student and, by so doing, to submit them to his evaluation and criticism" (p. 17). Komisar (1968) views clear intellectual activity as an example of this type of teaching. This requires that the teacher communicate

> not only with the intention of securing a certain "uptake" (an awareness of some point), but also so as (a) to divulge to the student what the intention is and (b) to achieve his awareness by identifying the reasons given as the intelligible grounds for the point the students are to become aware of. (pp. 79-80)

To the degree to which teachers are concerned with fostering rationality, critical thinking, and autonomy in their students, they are committed to a concept of teaching which presents reasons and evidence in support of knowledge claims as well as the specific knowledge claims themselves.

The major portion of this paper investigates the manner in which different views of the nature of evidence can influence what a teacher does in the classroom. Before proceeding with this, however, I would like to outline how the adoption of a particular "world view" shapes even the simple observational "facts" that we have to deal with.

World Views and Facts

On first inspection it would appear to be relatively simple to supply the evidence warranting a knowledge claim. But what is it that counts as evidence? Certainly if I claim that centipedes have one hundred legs, it is a simple matter to verify this claim by catching a centipede and counting the number of legs it has. In order to increase the credibility of such a claim, it would likely be necessary to have a number of observers catch a number of centipedes and perform the required leg counts. As Pepper puts it, the "grounds for belief are . . . always in terms of weight of evidence, which means in terms of the amount of corroboration of evidence that can be achieved" (Pepper, 1945, p. 6). In this particular case we have an example of what is called multiplicative corroboration. An observation is taken repeatedly, preferably by a number of different observers, and if there is essential agreement among the observations then the fact observed is said to be corroborated:

> [Multiplicative corroboration] is the corroboration of one observation with another, or of one man with another, where the fact observed is supposed to be exactly identical in the different observations. (Pepper, 1945, p. 6)

There is, however, a certain difficulty with attempting to corroborate all facts in this manner. It is that relatively pure observations of this sort are rather rare. In fact, most observations are made, as one might say, "through a set of lenses" provided by a view of what the world is ultimately like. Hanson (1965) has characterized this rather nicely by speculating on the differences in the manner in which Tycho Brahe (a Danish astronomer of the 16th century who believed in a universe with the earth fixed at its centre) and Johann Kepler (who believed that the earth rotated on its own axis once every 24 hours while travelling in an orbit about the sun) would "see" daybreak.

> Tycho sees the sun beginning its journey from horizon to horizon. He sees that from some celestial vantage point the sun (carrying with it the moon and planets) could be watched circling our fixed earth. Watching the sun at dawn through Tychonic spectacles would be to see it in something like this way.
>
> Kepler's visual field, however, has a different conceptual organization. Yet a drawing of what he sees at dawn could be a drawing of exactly what Tycho saw, and could be recognized as such by Tycho. But Kepler will see the horizon dipping, or turning away, from our fixed local star. (Hanson, 1965, p. 23)

On reflection it becomes evident that most, if not all, observations are to some extent theory laden in this way, i.e., they presuppose a view of reality within which they make sense. To the extent to which this is the case, they have to be corroborated by what Pepper calls "structural corroboration."

> Structural corroboration is the corroboration of fact with fact. It is not a multiplicity of observations of one identical fact, but an observed convergence of many different facts towards one result . . . . Such corroboration requires a hypotheses to indicate the way in which the evidence may converge to a given fact. The hypothesis holds all the corroborating facts together in a system and, in so far as the hypothesis is verified, the whole system of facts gains in probability. (Pepper, 1945, p. 7)

To extend this approach so that it is possible to deal more broadly with the problem of what it means to provide evidence, it is necessary to use structural hypotheses of much broader scope. Pepper has called hypotheses of this sort world hypotheses. He states that "[t]he ideal structure hypothesis . . . is one that all facts will corroborate, a hypothesis of unlimited scope. Such a hypothesis is a world hypothesis" (Pepper, 1942, p. 77).

A totally adequate world hypothesis has yet to appear. Pepper, however, has outlined four relatively adequate world hypotheses from the history of human thought. These four world hypotheses display a high degree of both precision and scope. While these world views have been known by a number of different names, Pepper has chosen the terms formism, mechanism, contextualism, and organicism to denote them. Each provides a different view of

reality, but inasmuch as they attempt to organize the totality of evidence in the world, they provide "four different approximations to the nature of the world" (Pepper, 1945, p. 9).

According to Pepper, world hypotheses provide unique, coherent ways of organizing the available evidence, so that attempts to combine them inevitably destroy this organization, producing something less adequate than either of the components. Also, because each of the world hypotheses displays such a high degree of adequacy its proponents assume that they are describing the world as it is and that all other world hypotheses are in error. In Pepper's view, however, "they all seem to be about equally adequate [so that] we cannot dispense with any of them until a definitely superior hypothesis should appear" (Pepper, 1945, p. 9).

In what follows, I will address two main issues: (1) the different concepts of evidence derived from different world views, and (2) how these different concepts of evidence could shape a teacher's teaching strategy. Pepper's four adequate world hypotheses—formism, mechanism, contextualism, and organicism—provide four distinct views of evidence which I will use to sketch out four possible teaching strategies for teaching a familiar topic from science education—Newton's Law of Motion.

Formism and Formist Teaching

In *World Hypotheses* (1942) Pepper proposed that world hypotheses are developed from common sense analogies or what he called "root metaphors." For formism the root metaphor is our everyday perception of *similarity* in the world around us. This provides the individual utilizing the formist approach with "a very strong feeling of certainty . . . . No other root metaphor of a favored theory is blessed with nearly so strong a feeling of certainty" (p. 144).

For the formist, things are similar because they have been developed according to some ideal form or plan. Every object in the world participates in a number of forms and it is this participation that gives it its characteristics. An orange picked from a tree, for example, participates in the universal forms of roundness, orangeness, and fruit. However, each orange is only an imperfect manifestation of any of these universal forms, and compared to other oranges may more or less closely represent the essence of any one particular form. Forms, while not "existing" in the same sense as physical objects, are every bit as real to the formist. The formist captures this distinction by saying that forms *subsist* while physical objects *exist*.

The formist then sees evidence as the exemplification of universal forms. There is no doubt that every fact in the universe fits into a number of categories, within which one can judge the degree to which it exemplifies the form of the category. Any particular object is seen as being made up of all these characteristics which in turn are seen as being due to its participation in a

number of universal forms. The fact then is simply the sum of its parts or characteristics, and truth is nothing more than "the degree of similarity which a description has to its object of reference" (Pepper, 1942, p. 181). This view of truth is often referred to as the "correspondence theory" of truth. Within this theory, the truth of any knowledge claim is judged by its correspondence with fact.

Formist Teaching

How then does a formist world view shape a teacher's efforts to present evidence? The correspondence theory of truth judges the truth of a claim by its similarity or correspondence with the observed facts. Students then need to have direct access to the phenomena being studied if they are to be able to employ this theory of truth for themselves. At the same time, to develop a clear concept of the form, they need to be exposed to examples which lucidly portray its essence.

Consider for a moment a teacher embarking on the teaching of Newton's Law of Motion. In order for students to grasp the evidential base that supports this generalization, they need to have had experience with forces applied to various objects and their resultant accelerations. These objects have to be seen, however, as participating in the form "mass." This can be difficult, as most students will not have met this concept before, and will have a strong tendency to confuse it with volume or weight. The choice of examples that will clearly distinguish mass from these other concepts is obviously critical. But for the formist, Newton's Law of Motion is also a universal form. So the formist will also demonstrate the manner in which decreasing the friction brings results that are closer and closer to the ideal form $F=ma$ —relating acceleration, mass, and force. In fact, this would be a particularly strong demonstration of the adequacy of one's world view. In order to adequately present the evidence then, the formist teacher has to provide students with a clear conception of the forms themselves, and also with access to the phenomena that the forms purport to explain.

The greatest danger of the formist approach, however, is that of rigidity. Because of the very strong feeling of certainty associated with formism, it is very easy for the teacher to believe that *his or her concept* of the form is identical with the form itself. Every critique of education has its own story of student initiative being squelched by some overly rigid formist—the novel solution dismissed because it wasn't found in the teacher's manual, or the insightful question rejected because it seemed irrelevant. This difficulty grows out of the lack of precision that plagues formism. While the root metaphor of similarity is compelling, the difficulty lies in determining the appropriate form for a particular case. If the formist is to avoid this rigidity, he or she needs to continually strive to remain open to alternative interpretations in order to see

the ways in which the same fact might be interpreted differently in the light of a different form. Although formism is based on ideal forms that are universal for all time, there is no assurance that one has totally grasped the essence of a form. Indeed the very fact that we are concrete existent particulars separates us from the realm of subsistence inhabited by forms. Mortals can only perceive ideal forms imperfectly.

Mechanism and Mechanist Teaching

The machine is the root metaphor of mechanism. Explanations are constructed in terms of the interconnections of the various parts of the whole. It is these interconnections that give rise to the laws which hold between the various parts of the machine in its action. The parts themselves are real only in that they can be located in time and space. For the mechanist reality is bounded by the spacio-temporal field. It is this preoccupation with physical location that leads to mechanism's propensity to measure and quantify.

The primary qualities, with which mechanism is directly concerned, are not characteristics of our everyday perception. Newton's laws deal with abstractions such as mass, acceleration, force. None of these are directly perceived, nor are the atoms that make up all matter. "What we experience are secondary qualities only, from which as evidence we infer the mechanical efficient structure of the universe" (Pepper, 1942, p. 216). These secondary qualities are a result of the interaction between the entities of the external world and the observer. Without an observer to perceive, there is no colour, sound, or odour, although there may still be the molecular motions which can cause them. It is these secondary qualities, however, that constitute evidence, so the mechanist takes the nominalist position that a *name* is nothing more than "a specific response made by an organism on the stimulus of specific environmental configurations . . . [and] truth becomes a name for physiological attitudes which are in adjustment with the environment of the organism" (Pepper, 1942, pp. 226-228). Pepper further states,

> We thus learn about the structure of the great machine by a sort of detective work. We note the changes among our private secondary qualities, infer their correlations with the physiological configurations which are in our organism, and thence infer the structural characters of the surrounding field from its effect upon the configuration of our organism. (Pepper, 1942, p. 229)

This theory of truth is known as the "causal-adjustment theory."

Mechanist Teaching

The mechanist's view of evidence dictates a somewhat different style of teaching from that of the formist. Measurement and calculation are used to

produce numerical evidence, so that the whole area of the precision of measurement becomes of central concern. At the same time, it becomes important to explicate the fundamental entities involved and the causal relationships between them. Let us consider once again our hypothetical teacher about to teach Newton's Law of Motion; an individual firmly committed to an approach that will present the evidence. How will a mechanist world view shape the instructor's actions in the classroom?

Certainly it would not be sufficient to demonstrate to students that the same force will give a more massive object a smaller acceleration than it will give a less massive object. Rather, the teacher would be forced to employ procedures that provide numerical values for the accelerations, forces, and masses involved. Also he or she would need to provide an analysis of the measurement errors to enable students to see that the experimentally determined accelerations were within the ranges expected from Newton's Law and the measurement errors of their respective forces and masses. At the same time, it would be important to draw out the concept of an unbalanced force causing a mass to accelerate with an acceleration whose specific value depends on the values of both the mass and the force involved.

It is not coincidental that many science teachers find the mechanist view of teaching quite natural, because the roots of mechanism are firmly planted in Newtonian mechanics. But even within the confines of our example there are liabilities inherent in this approach. In particular there is a strong tendency to restrict meaning to that which can be quantified, as in the following quotation attributed to the 19th century British scientist William Thomson.

> I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind. (Cited in Holton and Roller, 1958, p. 229)

This can lead to what is often referred to as "number bashing," in which precision of measurement and statistical significance become of overriding concern to the detriment of legitimate concerns about validity. It is much too easy for both students and teacher to become preoccupied with getting the *right* answer and getting it to as high an accuracy as possible, without giving sufficient consideration to what it is that is being measured, or to the degree of precision that is appropriate in the situation.

Contextualism and Contextualist Teaching

The root metaphor of contextualism is the *historic event*. Contextualism sees a world of continual flux in which there is no underlying fundamental structure. Its focus then is restricted to the "changing present event" which is intuited directly and holistically. Unlike both formism and mechanism, con-

textualism views elemental analysis as intrinsically distortive, and explains away the apparent elements of analysis found by these world hypotheses as being due to "fusions." These fusions occur much in the same way that we perceive first an A minor chord and then three separate notes. For the contextualist there is no sense in which either the chord or the individual notes are more fundamental. They are both arbitrary fusions of reality.

Central to the contextualist view is the concept of the human being as an active organism attempting to control the environment. Confronted with a problem, one hypothesizes a solution and then acts on the basis of this hypothesis to test its veracity. Truth then refers to the hypothesis, and is determined by whether or not the action based on the hypothesis succeeds in removing the problem. (It is in this sense that contextualism is seen as pragmatic.) This "operational theory" of truth provides for a world of multiple realities, as there may well be numerous hypotheses that yield solutions to a particular problem. It also firmly roots truth in the present context of a problem so that truth is as changeable as the universe to which it speaks.

Contextualist Teaching

The central concern of the contextualist teacher is to set what he or she is teaching within the context of a particular problem. Scientific laws and theories are seen as tools that an investigator may use to solve particular problems arising in particular situations. Concepts such as mass, acceleration, and force are arbitrary fusions of reality that are justified by their utility in solving the problem at hand.

Faced with the task of teaching Newton's Law, the contextualist teacher might pose the problem of determining how strong a car's seat belts need to be.[1] Students would then be involved in considering such factors as the maximum mass of the driver to be restrained, the speed that the car might be travelling at, and how quickly it might come to a stop. Newton's Law could then be introduced to work out the maximum value that the seat belt would have to be capable of exerting if it were to restrain the driver. The truth of the law is then demonstrated by the seat belt's ability to restrain the driver under the appropriate conditions. Because of the normal restrictions of the classroom this would likely involve either a simulation or a film presentation of actual test results.

While the contextualist view of teaching is particularly appealing because of the way in which it can make instruction relevant to the students' experience,

[1]In choosing a practical problem to illustrate contextualist teaching I am acknowledging the tendency in contextualism to blur the distinction between science and technology. It would also be possible to choose a problem that is theoretical in nature, e.g., the original problem Newton faced in deriving his Law of Motion.

it too has its shortcomings. In particular contextualism has a tendency to so immerse itself in the particulars of the problem that it loses sight of considerations of general validity. Contextualist theories are validated simply in terms of their ability to provide a solution to the immediate problem. This leads all too easily to a relativist view of knowledge in which all theories that provide a solution to a problem are equally good irrespective of their concern with ultimate ends or their consistency with the rest of human knowledge.

Organicism and Organicist Teaching

The root metaphor of organicism is *integration*. The organicist believes that everything is related to everything else and that what we perceive of as particulars are, in fact, parts of one all-inclusive whole. Ultimately the organicist expects to uncover the manner in which apparently separate facts are integrated into the whole in a way similar to that in which the classical theories of dynamics and electromagnetic radiation were united by Einstein's Theory of Special Relativity.

Inherent in organicism is a view of progress. With each integration, fragments of one order of inclusiveness are combined at a higher level as progress is made towards more complete knowledge. As knowledge progresses from level to level of integration, it displays increased degrees of inclusiveness, determinateness, and organicity. Each level includes more fragments from the previous level as part of its integration while at the same time it determines more precisely each fact and how it is related to other facts in the integration. The degree of organicity or "wholeness" is a measure of the degree to which each fact has become related and hence dependent on all the other facts. As the degree of organicity increases, each element in the integration becomes more dependent on *every* other element to such an extent that the "alteration or removal of any element would alter every other element or even destroy the whole system" (Pepper, 1942, p. 300).

For the organicist, the truth of any statement is determined by the degree to which it is integrated with the totality of our knowledge. As a result the organicist will talk about "degrees of truth" in the same way that he or she talks about degrees of integration. The criteria the organicist uses to determine the degree of truth of a statement are precisely those criteria that he or she uses to determine the degree of integration, i.e., inclusiveness, determinateness, and organicity. This theory of truth is referred to as the "coherence theory" of truth.

Organicist Teaching

The organicist view of evidence requires that a teacher, who is intent on providing evidence, display clearly how what is being taught resolves inconsis-

tencies and helps integrate disparate facts. This requires not only that the teacher trace out the interconnections between facts but also that he or she show how each fact is of critical importance to the whole.

Let us turn then to our hypothetical teacher about to teach Newton's Law. If the teacher is to demonstrate how Newton's Law integrates a number of kinematic facts one must, first of all, insure that one's students are familiar with these facts—typical terrestrial motion under the influence of friction, and apparently perpetual, celestial motion. This will involve at least some familiarity with straight line motion, circular motion, and perhaps projectile motion. In order then to demonstrate the integration achieved by Newton's Law, the teacher has to establish clearly the links with material previously taught, and perhaps allude to material yet to be covered. This makes it impossible for Newton's Law to be taught in a neat little conceptual package and makes substantial demands on the teacher's ability to provide extensive conceptual links with related content areas.

The organicist approach to teaching has the obvious psychological advantage of maximizing the interconnectedness of what a student learns. It encourages the student to integrate new knowledge with that already known and in doing so increases the number of routes whereby any particular piece of knowledge may be retrieved. At the same time, however, there is the distinct danger that in stressing the integration of knowledge, that facts, principles, and theories, initially introduced to provide a needed integration, come to lead a life of their own disassociated from those facts they were meant to integrate. In such situations students may well be unaware that a coherence rather than a correspondence theory of truth is what is appropriate. The net result is confusion.

The following excerpt from an interview with a number of grade eleven physics students illustrates just this sort of confusion on the part of one student. The students have been discussing how it is that they know that electricity flows through the wires in a completed electrical circuit, when Sarah objects that she doesn't really know that the electricity is flowing but is only taking the teacher's word for it.

Interviewer:	What would I be able to do to show you . . . to prove to you, that there was electricity flowing?
Sarah:	What would you have to do to prove it to me? I want you to show me electricity, and before you get there you'd have to show me an electron . . . and then you would have to work yourself up to the electron flow . . . . But, as of yet . . . we define small things and we never show them. And I guess they're just like mythology, we use them as an explanation for something that occurs.

Sarah is apparently unaware of the way in which the concept of an electron flow acts to integrate numerous directly observable facts about electric circuits. It is the ability to achieve this integration that justifies the concept of an

electron flow, not any act of direct observation.

The kind of conceptual confusion displayed by Sarah is not limited to situations in which a teacher employs an organicist view of teaching. As alluded to earlier, this sort of problem arises from a mismatch between different views of what constitutes evidence. In order for learning to take place, the student has to understand the concept of evidence on which a knowledge claim is based. For *teaching* to take place, provision has to be made for the student to grasp this concept of evidence. Pepper's four world hypotheses provide the basis for a framework that conceptualizes different concepts of evidence. In doing so, they provide the conceptual apparatus necessary for a teacher to make provisions for students to understand the concepts of evidence on which knowledge claims are based.

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