ON THE CONCEPTS OF QUANTITY AND QUALITY IN THE HISTORY OF WESTERN THOUGHT

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ABSTRACT

This paper charts a cognitive history of the concepts of quantity and quality from three inter-related and inter-dependent perspectives of mathematics, logic, and physics. In so doing, other notions associated with the evolution of these concepts are identified and explicated. It is argued that the concepts of quantity and quality, considered in terms of primary and secondary qualities originating with the ancient Greek Atomists, came into full prominence during the Enlightenment, providing ground for a then emerging and now well-established but as yet poorly understood distinction between quantitative and qualitative research. Placing these key concepts in historical context informs epistemological and ontological issues underlying contemporary debates regarding what constitutes "evidence-based" educational research.

A PREFACE TO AND PRÉCIS OF THE STUDY

The commonly accepted and relatively uncontroversial pragmatic view these days is that qualitative and quantitative methods are complementary approaches to educational research: Qualitative methods offer critiques of social norms and values affecting education, while also providing "thick descriptions" from small-scale studies of subjective and situated aspects of educational phenomena. Quantitative methods provide large-scale studies that attempt to objectively determine and validate the general frequency of educational phenomena.

Recent advances in quantitative methods, coupled with an increasing popular penchant for "standards-based" education, and "evidence-based" educational research, is fueling a strong resurgence in the traditional priority and dominance of quantitative research. If compatibilities between quantitative and qualitative research are to be preserved, we should not take the tentative pragmatic truce between the two for granted. It may serve educational researchers well, irrespective of theoretical and methodological affiliations, to gain deeper insight into the relation between the crucial concepts of quantity and quality. Such is the aspiration of this paper.

In lending historical context to educational inquiry Rizo (1991) traced the perennial controversy between quantitative and qualitative research as far back as the 17th century. Although Rizo alludes to philosophical aspects of the debate between quantitative and qualitative research, he stops short of providing much insight into what those philosophical aspects are, how they emerged, and what they entail. He ventured to predict, however, that for the opening decade of this century: "Confrontation will continue. But

that does not mean that there is not any advance or that history is cyclical: Controversy is the way to progress. By learning from old discussions, we will be able not to suppress but to surpass them" (ibid., p. 9). The main objective of this paper is to take up where Rizo left off, and delve beneath theoretical and methodological differences between quantitative and qualitative research in an attempt to excavate some of the deeper and more profound philosophical issues involved.

Philosophical framework

The philosophical modes of inquiry for this paper are historical and conceptual analyses, respectively informed and guided by hermeneutics and phenomenology. I refer to these modalities of inquiry as comprising a "cognitive history." Rather than explicating this notion here, I demonstrate it through a study of the cognitive history of the key concepts of quantity and quality. In so doing, I hope to provide some new insights and shed more light on the connections between quantitative and qualitative research. An ancillary objective of this paper, in-keeping with the theme of this conference, is to help inform and temper contemporary debate as to what constitutes legitimate educational research.

As Romberg (1992) has stated: "To relate one's ideas to the work of other scholars, one must understand the philosophic perspectives that underlie one's work." I distinguish between *research paradigms*, defined as collective bodies of theories and methods pertaining to communities of practice, and the philosophical perspectives underlying those theories and methods (Campbell, 2002). And I view quantitative and qualitative educational research as comprising distinct, though not wholly disjoint communities of practice. Distinguishing, then, between research paradigms and philosophical frameworks enables more focused study on philosophical perspectives pertaining to quantitative and qualitative research apart from theories and methods characterizing and governing those communities of practice. I apply this approach to the historical emergence and evolution of the key concepts of quantity and quality and the relations between them.

Data sources or evidence

Data sources and evidence are drawn from primary and secondary literature in the history of philosophy. Further substantiating evidence is obtained by inference and interpretation, justified through criteria of historical coherence, logical consistency and contemporary relevance.

Results and/or conclusions/points of view

I identify the distinction between quantity and quality in this paper as a crucial distinction in the history of Western thought, and one that has been formulated in various fields throughout history in a variety of inter-related ways. With regard to early conceptions, the distinction between the concepts of quantity and quality is shown to have great significance in the disciplines of mathematics, logic, and physics. Concepts of great significance rarely stand alone, however, and those of quantity and quality are woven with other important conceptual distinctions.

As a case in point, in the cognitive history of mathematics, the distinction between "how many?" and "how many *what*?" reveals a fairly concrete distinction between quantity as *amount* and quality as *kind*. The relation between quantity and quality at more abstract levels of mathematical thinking, though, becomes much more nuanced. Questions arise as to what kind of objects numbers are, whether numbers are objects in themselves, or whether they are merely attributes of objects.

Evidence from the history of philosophy indicates that such mathematical considerations are subsumed, at least quantitatively, by logical considerations concerning particular and universal propositions. Qualitative considerations are thereby elevated to more critical considerations regarding the affirmation and negation of propositions, i.e., such as quantitative propositions concerning the particular and universal. Whether one views knowledge as a matter of perception or intellect is shown to have substantive implications regarding the validating criteria involved in establishing knowledge.

There remain substantive gaps between these early mathematical and logical distinctions of quantity and quality and philosophical perspectives underlying differences between quantitative and qualitative research. I establish a stronger connection, incorporating those considerations to some extent, by tracing a distinction originating with the ancient Greek Atomists between *primary qualities*, aspects of objects such as size and shape, and *secondary qualities* such as taste and color (thereby distinguishing quantitative aspects of the natural world from qualitative aspects typically associated with our perception thereof).

To map a resurgence of the Atomists' distinction between primary and secondary qualities through the Renaissance and into the Enlightenment, I revisit concepts pertaining to the emergence of the early Greek distinction between intellect and sense. Medieval Europeans recast this distinction and broke new ground with it in a way that would culminate in modern science. Unresolved problems that took root from the seeds of ancient Atomism, however, also came into prominence with the scientific revolution — problems presenting challenges that remain relevant to this day as to what constitutes bona fide contemporary educational research.

The Atomists' distinction between primary and secondary qualities was initially bound up with physical realism and an atomic, or corpuscular, theory of matter. Accordingly, the world has an independent existence and the objects within it are composed of particulate matter behaving according to principles that can be induced through observation and experiment. This classical empiricist view was challenged in two ways. Epistemologically, rationalists, such as Descartes and Leibniz, believed in principles governing the natural world that transcended the senses. Such principles, such as non-contradiction, were intuitively self-evident to the intellect, or deduced through logical reasoning. Ontologically, Bishop Berkeley, himself an empiricist, leveled an idealist challenge against the primary-secondary quality distinction by arguing, as all experience is intrinsically mental experience, that there are no grounds for postulating the existence of matter at all. I seek to show how both of these challenges have significant implications for many of the philosophical perspectives underlying contemporary paradigms of educational research.

Philosophical, scientific, and educational importance

Philosophical ideas, even modern ones, have a history. Just as the Greek Academics and the Medieval Scholastics influenced Enlightenment thinking, philosophical debates that emerged in the 17th and 18th centuries remain relevant to contemporary problems in educational inquiry. Educational researchers working in the "analytic-empirical" tradition take for granted that knowledge claims must be substantiated by rational argumentation and/or empirical observation. Yet even today, as Martin and Sugarman suggest, the two approaches remain quite polarized and the relation between them poorly understood (1993).

Berkeley's "idealist" stance, a view shared by radical constructivists, maintains there are no rational grounds for justifying knowledge claims about an "ontic" realm existing apart from human experience. Realists, however, account for the ontogenesis of experience on the basis of an independently existing

reality of physical objects. In the face of Berkeley's critique, a foundational problem for the realist remains: How is one to distinguish which experiences of objects reflect qualities intrinsic to the objects themselves from qualities resulting from our perception of those objects?

Prima facie, mathematics and perhaps the notion of disciplined observation in general, provides an operational basis for such a distinction. To the extent that measurements can be repeated, they are verifiable in that they can be objectively validated. To the extent that secondary qualities are unquantifiable, they can all too readily be devalued as inconsequential psychological dispositions or subjective impressions. According to material realists, secondary qualities are causally derived from our particular physiological states and capacities. Indeed, realist aspirations to ground psychology on a scientific foundation involve a legacy of attempts to operationalize secondary qualities. Quantifiable observations of primary qualities, on the other hand, were taken by natural philosophers to provide a method for mathematically representing the world as it "really is," and thus support a more refined and sophisticated form of scientific realism.

But are quantitative methods of validation the only avenue to objectivity? Some researchers maintain they are not (e.g. Miles and Huberman 1984; Howe and Eisenhart 1990), while others resist making claims of objective validity, stressing the importance of legitimating subjective meanings in qualitative research (e.g., Marshall 1984; Moss 1996). Why such differences?

A lasting consequence of Berkeley's critique was to undermine any strict ontological distinction between primary and secondary qualities. This ontological equivalence of primary and secondary quantities is particularly relevant from the perspective of contemporary qualitative research. Such a view provides a basis for arguing for the scientific legitimacy of investigating non-quantifiable phenomena in two ways.

From a realist perspective, secondary qualities result from and indirectly reflect attributes of an independently existing real world. Such a view supports the possibility for methods or criteria that could lend objectivity to the investigation of secondary qualities. Thus, realist perspectives toward qualitative research attempt to study secondary qualities in ways that emulate the objective aspirations of quantitative research. This is typically accomplished using a coherency criterion for establishing the objective validity of results. A classic example of this is triangulation, whereby a variety of different approaches and data sets are used to investigate the same problem (e.g., Miles and Huberman 1984).

On the other hand, primary qualities themselves, from an idealist perspective, despite the apparent objectivity they gain from quantification, are taken to be intrinsically subjective. In this case, qualitative

theorists have a basis for arguing that quantitative research does not warrant a privileged status but is rather just one particular way of interpreting certain (more readily quantifiable) aspects of human experience. The very possibility of objective validity is thus brought under critical scrutiny. Consequently, emphasis can be placed upon meaningful understandings of experience (Marshall 1984). More radically, qualitative research can even be seen to subsume quantitative research. That is to say, the latter is but an instance of the former. Such views, however, must address recalcitrant questions as to how subjective meanings can give rise to, or account for, beliefs that we live in a shared objective world.

As Salomon (1991), citing Bandura (1978), has pointed out, when one notion tends to entail, implicate, or be regularly associated with a number of others, there can be an mutually influential effect amongst them referred to as *reciprocal determinism*. From the early days of the Enlightenment it is evident that closely associated clusters of notions were coalescing around the primary-secondary quality distinction. One cluster included empiricist notions as the natural world, materialism, objectivity, *a posteriori* knowledge, and inductive reasoning. Another included rationalist notions of self-awareness, mentalism, subjectivity, *a priori* knowledge, and deductive reasoning. I show that many of the notions internal to one cluster or the other have been reciprocally determined in substantive ways. Given Berkeley's critique of the essential similarities between primary and secondary qualities, and the important relation between inductive physical principles and mathematical deductions involving those principles, it is evident these clusters of notions are not independent of each other. They are intimately related and need to be considered as such.

This study in the cognitive history of quantity and quality suggests that significant epistemological and ontological problems remain deeply embedded within the scientific and intellectual heritage of Western culture. Pragmatists typically like to think we have “moved beyond” such antiquated modes of thought and that these matters are irrelevant, or can safely be ignored. This paper and recent events affecting educational researchers suggest otherwise. Is pragmatism up to the task of reconciling philosophical issues underlying and latent within quantitative and qualitative research? Could a return to quantitative hegemony in our field be justified pragmatically, on the basis that quantitative research is the only research that “works”? Without more clearly coming to terms with age-old philosophical problems, educational researchers will likely continue to encounter difficulties in relating and justifying the relevance of their work to others.

PARADIGM WARS: A BRIEF HISTORICAL SYNOPSIS

The commonly accepted and relatively uncontroversial pragmatic view these days is that qualitative and quantitative methods are complementary approaches to educational research: Qualitative methods offer critiques of social norms and values affecting education, while also providing "thick descriptions" from small-scale studies of subjective and situated aspects of educational phenomena. Quantitative methods provide large-scale studies that attempt to objectively determine and validate the general frequency of educational phenomena.

Having once held hegemony in educational inquiry, in the past few decades the dominance of quantitative research has been eroded due to impoverished results (Campbell & Stanley, 1966/1963). Educational researchers have come to gain a much deeper respect and appreciation for the impact of the diverse and rapidly changing contexts affecting education. However, with the advent of computer technology, along with new web-based data gathering techniques, developments in the meta-analysis of quantitative studies, and improved resolution of educational phenomena through qualitative pilot studies, the analysis of quantifiable trends may yet lead to the determination of general principles educational research (Keeves, 1988).

Recent advances in quantitative methods, coupled with an increasing popular penchant for "standards-based" education, and "evidence-based" educational research, is fueling a strong resurgence in the traditional priority and dominance of quantitative research. If compatibilities between quantitative and qualitative research are to be preserved, we should not take the tentative pragmatic truce between the two for granted. It may serve educational researchers well, irrespective of theoretical and methodological affiliations, to gain deeper insight into the relation between the crucial concepts of quantity and quality. Such is the aspiration of this paper.

In lending historical context to educational inquiry Rizo (1991) traced the perennial controversy between quantitative and qualitative research as far back as the 17th century. He identified two somewhat related but distinct dispositions toward gathering information pertaining to "state affairs" that emerged in the 1660's. In Britain, according to Rizo, ascendants of quantitative researchers developed the study of demographics as a form of "political arithmetic" for numerically condensing and recording various aspects of social and political reality, such as mortality tables. On the European continent, around this same time, another initiative was being made to compile "information about public things" based on an approach to

classification in accord with different forms of Aristotelian causality. This approach included qualitative information regarding purposes, laws and political leaders in addition to quantifiable information on population and resources.

Quoting (Heise 1975, p. ix), Rizo illustrated how workers in these traditions ("social SCIENTISTS" and "SOCIAL scientists") have "verbally bombarded" one another. It will be helpful, for the sake of introduction to the topic at hand, to recount a couple of these episodes, as they serve well in pointing to issues that go deeper than ostensible methodological differences might suggest. The first example is a volley from the qualitative camp towards the "vulgar statisticians" of the quantitative camp that grew out of the two approaches noted above:

> Those poor idiots spread out their foolish idea that it is possible to understand the power of a State simply by knowing its surface, its population, and the number of heads of cattle that pasture on its grazes... The machinations to which those criminals "political statisticians" [sic] devote their efforts, for expressing everything with figures... are negligible and rediculous [sic]. (Rizo, 1991 p. 12 quoting Lazarsfeld 1970, p. 99)

Evidently the European faction felt that there were qualitative features of political life that could not be meaningfully reduced to numbers.

The second anecdote reflects a somewhat less pejorative and more contemporary clash of wit. In the early part of the 20th century, the Chicago school was in the early stages of developing a strong tradition of case-based qualitative studies. Columbia, on the other hand, was renown for its quantitative orientation to research in the social sciences. As Rizo (1991, pp. 10-1) tells the tale, William F. Ogburn from Columbia transferred over to Chicago and managed to have Lord Kelvin's motto "When you cannot measure, your knowledge is meager and unsatisfactory" carved on the University of Chicago's new social science research building. He recounts reactions of two members of the qualitative camp:

> Frank Knight was heard to mutter in the 1930's while contemplating Ogburn's inscription: "And if you cannot measure it, measure it anyhow." Jacob Viner reportedly said: "If you can measure... your knowledge will still be meager and unsatisfactory." (Rizo, 1991, pp. 10-11, quoted from Bulmer 1985, p. 184)

Although Rizo alludes to philosophical aspects of the debate between quantitative and qualitative research, he does not provide much insight into what those philosophical aspects are and what they may actually entail. He ventured, rather, to prophetically predict for the opening decade of this century: "Confrontation will continue. But that does not mean that there is not any advance or that history is cyclical: Controversy is the way to progress. By learning from old discussions, we will be able not to suppress but to surpass them" (p. 9).

This paper, in taking up where Rizo left off, delves beneath methodological differences between quantitative and qualitative research in an attempt to excavate some of the deeper and more profound philosophical issues involved. The hope is that study of the cognitive history of the key concepts of quantity and quality can provide more light on the relation between quantitative and qualitative educational research.

More specifically, I chart the origins of the concepts of quantity and quality from the three inter-related and inter-dependent perspectives of mathematics, logic, and physics. In so doing, I identify and explicate some other notions intimately associated with these concepts. I argue that a crucial distinction between primary and secondary qualities originating with the ancient Greek Atomists that came into philosophical prominence during the Enlightenment provided the original ground for the distinction between quantitative and qualitative research. The fundamental epistemological and ontological issues concerning differences between quantitative and qualitative research are thus placed in greater relief.

ON THE ORIGINS OF THE CONCEPTS OF QUANTITY AND QUALITY

The distinction between quantity and quality extends back, as does so much of Western thought, to the ancient Greeks. The root of this distinction extends back even further, however, as both quantity and quality can be closely linked with the most basic levels of numerical consciousness. Herder, according to Egan (1997), indicated a magical and sacred relationship between naming and numerosity by observing that "... in so many myths, gods or sacred ancestors created the world by naming the things in it, one by one" (p. 34). The very act of isolating, identifying and naming an object entails, at least implicitly, the notion of unit. What is more, any difference between objects, in kind or degree, both assumes and justifies a distinction between quality and quantity. Relations between quality and quantity clearly run deep.

Mathematical origins

When one considers the question of "how many?" in concrete terms, one is implicitly considering the question "how many what?" For instance, when considering the meaning of the statement "four sheep," there is a difference to be made between the *amount* itself, "four," and the *kind* of thing that there is an amount of, namely, "sheep." Thus, the origin of the quantitative and qualitative distinction appears to be grounded in the difference, and close connection, between the emergence in human consciousness of

numerically and semantically intertwined concepts of amount and kind. Aristotle lends his authority to this idea when he indicates that a quantity refers to a particular measure, whereas quality refers to the specific kind of thing being measured (Aristotle 1941, 1053a).

Attributing qualities to numbers appears commonplace throughout different ages and cultures (Schimmel 1993). As a case in point, two centuries before Aristotle, the Pythagoreans conceived of numbers both in terms of quantity and quality. They took the number 4, for instance, to signify "justice," apparently due to the sense of balance that quantity can evoke. In the absence of some definitive criteria for attributing qualitative characteristics to numbers, however, this tendency appears to be rather subjective and arbitrary. No doubt the Pythagoreans had their reasons, yet one can only wonder as to why they did not select some other number, such as 2 to signify "justice," or even why they chose something like "justice" as a quality to attribute to a quantity at all. There were, however, important cases where the Pythagoreans *did* provide definitive criteria in assigning qualitative attributes to numbers *per se*, such as the qualities of evenness and oddness for example.

This brief discussion regarding quantity and quality from a perspective of the history of mathematics illustrates how these two concepts can be considered at two different levels in terms of an object/attribute distinction. The first, considering "how many what," operates at a concrete level of experience. Here, quantity relates to everyday objects of experience and quantity relates to the attributes of those objects. Making such distinctions over a sufficient period of time would presumably lead to an increased familiarity with, and propensity towards, separating concrete, perceptual, attributes from concrete objects. One of the great mathematical accomplishments of the Pythagoreans was to consider numerical units as objects in the absence of all perceptual attributes with the exception of spatial extension (Kirk and Raven 1966/1957, p. 246). Eventually, Parmenides came to envision an object in general, the "One," at a more abstract level, in the absence of any concrete sensory attributes whatsoever (Campbell, 1999).

It is difficult, if not impossible, to imagine what would be left of a concrete object if one were to take the process of abstraction to the limit and remove *all* of its experiential qualities, including extension. If nothing tangible is left to consider, what happens to quantity? Can quantity possibly be a quality? That is to say, is the oneness of an object a tangible attribute of that object? If so, at what point does one remove *that* attribute? According to Aristotle, Plato was in agreement with the Pythagoreans in saying that quantity, "the One," was a substance and not a predicate (Kirk and Raven 1966/1957, p. 241). The difference

for Plato was that the substance he had in mind was a substance that exists apart from sensible things. Clearly, the concepts of quality and quantity are integrally involved with the general distinction between an object and its attributes, as exemplified by abstract concepts of number and their concrete instantiations.

Logical origins

From a logical perspective, Aristotle made a distinction between quantitative and qualitative propositions that has extended well into medieval and modern times. According to Alonzo Church (1962), Aristotle related quantity to particular and universal propositions, and quality to affirmative and negative propositions.[1] One of Aristotle's great contributions to the history of mathematics and logic was to establish "homogeneity" between the abstract numerical measure and the concrete measured object (Klein, 1992/1968), allowing for a more general logical classification of quantitative propositions. Mathematical differences manifested between quantity and quality at the concrete and abstract levels were subsumed by a more general logical quantitative relation between the particular and the universal — particular and universal propositions to be contrasted with a dialectical form of proposition that, informally, appears to have originated from simple acts of acceptance or rejection. [2] Such dialectical propositions were identified and refined by the Ancient Greek Eleatics, Parmenides and Zeno, and later expanded upon and formalized by Socrates, Plato and Aristotle (Campbell, 1999, 2000). Such reasoning ultimately hinged upon the difference between the being or non-being of any given thing. Assertive propositions of this type could be either affirmed or negated, but they could not be both. These are the kinds of propositions that Aristotle classified, from a logical perspective, as qualitative.

Parmenides had shown, and Plato had reaffirmed, that in the sensory realms of concrete experience, something could both be and not be, whereas in the realm of the intellect, things could not both be and not be: They either existed or they did not exist. According to Plato, the sophist, Protagoras, with his

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[1] Kant (1965) adopted and expanded this view as comprising fundamental categories of human understanding.

[2] To appreciate how Aristotle may have subsumed the two levels of mathematical differences inherited through the Pythagorean tradition noted in the subsection above, consider that the difference between particular and universal propositions can be illustrated abstractly as the (quantitative) difference between "one man" as a particular instantiation of the universal "one," or more concretely as the (qualitative) difference between "one man" as a particular instantiation of the universal "man." In the latter case, "man" is the object and "one" is the attribute, whereas in the former case, the object-attribute roles are reversed. A more sophisticated mathematical example is illustrated by the difference between the particular proposition "these five men and these seven men are twelve men" and the universal proposition "five plus seven is twelve." We now know, with increasing layers of generality, that this binary distinction between the particular and the universal is relative, not absolute. The

emphasis on rhetoric and persuasion held the view that "knowledge is sense-perception" (Bakewell 1907, p. 78). Furthermore, Plato claimed that Protagoras proscribed to the following view: "Man is a measure of all things, of things that are, that they are; and of things that are not, that they are not" (ibid., p. 67). Aristotle scoffed away this view:

> Protagoras says 'man is the measure of all things', as if he had said 'the man who knows' or 'the man who perceives'; and these because they have respectively knowledge and perception, which we say are the measures of objects. Such thinkers are saying nothing, then, while they appear to be saying something remarkable. (Aristotle 1941, 1053b)

For Aristotle, "(t)he one is the measure of all things ... (t)he measure is always homogeneous with the thing that is measured" (ibid., 1053a). The "one" to which Aristotle refers to here is his conceptualization of an arithmetic unit as a generalized unit of measure. This shift from the Pythagorean and Platonic view of an arithmetic unit as one of quantity to one of measure can be taken to constitute a watershed event in the history of the philosophy of mathematics (cf., Klein 1992/1968).

At first sight, Aristotle appears to focus only upon the mathematical, or "measurement," aspect of Protagoras' view and does not address the logical aspect concerning affirmation and negation. Yet, with respect to mathematical propositions, it seems that for Aristotle, the distinction originally underlying the difference between quantity and quality has shifted to a new level. It appears to have been recast as a logical distinction between object and value. From a quantitative perspective, the object (be it particular or general, concrete or abstract) now relates "homogeneously" to both to the measure and that which is measured. From a qualitative perspective, the value is the (dialectically determined) truth or falsity of the proposition (presumably independently of quantity — whether or not it involves a measure). I suggest it is with respect to the latter, the "truth value" of a proposition, and whether or not that value is to be dialectically or rhetorically determined, is what most deeply concerns Aristotle regarding Protagoras's view. The central issue is whether or not one advocates the truth of a proposition as a matter of knowledge or perception. (Note that the sophist can readily argue that dialectic is just a particular form of rhetoric. Moreover, it is not difficult to see that such a view is somewhat akin to arguing that quantity as a particular kind of quality, or even that quantitative research as a particular kind of qualitative research.)

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arithmetic proposition "five plus seven is twelve," for example, is itself a particular instance of the algebraic proposition "A plus B is C."

Physical origins

As intriguing and clarifying as these early mathematical and logical distinctions of quantity and quality may be, there remains fairly substantial conceptual and historical gaps between them and the philosophical perspectives underlying the differences between contemporary quantitative and qualitative research. A more experientially and historically grounded connection can be established by tracing a distinction derived from the ancient Greek Atomists between quantitative and qualitative aspects of the natural world and our perception thereof. This approach also seems advantagous insofar as it can be seen to incorporate both the mathematical and logical distinctions noted above.

Aristotle, once again, reports that Leucippus and Democritus put forward a theory that based the elementary constituents of the cosmos upon the fundamental elements of “being” and “non-being.” The amalgamation of Pythagorean spatially-extended units and Eleatic logical dialectic is, to me, the most striking feature of this doctrine. Atoms of different shapes, locations, and in different combinations were taken as constituting being within a void of non-being (Barnes 1987, p. 248). For Democritus, “legitimate” knowledge related to the atoms in the void — the rest was “bastard” knowledge derived from the senses (Lloyd 1967, p. 449). Presumably the void, much like some modern views of the mind, was taken as a something about which nothing can be said. Galen, in the 2nd century AD, reports:

> All these people presuppose that the primary element is qualityless, having no natural whiteness or blackness or any other colour whatever, and no sweetness or bitterness or heat or cold or in general any other quality whatever. For, says Democritus, *by convention colour, by convention bitter, by convention sweet: in reality atoms and the void*. And he thinks that it is from the congregation of atoms that all the perceptible qualities come to be — they are relative to us who perceive them, and in nature there is nothing white or black or yellow or red or bitter or sweet. For by the term 'by convention' he means something like 'by custom', 'relatively to us', 'not in virtue of the nature of the things themselves'. This in turn he calls 'in reality', deriving the word from 'real' which means 'true'. (Barnes 1987, p. 255)

Within this remarkable passage, referring to the Greek Atomists of the fifth century BC, superimposed and in embryonic form, are three crucial philosophical distinctions concerning human consciousness and it's relationship with the world. Explicitly evident is a distinction between *nomos* and *physis*, custom and nature. But also, albeit implicitly, there is a distinction between *aisthesis* and *noesis*, sense-perception and thought, between “bastard and legitimate knowledge.” This distinction, dating back to Parmenides, preceeds the Greek Atomists and was subsequently firmly established and popularized by both Plato and Aristotle. The third distinction relates to the “real” world as it “truly” is, and as it “appears” to us.

It will be seen that these three distinctions remain, in one way or another, at the core of most of the philosophical perspectives underlying and differentiating contemporary educational research. For now, it

will suffice to note that for the Atomists, legitimate knowledge concerned the reality of nature, as constituted by the shapes and configurations of atoms. The "illegitimate" knowledge of the senses such as colors and tastes, in contrast, were thought to be manifestations of an underlying Atomic reality. As such, they constituted nothing more than subjective impressions of the real world. The ancient Atomist perspective still separates quantitative and qualitative research today. The natural, physical, world is the real world, which is legitimately known only through intellect. And yet, our world is a world that appears to the senses in a manner we can only know in a conventional sense — relative to our own experience. Which shall it be? Is it both? Is it neither?

Thus, we have, in ancient Atomism, the seeds of a very difficult set of problems that would come into prominence with the scientific revolution and that remain with us to this day. If the perception we have of the world is derived and conventional, how is it that primarily by thinking, we can know the world "as it really is" through this subordinate "veil of perception"? Democritus himself was keenly aware of this problem, and was apparently quite skeptical regarding its solution. He extended the following warning to the mind on behalf of the senses: "Wretched Mind, who get your evidence from us and then try to overthrow us, our overthrow is your destruction" (quoted in Cherniss 1951, p. 343). Other important distinctions would come to the fore in the late 16th and early 17th centuries with the rise of natural philosophy — perhaps none more informative, if not most crucial, than that between primary and secondary qualities.

THE PROBLEM OF UNIVERSALS

To help contextualize the emergence of the distinction between primary and secondary qualities during the Renaissance and Enlightenment, it will be helpful to first revisit some of the major ideas involved in the emergence of the Greek distinction between sense and intellect. These ideas re-emerged and were recast by the Europeans in the medieval era in a way that would set the stage for the advent of modern science.

Ancient and classical Greek doctrines

Understanding the relationship between the intellect and the senses has been a perennial problem in the history of philosophy — manifesting the basic fact that, perhaps as a consequence of our linguistic abilities, we are reflective, as well as sentient beings. Shortly after the advent of literacy in the 8th century BCE, early Greek Physicists, such as Thales and Anaximander, began to speculate about the fundamental

principle (*arche*) giving rise to (*physis*) an orderly world (*kosmos*). Over the ensuing centuries, speculations on the nature of such principles gave rise to a kind of understanding that the Ancients took to be qualitatively distinct from any knowledge that could be grounded in, or derived from, sensory experience. Dialectical refinements by the Greek logicians Parmenides and Zeno, regarding being and non-being, led both Plato and Aristotle to place a fundamental emphasis upon the rational and discursive nature (*logos*) of the intellect (Snell 1982/1953).

Plato emphasized the fundamental nature of the distinction between the particular instances of objects of perceptual experience with respect to their associated general ideas — the latter of which, he argued, were true existents accessible to intellect alone. For Plato, the fundamental purpose of teaching mathematics and dialectical (*qua* logical) reasoning was to turn students away from the mundane world of transient sensory particulars toward a transcendent realm of essential and unchanging universal truths. According to Plato, a perception of a sensory object could be confused, in that it could be, say, both large, with respect to one thing, and small with respect to another. The intellect was able to resolve and distinguish such contradictory intuitions by considering attributes, such as big and small, as distinct concepts in and of themselves independently of any particular perceptual object (Plato ~388-378 B.C.E./1945). The idea was that in liberating such universal concepts from sensory particulars, the intellect could reason in a manner purportedly free of, or at least less prone to, contradiction. Arithmetic and geometry principles and relationships often typified the results of such reasoning.

A major problem for Plato in arguing that these universal "ideas," or "forms," as objects accessible to intellect alone, were prior to objects of perception, was to account for how the former "participated" with the latter. That is to say, for example, how does the universal idea of a straight line participate in a particular instantiation of a straight line? This problem follows from the "third-man" argument [Plato, ~368 B.C./1961 #775, p. 132 ff]. If the universal form of a collection of particulars is, in some respect similar, but not identical, to that which is held in common by those particulars, then there must be a second form that constitutes what is similar between the first form and the original particulars. Repeated application of this argument generates an infinite regress of forms. On the other hand, if the form is identical to that which is held in common by the particulars, then it cannot be transcendent of them. And yet, where is one to find a perfectly straight line in the world of particular lines? The logical implication of the "third-man" argument is that the universal form must in no way be similar to that which is held in common by the set

of particulars. This begs the question: what exactly is a universal form, and how is it to participate in the particular instantiations of itself? For Plato, the Forms provided the underlying subject matter of dialectic. Without them, what was philosophy to do? When Plato has his Parmenides present these arguments to his young Socrates, Socrates is given to respond: "I can see no way out at the present moment." Neither, apparently, could Plato.

Aristotle offered a solution to the problem of participation by inverting the metaphysical priority Plato had given to the Forms. His solution was to derive universals inductively, and through a separation or abstraction, from concrete particulars, such as the number four from various instances of four things (e.g., Aristotle 1941). In this way, the notion of a universal was dependent on particulars (*universalia in rebus*), whereas for Plato they were independent of them (*universalia ante rem*). For Aristotle, abstract concepts, including mathematical objects, could not exist prior to, or independently of the senses. And yet neither were abstract objects identical to the concrete objects in which they were immanently manifest. Again, where in the world is one to find a perfectly straight line? Such forms were idealizations realized through experience. This classical received view of Aristotle's, that concepts originate in, and are abstracted, from concrete particulars, remains prevalent today, especially in mathematics education. So much so, in fact, that it can quite reasonably be referred to as both the "popular" and "received" view. However, as Aristotle was well aware, abstraction begs the question as to the ontological status of such objects. Aristotle also believed that they must have some real and objective status, but appears to have been no more successful at resolving this issue than was Plato.

Medieval doctrines

Greek philosophy lay dormant for many centuries in the political upheavals following the worldly conquests of Alexander and Caesar. Much of it was preserved through the Hellenistic age. Some of the essential works of Plato and Aristotle were later transmitted to Europe in the Middle ages by the Moors. Philosophy began to stir again as medieval Catholic priests came to be preoccupied with reconciling reason with faith, as typified by Catholic dogma regarding God and His creation. The two major doctrines espoused by these medieval schoolmen — the moderate Aristotelianism of St. Thomas Aquinas and the Platonic Augustinianism of St. Bonaventure — reflected a perennial philosophical polarization. Should priority be

given to an ideal world beyond experience, accessible by intellect alone, or to a real world beyond experience as given through the senses?

Due to the religious predilection of the medieval schools to reconcile faith and reason, there arose a fundamental debate between the two regarding the nature of the relation between them. Basically, the problem was defined in terms of how it is that "Man" comes to know God. The central tenant of the Augustinian school in this regard was the theory of divine illumination. This view assumes that innate within humanity is the idea of God, providing an explanation for the Platonist notion of a rational desire for the supreme good, which is thus seen as the motivation for humanity's ascent towards God. For the Aristotelian school of St. Aquinas, the emphasis was upon coming to know God through the realization and appreciation of "His" immanence as manifested within the world. Whereas the Platonic-Augustinians considered the proper object of the human intellect to be God Himself, the Aristotelian-Thomists looked more to the nature of His creation. Thus, the two sides of this theological debate reflects, in an essential way, Plato's and Aristotle's respective philosophical views on universals.

A complex mix of social, political, technological, and economic conditions, that need not concern us here, gradually loosened the grip of Scholastic Catholicism. These developments led to a progressively deepening separation of sacred and secular concerns though the Renaissance and Enlightenment (cf., Tarnas 1991). Debates regarding the sacred nature of humanity's relation with the divine gave way to more secular concerns with the nature of the principles governing creation. Were such principles transcendent, in the Mind of God, existing independently of, and prior to, the creation of the world, or were they principles immanent within His creation of the world itself? This fundamental theological question eventually mutated back into two fundamental philosophical questions: 1) the (epistemological) question of whether intellect, *qua* reason (rationalism), or the senses, *qua* experience (empiricism), constitutes the true source of knowledge; and 2) the affiliated (ontological) question of whether there was something that could be known beyond, and existing independently of, experience (realism), or not (idealism). But there were other factors that would come into play in the secularization of these questions. With the rediscovery of Atomist doctrines, it quickly became evident there was more to Greek philosophy than the works of Plato and Aristotle.

PRIMARY AND SECONDARY QUALITIES

Inspired by Copernicus in their rebellion against the received view of Aristotlian physics, both Francis Bacon and Galileo Galilie, in the late 16th century, contributed to the resurgence of the ancient Greek Atomist doctrines of Leucippus and Democitus. These works predated the classical works of Plato and Aristotle. Although no original works have survived some fragments of Atomist doctrines were preserved and perpetuated by Galen and various others, but most notably by Epicurius in the 4th century BC, and by Sextus Empiricus late in the 2nd century AD. Influenced by these doctrines, Bacon and Galileo adopted Empiricus's skeptical stance toward knowledge, especially toward Aristotle's rationalist speculations on the physics of motion. They championed the role of observation and experimentation (largely an outgrowth of the alchemical tradition) when it came to the study of the natural world. Galileo, certainly not least amongst his many accomplishments, appears to have been the first figure of note since the Greek Atomists to distinguish between objective, or primary, and subjective, or secondary, qualities of matter.

Galileo was particularly influenced by Democritus' notion that "sweet and bitter, warm and cold, and colour exist only by convention, and in truth there exist only atoms and the void (Fr. 9, Diels and Kranz)" (Hirst 1967). He also believed, in accord with a neo-Pythagorean tradition revitalized by Copernicus and Kepler, that "the book of nature is written in mathematical characters, without a knowledge of which men cannot understand it" (Drake 1967, pp. 264-5). Thus, Galileo came to focus on those attributes of physical objects, such as size, shape, etc., that could be measured and assigned a numerical value. Such attributes were considered to be objective, and came to be referred to as *primary qualities*. Sensory attributes such as color and smell that could not be readily quantified came to be referred to as *secondary qualities*. Such subjective phenomena were considered of no scientific interest to Galileo and of no relevance to physics.

Hobbes, a British empiricist who shared Bacon's contempt for Aristotelian physics, made a pilgrimage to visit Galileo in the early 17th century. Hobbes was enthralled with Galileo's revolutionary anti-Aristotelian view that motion, rather than rest, was the natural state of matter. Hobbes came to argue that change could only be accounted for through variations of motion of matter (Peters 1967). Boyle, another British empiricist, was also inspired by Galileo's ideas to investigate and popularize the primary qualities of matter and the causal effect they have in giving rise to the secondary qualities subjectively manifested in sensation (Passmore 1967).

Rene Descartes's first rule of philosophical method was to "... to embrace in my judgment only what presented itself to my mind so clearly and distinctly that I had no occasion to doubt it" (Anscombe and Geach 1970/1637, p. 20). This rule helped to justify his assertion " ...that the intelligent and the corporeal nature are distinct" (ibid. p. 34). Appealing to this paradigmatic rationalist criterion, Descartes posited a fundamental ontological difference between the mental (*res cogitans*) and the material (*res extensa*). With regard to the latter, although differing from the Atomists regarding the indivisibility of corporeal material, Descartes was completely in accord with the empiricists regarding primary qualities:

> I openly state that the only matter that I recognize in corporeal things is that which is subject to every sort of division, shape, and movement — what geometers call quantity and take as the object of their demonstrations. ... Because all the phenomena of nature can be explained in this way, I think that no other principles of physics need be admitted, nor are to be desired. (quoted in P. H. J. Hoenen 1967, p. 355)

However, echoing the perennial rationalist distrust of the evidence of the senses, Descartes also noted that "I have sometimes caught the senses deceiving me; and a wise man never entirely trusts those who have once cheated him" (Anscombe and Geach 1970/1637, pp. 61-2). Descartes's renowned second meditation brings him to the realization: "I now know that even bodies are not really perceived by the senses or the imaginative faculty, but only by intellect; that they are perceived, not by being touched or seen, but by being understood" (ibid. p. 75). From a rationalist perspective it is the intellect, not the senses, that "perceive" primary qualities.

According to Locke, primary qualities were those qualities that all physical objects must have in order for them to be considered as physical objects at all. He argued that they could never be "taken away" from any material object, and offered a criterion to that effect through a process of repeated division:

> For division ... can never take away either Solidity, Extension, Figure, or Mobility from any Body, but only makes two, or more distinct separate masses of Matter, of that which was but one before, all which distinct masses, reckon'd as so many distinct Bodies, after division make a certain Number. (Locke 1975/1689 p. 135)

Secondary qualities, for Locke, "... are nothing in the Objects themselves, but Powers to produce various Sensations in us by their *primary Qualities*" (ibid.). Primary qualities may be realized as abstractions to the intellect, but for empiricists, such attributes are evidenced through the senses.

Thus, rationalists and empiricists alike took primary qualities to be objective, quantifiable, properties of corporeal matter intrinsic to physical objects themselves. Secondary qualities were related to the subjective experiences that, somehow, physical objects had the "power" to invoke within us (Clapp 1967). But how was this possible?

Both Leucippus and Democritus had sketched physiological accounts of how physical objects manifest themselves in sensation, particularly with respect to vision (Lloyd 1967). For Leucippus, sensations originated in physical objects which, in turn, were taken to be continually transmitting images to the eye — presumably through the emission of Atomic particles from those objects. Democritus suggested that images were actually impressed upon the air intervening between eye and object. Presumably phenomena resulted from the convergence of atoms emanating from both. Furthermore, the shapes of atoms were taken to account for taste. For instance, bitterness was explained as the affect of atoms with little hooks, sweetness with smooth round atoms, etc. Thought was explained by the penetration of minute "soul" atoms: A notion Leibniz may have seized upon to develop his "monadology" — a mentalistic form of Atomism (Loemker 1969, pp. 643-53). For Hobbes, visual imagery was generated within the eye itself through its superficial interaction with minute atomic particles emitted from physical objects. He proposed that other experiential affects, such as volition, resulted from the internal material reactions to external stimuli. Thus, Hobbes developed a mechanistic psycho-physical theory whereby the subjective experiential attributes of sensation were accounted for by the objective material attributes of matter in collision with the sensory organs (Peters 1967). Leibniz, the consummate rationalist, argued, however, "... that perception and what depends on it are *inexplicable by mechanical reasons*" (Loemker 1969, p. 644).

The distinction between primary and secondary qualities was initially bound up with physical realism and an atomic, or corpuscular, theory of matter. Accordingly, the world had an independent existence and the objects within it were composed of particulate matter behaving in accord with principles that could be induced through observation and experiment. This empiricist view was challenged on two philosophical fronts. Although subscribing to the primary-secondary quality distinction, rationalists such as Descartes and Leibniz, presented an epistemological challenge to the view that the principles structuring the natural world were immanent within, and accessible through, sensory experience. Rationalists were partial to the view that the mathematical and metaphysical principles governing the natural world transcended experience. Such principles were either innately given in a manner intuitively self-evident to the intellect, or deduced through logical reasoning. In his Discourse on Method, Descartes' elucidates a mathematically-inspired rationalist approach to philosophy:

> Those long chains of perfectly simple and easy reasonings by means of which geometers are accoustomed to carry out their most difficult demonstrations had led me to fancy that everything that can fall under human knowledge forms a similar sequence; and that so long as we avoid accepting as true what is not so, and always preserve the right order for deduction of one thing from another, there can be

> nothing too remote to be reached in the end, or too well hidden to be discovered. (Anscombe and Geach 1970/1637, p. 21)

On the other front, an empiricist, Bishop Berkeley, indirectly leveled an ontological challenge against the primary-secondary quality distinction by arguing, as all experience is intrinsically mental, that there are no grounds for postulating the existence of matter at all. Both of these challenges have significant implications for many of the philosophical perspectives underlying contemporary paradigms of educational research.

Realism and idealism

Berkeley (1965) posed a fundamental objection to the distinction between primary and secondary qualities. He noted that primary qualities of objects, like secondary qualities, were necessarily mediated through experiences — "ideas in the mind" — and could not be separated from them — "an idea can be like nothing but an idea" (Berkeley 1965). Most natural philosophers of the Enlightenment were realists insofar as they believed that physical objects composed of particulate matter had "objective" qualities intrinsic to the objects themselves and those objects and their qualities existed independently of human experience. However, as we have seen, these physical objects were also assumed to be capable of somehow invoking perceptual experiences within us. Berkeley's critique hinged on the fact that ultimately the experience of primary qualities was also subjective, thus directly attacking the realist view and, more importantly, undermining the grounds justifying the distinction.

Berkeley's "idealist" stance, essentially a phenomenalist view shared today by many, if not most, radical constructivists today, amounts to the anti-realist claim that there are no rational grounds for assuming anything can exist beyond consciousness. Realists at the time preferred to account for the orderly and objective structure of experience on the basis of an independently existing reality of physical objects rather than to accept Berkeley's notion that all things were "ideas in the mind of God." Nevertheless, given Berkeley's critique, the problem remained: How is one to determine which experiences of objects reflected qualities intrinsic to the objects themselves from qualities resulting from our perception of those objects?

At first sight, mathematics and the notion of measurement in particular, appears to provide a basis for such a distinction — at least to the extent that measurement can be considered to be objective. According to Hirst "(m)easurement is objective and does not vary significantly because it is an operation that depends on the coordination of a number of separate perceptions and that may be performed by a

number of different persons" (1967, p. 456). In other words, to the extent that measurements, or quantitative observations, can be repeated, they are verifiable in that they can be objectively validated. From the perspective of physics, the act of measurement readily lends itself to the opinion that quantifiable qualities of perceived objects are the only qualities that can provide a basis for objective scientific knowledge of the world. For Galileo, a fundamental task of science was to "(m)easure everything. What you cannot measure directly, measure indirectly" (McCall 1983, p. 13, quoted in ; Karlsson 1993, p. 31). As we have seen above, this view has been echoed by quantitative researchers ever since.

Thus, the objectivity of measurement provides a basis for maintaining the distinction between primary and secondary qualities in the face of Berkeley's critique. To the extent that secondary qualities are unquantifiable, they are readily devalued as inconsequential psychological dispositions or subjective impressions. According to material realists, secondary qualities are causally derived from our particular physiological states and capacities. Indeed, most realist aspirations to ground psychology on scientific foundation in this century have involved attempts to "operationalize" secondary qualities. Operationalism lies at the heart of the psychophysical method, in that subjective psychological experience is accounted for in terms of objective (observable and measurable) physiological changes. Quantifiable observations of primary qualities, on the other hand, were taken by natural philosophers to provide a method for mathematically representing the world as it "really is," and thus served to support a more refined and sophisticated form of realism.

But are quantitative methods of validation the only avenue to objectivity? Some qualitative researchers are wont to point out that they are not (e.g. Miles and Huberman 1984; Howe and Eisenhart 1990), while others resist making any claims to objective validity, stressing instead the importance of legitimating subjective meanings in qualitative research (e.g., Marshall 1984; Moss 1996). Why might this be?

Although his arguments against materialism and representational realism left many unconvinced, an important implication of Berkeley's critique was to undermine the grounds for maintaining an strict ontological difference between primary and secondary qualities. It does appear to convincingly follow from his arguments that primary and secondary qualities "... have the same status, whatever that status is" (Armstrong 1965, p. 13-4). That is to say, in terms of the distinction between realism and idealism, they

could either both relate to objective properties of an independent physical world, or they could both be taken to be essentially subjective in nature. (Matthews exemplifies these differences)

The ontological equivalence of primary and secondary quantities is particularly relevant from the perspective of contemporary qualitative research. Such a view provides a basis for arguing for the scientific legitimacy of investigating non-quantifiable phenomena in at least two ways. On the one hand, if one adopts a realist perspective, secondary qualities, like primary qualities, can be taken to reflect attributes of an independent physical world. Such a view opens a door to the possibility of (non-quantificational) methods or criteria that would lend objectivity to the investigation of secondary (non-quantifiable) qualities. The emphasis from this perspective is upon gaining objective knowledge of the world independently of subjective experience. Realist perspectives toward qualitative research attempt to study secondary qualities in ways that emulate the objective aspirations of quantificational research. This is usually accomplished using a coherency criterion for establishing the objective validity of results. A typical example of this is triangulation, whereby a variety of different approaches and data sets are used to investigate the same problem (Miles and Huberman 1984).

On the other hand, primary qualities themselves, from an idealist (or anti-realist) perspective, despite the apparent objectivity they gain from quantification can be taken to be as intrinsically subjective. In this case, qualitative theorists have a basis for arguing that quantitative research does not warrant a privileged status but is rather just one particular way of interpreting certain (more readily quantifiable) aspects of human experience. The very possibility of objective validity is often brought into question. The main emphasis from this perspective is more upon gaining an understanding into the ways in which the world can be meaningfully experienced (Marshall 1984). Accordingly, qualitative research can be taken to subsume quantificational research. That is to say, the latter is but an instance of the former. Such views often leave unaddressed and unanswered important epistemological questions as to how subjective meanings can give rise to, or account for, beliefs that we are living in a shared objective world.

Empiricism and rationalism

One of Galileo's greatest contributions to natural philosophy was to "look to the world" for knowledge, rather than to rely solely upon the dogmatic and unsubstantiated assertions and pronouncements of classical academics and medieval scholars. However, in his rejection of Aristotelian physics, and his emphasis on

observation, Galileo also contributed to the widening of a perennial philosophical rift regarding the priority of the senses over the intellect and vice versa. Since Parmenides initiated the study of logic in the 6th century BC and Aristotle's classical systematization of the subject two centuries later, philosophers have placed intellectual principles upon hallowed ground. Logical principles—such as the law of non-contradiction (a proposition cannot be both true and not true), and the law of the excluded middle (a proposition is either true or not true)—have provided philosophers and mathematicians alike with a rational basis for sound judgment and valid inference.

Although the fundamental status of logical principles — along with some of the rationalist notions of identity and consistency that they presuppose — have been challenged recently by postmodernists such as Derrida (1976), they were not challenged by Galileo. Rather, it was Aristotle's *theoretical* principles regarding the *empirical* nature of motion that did not fare at all well under Galileo's scientifically constrained and experimentally controlled quantificational methods of observation. Evidently, Galileo, through the introduction of these disciplined forms of observation, was finally able to take heed of Democritus' warning to the intellect on behalf of the senses. This fundamental new role of the senses led to the foundational principle of empiricism: There is nothing in the intellect that was not previously in the senses (Tarnas 1991). Thus, in matters pertaining to the pursuits of natural philosophy, an empirical view emerged whereby the inspiration for, and the validity of, scientific principles ultimately relied upon that which is experienced through the senses. For the empiricists, the testimony of the senses, experimentally constrained by disciplined methods of observation, became the ultimate court of appeal for knowledge pertaining to the ways of the natural world.

Although this empirical emphasis in natural philosophy served to emancipate the senses and legitimize the profane secular study of mundane worldly matters, the centuries of distrust regarding the reliability of the senses were not completely unwarranted. For many, like Descartes, the senses remained, as Parmenides had warned, a "way of seeming," and not a "way of truth" (Bakewell 1907): The senses, apparently, were considered for the most part to be inconsistent and untrustworthy. For the rationalists, any knowledge worthy of a claim to truth had to be liberated from the senses, and ultimately be founded upon, or deduced from, "self-evident" intellectual principles. For the rationalists, the natural world was a rational world that was ordered and governed by rational principles accessible through the faculties of intellect.

In his famous exchange with Newton (through Clarke), Leibniz illustrates that such epistemological differences — at least between empirical materialists (Berkeley was an empiricist, but not a material realist) and Christian rationalists — were ultimately based upon an important ontological difference: Cartesian Dualism. He notes that, while both appeal to mathematical principles, "... the materialists... confine themselves altogether to mathematical principles and admit only bodies, whereas the Christian mathematicians admit also immaterial substances" (Loemker 1969, p. 677). Rationalists, as Leibniz futher illustrates, were at times prone to questionable claims based on empirically unconstrained rationalist principles:

> The great foundation of mathematics is the *principle of contradiction or identity*, that is, that a proposition cannot be true and false at the same time... This single principle is sufficient to demonstrate every part of arithmetic and geometry... But in order to proceed from mathematics to natural philosophy, another principle is requisite... *the principle of sufficient reason*, viz., that nothing happens without a reason why it should be so rather than otherwise... (for instance, Archimedes) takes it for granted that if there be a balance in which everything is alike on both sides, and if equal weights are hung on the two ends of that balance, the whole will be at rest. 'Tis because no reason can be given why one side should weigh down rather than the other. Now by that single principle... one may demonstrate the being of a God and all the other parts of metaphysics or natural theology ... (Loemker 1969, pp. 677-8)

The principle of sufficient reason, however, is not so much an argument for the existence of God as it is an expression of faith in the rational nature of the world of His creation. In his seminal *Critique of Pure Reason*, Kant collared such extravagant rationalist claims for the existence and omnipotence of God, and the immortality of the soul. With respect to our knowledge of primary qualities, however, like Descartes, Leibniz concurred that "... so far as can be done, everything should be derived from the nature of body and its primary qualities — magnitude, figure and motion." However, he goes on to argue that such primary qualities are *not* intrinsic to the bodies themselves and "cannot subsist without an incorporeal principle" (Loemker 1969, pp. 110-1). For Leibniz, materialism was insufficient to account for animate matter.

BACK TO THE FUTURE: CONSOLIDATING AND RESOLVING DIFFERENCES

Although there are exceptions, rationalists and empiricists alike tend to adhere to some form of representational realism and other dualist notions that distinguish primary qualities from secondary qualities, physics from psychology, and subjective experience from an objective world. Descartes, and rationalists after him, such as Leibniz and Spinoza, in granting ontological status to both the incorporeal mind and corporeal matter, were left with the problem as to how the structure of the material world was represented in the psychological structure of mental experience. For materialist-realists who wished to explain phenomena empirically, the role of subjective experience, because it is not (objectively) observable, was either down-

played, or ignored, on scientific grounds. As we have seen, for strict materialists, the problem is more often one of how the structure of an independent existing world comes to be *physiologically* represented within an observable *biological* organism that is embedded in, and acting upon, that world. This view has experienced resurgence with the advent of neuroscience.

The differences between empiricists and rationalists are also fairly well defined regarding the priorities and commitments respectively extended to sense and intellect, or more precisely, disciplined observation and formal reasoning. The differences between them that came to be of most concern from an epistemological perspective were the priorities given to *a posteriori* knowledge (dependent upon experience) and *a priori* knowledge (independent of experience) and their respective modes of inductive and deductive reasoning. However, to suggest that either school of thought held either observation or reasoning in complete disdain or disregard would be misleading, if not mistaken. A number of philosophical frameworks for situating educational research have recently been proposed that allude to similarities and differences between rationalism and empiricism, but do not address how these perspectives can be reconciled or resolved.

Martin and Sugarman, for instance, in appealing to the work of Cassirer and Lewin, have construed empiricist and rationalist tendencies in terms of "Aristotelian" and "Galilean" approaches to science respectively (1993). They claim that other philosophical distinctions used in framing paradigms of educational research such as the quantitative/qualitative distinction, amongst others, are predominantly Aristotelian in that "(t)his approach to inquiry overly emphasizes the empirical and methodological branches of research programs to the detriment of the theoretical and conceptual" (ibid., p. 17). An empiricist over-reliance upon observational methodology at the expense of rationalist-oriented conceptual theorizing may indeed be a sound assessment of contemporary state of research in education. However, it may come as much of a surprise to Galileo, the father of experimental science, to find his name used to characterize rationalist dispositions as it would for Aristotle, the father of classical logic, to find his name being used to characterize empiricist dispositions.

Furthermore, Locke has been characterized by some educational researchers as basing all knowledge on the senses (Reynolds, Sinatra et al. 1996). Locke was definitely an empiricist, insofar as he took all knowledge to be based upon *experience*. But for Locke, there were *two* fountains from which experience gives rise to knowledge: *sensation and reflection*. Sensation, in accord with his material realist ontology, he

took as experience conveyed to us from "external objects," in the form of primary and secondary qualities (see above). Reflection, for Locke, referred to the "*Perception of the Operations of our own Minds*:" Operations, such as knowing and reasoning, that pertain to our physiological constitution independently of external objects (Locke 1975/1689, p. 104-5). What is missed in interpreting Locke too strictly as an empiricist, is his insistence that our rational abilities play a fundamental role in forming our understanding of the world, and that we can reflect upon these abilities.

The differences between empiricists and rationalists, especially as mirrored in the beliefs of many educational researchers and theorists today, cry for resolution, not further polarization and prioritization. Both dispositions have important contributions to make in our understanding of ourselves and the world — and yet both, taken in isolation, or in opposition to each other, are fundamentally inadequate. Hume questioned both empiricist and rationalist claims to certain knowledge. As we have seen, he rejected Descartes's rationalist *a priori* deduction of the existence of an incorporeal soul, or in more modern terminology, an experiencing self (Anscombe and Geach 1970/1637). However, Hume also laid to rest any empiricist aspirations to certain knowledge in identifying a fundamental limitation of inductive reasoning: No matter how many times a given observation substantiating an scientific hypothesis is made, there can be no empirical grounds for establishing its universal validity (Hume 1977/1739). Thus, Hume both tempered Locke's enthusiasm for empiricism and quelched Descartes's rationalist aspirations with a thorough-going skepticism toward any claims to *a priori* knowledge about the natural world or our experience of it.

Thus, with the advent of natural philosophy a deep rift developed between the empiricists prioritizing principles derived from experimental observation, and the rationalists prioritizing self-evident intellectual principles on an intuitive or logical basis. I have interpreted these different dispositions towards understanding the natural world as a secular transmutation of the medieval scholastic debate as to whether the principles governing God's creation were immanent within the world as experienced by the senses, or transcendent in a way accessible only to intellect. Moreover, this debate, in turn, was deeply influenced, if not initially inspired, by Plato and Aristotle's respective views regarding universals.

Philosophical ideas, even modern ones, have a history. Just as the Greek Academics and the Medieval Scholastics influenced Enlightenment thinking, the philosophical debates that emerged in the 17th and 18th centuries remain relevant to contemporary problems in understanding educational inquiry. Indeed, it

is widely assumed by educational researchers working in the so-called "analytic-empirical" tradition that any knowledge claims must be substantiated in some way by either rational argumentation and/or empirical observation. Yet even today, as Martin and Sugarman suggest, the two approaches remain quite polarized and the relation between them poorly understood (1993).

As Salomon (1991), citing Bandura (1978), has pointed out, when one notion tends to entail, implicate, or be regularly associated with a number of others, there can be an effect that can be referred to as *reciprocal determinism*. It is evident that, in the early part of the Enlightenment, two closely associated clusters of notions were coalescing around the primary-secondary quality distinction. One cluster included such empiricist notions as the natural world, materialism, objectivity, *a posteriori* knowledge, and inductive reasoning. Another included such rationalist notions of self-awareness, mentalism, subjectivity, *a priori* knowledge, and deductive reasoning. As has been seen here, many of the notions internal to one cluster or the other were to a large extent reciprocally determined. However, given Berkeley's critique of the essential similarities between primary and secondary qualities, and the important relation between inductive physical principles and mathematical deductions involving those principles, it is also amply evident that these respective clusters of notions are not unrelated. Pressing philosophical questions, which remain today, concern what the proper epistemological relation is between empiricism and rationalism and how to resolve the ontological differences between realism and idealism. These fundamental philosophical problems are deeply embedded within the scientific and intellectual heritage of Western culture. Without clearly coming to terms with them, educational researchers will continue to confront age-old difficulties, not only in relating their own ideas to the work of others, but in understanding them at all.

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