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THE ROLE OF AMBIGUITY IN LEARNING*

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Introduction

"What a ridiculous topic! Everyone knows that there should be no ambiguity in learning. What students learn should be clear and unequivocal and not vague and ambiguous." How many of you readers agree with these statements? Disagree? Quite interesting, some of you agree and some of you disagree. Also, it seems that some of you are unsure as to whether you agree or disagree. I suspect you seek additional information before you are willing to make a judgement on the issue. Clearly the results of this informal polling indicate that we are not dealing with simple notions here. If we were, we would probably have more of a consensus in responses rather than diversity.

This lack of unanimity in the polling responses provides the underlying motivation for this paper. We will focus on two concepts, learning and ambiguity, and attempt to provide a comprehensive examination of the possible relationships between the two ideas. The paper will introduce the hypothesis that ambiguity deals essentially with the characteristics of human intellectual perspectives of nature and the self and therefore ultimately does have some kind of role, or influence, on the conceptualization and shaping of the theory of learning. This implies that we are adopting a very wide scope in our inquiry. For example, changing scientific paradigms in the domains of physics and psychology are not outside of our consideration. Nor is learning that takes place outside of the educational structure beyond our consideration in this paper. The possible relationships operate through a multiplicity of intellectual domains. Moreover, much of this role is presently implicit rather than explicit in the minds of many teachers and educational designers due to the preference for a narrow framework for educational theories. The primary goal of this paper is to try to make it more explicit.

How shall we go about achieving our stated goal? Well first of all, as an individual reader, it should be quite obvious to you that my first paragraph is a literary contrivance and not really a

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factual statement. Unless one can get into the minds of the other readers, there is no empirical basis to my claim that there is diversity in the responses. So what's the purpose of this imaginary polling result? Is it for deceit? The answer is no. The literary device is for the purpose of setting the theme of this paper. We will be dealing with a wide range of concepts and theories of tangibles and of intangibles. The concepts may have different meaning to different individuals; and different individuals may side with conflicting theories. In principle, this would be sufficient for the diversity in responses that could occur in our polling. However, this is taken as a basic presumption of our inquiry and not as something that we plan to demonstrate by either empirical analysis or by force of argumentation.

The meaning of learning is shaped by a diversity of conceptual and theoretical perspectives contained in people's minds. It is not the purpose of this paper to side with one school of thought underlying learning over any other school of thought. Instead, the aim is to try to shed some insights regarding the manner in which an ambient concept like ambiguity could get incorporated into some meaningful theories of learning. Clearly, the author of this paper does have some normative biases. But hopefully they will not be too obvious in the discourse that ensues. Nevertheless, points of disagreements are *inevitable* as a consequence of the diversity of topics discussed.

Secondly, in order to accomplish our stated goal, we need to be careful of the fact that our scope of inquiry is wide but that our focus for gaining insight (or understanding) is quite narrow. Or, another way of putting it is that we would like to express the insights in a local setting rather than a global setting. As an analogy, consider a detailed road map of the continental United States of America. You will notice that any particular city, or location, is interconnected with another city, or location, by a network of roads. Thus, to fully understand the implications of an American city being an interconnected entity you will have to examine the network of roads as well as the nodes (cities). However, we could introduce an analytical contrivance for focusing on the nodes (local setting) even though we have some understanding that they are part of an integrated network (global setting). The analytical contrivance that is employed is the distinction among variables that are considered to be endogenous (internally determined) in the analysis being undertaken verses those that are considered to be exogenous (or assumed to be givens) in the analysis at hand.

Framework of Analysis

For the most part, the question of: What is learning? has been examined in a local setting rather than a global setting theoretical framework. Learning is associated with education. Although education is just one of many different kinds of human endeavors, such as arts, sciences, engineering, religion, etc., there is a propensity to answer the above question within the context of education itself (local setting) and not the wider framework of life (global setting). While

it is understood that learning can take place outside of the educational structure, theories of learning tend to focus on learning that takes place within the academy rather than outside of the academy. This bias towards formal education rather than informal education is quite understandable if you know something about the history of production specialization in many societies.

Consistent with the economic theory of division of labor, teachers are said to belong to the profession of education (a specialized channel of production) while other individuals belong to other professions such as: business, engineering, social work, theater, etc. Education is a part (a node) of the social network called a society or a community. Although education is an integral part of a whole, education is studied primarily in a local setting and not a global setting framework. Let us resort to a sociological concept at this juncture of our discussion. This in turn will conveniently provide us with the opportunity to establish the distinction between the two senses in which we will be utilizing the word 'role' in this paper. Within the academy, there are instructors (as well as supporting staff) and students. Simplistically, it is the role of instructors 'to teach' and the role of students 'to learn.' Thus the roles of teaching and learning basically identify formal education. But just what do teaching and learning entail? What is taught (learned)? When is it taught (learned)? How is it taught (learned)? Why is something taught (learned) and how effectively is it taught (learned)? Obviously, besides the agents involved, local setting theories underlying educational activities would have to deal with the additional conceptual elements of content, context and assessment also. The diversity of professionally generated (academic) theories of teaching and of learning provides the foundation for educational *practicum*. For after all, educational practices are not conceived and implemented in a conceptual and theoretical vacuum.

The role of ambiguity in learning is clearly *not the same* as the sociological role of a student to learn. The sociological concept of role has the connotation of social expectations. In other words, students are expected to learn and teachers are expected to teach. Not only that, these agents (teachers in particular) are expected to execute their roles in as successful manner as is feasible. [Thus, not only is there a distinct career path but also a system of professional rewards and advancement associated with education.] But by what criteria do we measure success? It is with respect to this last question that we will begin to become aware of the significance of ambiguity in learning (and teaching). Exogenous factors as well as endogenous factors significantly determine success within the framework of a profession. It is this determinant aspect of the concept of ambiguity that is being referred to in this paper as its role. In other words, we are using the term 'role' here as a substitute for the more formal language that successful learning is a function of ambiguity (and other factors or variables). If the agents of education do not effectively incorporate more of the external considerations (variables) into their teaching and learning practices, then the results (or outcome) of education will not fulfill social

expectations satisfactorily and the profession will be held in ill repute as a consequence. For a historical perspective, refer to David Nasaw (1979).

Currently there is a joke circulating in the discipline of economics due to the record of extremely poor predictions made by macroeconomists lately. *"The economy is too important to leave to the economists."* Some economists have simply ignored it. Others have taken it seriously and started to explore the boundaries of their model building (theorizing) in order to more effectively meet the policy (social) expectations placed on the profession. In a similar vein: *"Are teaching and learning too important to leave to the educators?"* I do not believe there is a need for an economist to stir up sentiments for academic reform. There already appears to be substantial professional interest in developing *new* educational theories of teaching and of learning to guide in the reform of educational practices, or at least to reassess the effectiveness of current practices with a view towards possible changes. Hopefully, this paper can provide some positive insights that will be of some assistance in this process of academic reconstruction of educational theories and reform in educational practices.

The Scope and Depth of Learning

Every so often one comes across a *really* mind-expanding kind of statement or observation. Such an experience happened to me recently. While hypertexting via the Internet (which itself is a mind-expanding type of exercise) recently, I came across a manuscript-in-process by Carl Bereiter (1998-9). In Chapter 8 of the manuscript, Bereiter attempts to establish what he calls "a workable distinction between learning and knowledge building." To begin with, he states:

> To head off one potential misunderstanding, we must note at the start that learning accompanies all conscious activity. Therefore learning necessarily accompanies knowledge building. But this does not make them the same thing. Learning occurs while setting out garbage, too, but we do not conclude from this that learning and setting out garbage are synonymous.

It quickly occurred to me that Bereiter was attempting to make his distinction on the basis of necessary and sufficient conditions, i. e. learning was a necessary but not a sufficient condition for knowledge building. I did not find myself disagreeing with his line of logical reasoning.

However, when he substituted setting out garbage for knowledge building, as another example of conscious activity, I immediately said to myself, Hey wait a minute, setting out garbage is *not* a conscious activity and therefore not logically substitutable for knowledge building. After some reflection however, I realized that at some earlier stage in my life, setting out garbage might have indeed been a knowledge building kind of exercise. But now it has become a routine sort of activity and is not a challenging problem any more, with the proviso that no unexpected constraints are introduced into that activity. If that should happen, setting out the

garbage may again become a problematic and not a routine activity. Nevertheless, Bereiter's discussion made me suddenly realize that a larger share of learning in a person's lifetime may in fact occur outside of school rather than inside the school.

Thus, a person's informal (non-academic) learning may be relatively more consequential than her formal (academic) learning. Yet, much of the existing theories of learning are academic-centered and not lifetime-centered. Consequently, there may be a significant misplaced emphasis in much of the existing theories of learning. To some extent, this is being corrected in the development of what are referred to as ecological theories of learning. [David Solomon (2000)] These ecological theories manifest more of a global setting view of learning relative to the academic-centered theories of learning. Thus, an asymmetry is developing between the theories of teaching and the theories of learning. This asymmetry between teaching and learning allows us to make sense of the reference that someone is 'self-taught.' It means that the individual has gained knowledge, or learned, about something without the direct assistance of a teacher.

The rest of Bereiter's discussion in his Chapter 8 is not very elucidating. In fact, I think that his introduction of the differentiation of conscious activities into the category of those for the purpose of learning from the residual category of activities for all other purposes (including knowledge building) to establish the distinction between learning and knowledge building is downright confusing. His categorization of conscious activities and the utilization of Sir Karl Popper's (1979) "three worlds" analogy in his elucidation leads me to believe that Bereiter is attempting to make his case (workable distinctions) in terms of a scope and depth methodology. However, his manner of specifying scope does not enable me to make some sense out of a normative statement like: *"We should teach students to learn how to learn."* When you ask the academician who made such a statement for a rationale or justification, the response is somewhat as follows: *"Because they will soon graduate and enter the 'real world' where knowledge is rapidly changing and they need to know how to successfully cope in such an environment."*

My own thoughts on the scope and depth of learning are expressed in what follows. But since this discussion is conceptually and theoretically biased, let me disclose the nature of the biases up front. I agree with Bereiter on the idea that learning is associated with human cognition, i.e. consciousness. Since consciousness relates to the human mind, it follows that our theories of the mind will have an impact on our theories of learning. However, I differ with Bereirter on the conceptual relationship between learning and knowledge building. He hypothesizes that learning and knowledge building can be conceived of as separate forms of conscious activities, whereas I currently adhere to the conceptual view that learning and knowledge building is a form of complementary cognitive activity.

So where does scope come in? Knowledge is specific to human (external) activities; and we can categorize human activities into various sorts. By virtue of different kinds of knowledge (derived from different activities), we can categorize different kinds of learning but we cannot cognitively separate knowledge and learning. So how would this kind of classification schema work? Consider this example, operating a machine is placed into a different activity category from designing and building the machine. Thus, knowledge associated with operating the machine is considered to be different from knowledge associated with designing and building the machine. And furthermore, the learning of one type of knowledge is distinguished from the learning of the other type of knowledge. This then could become the basis for dividing education into the sub-fields of vocational education and professional education. So now we can have academies that specialize in vocational education and other academies that specialize in professional education. On top of this type of scope distinction, we can add the distinction that we made earlier regarding learning that occurs within an academy (vocational or professional) from learning that that occurs outside of any academy (on the job learning). Notice that we are beginning to 'matrix' scope distinctions. However, this is not as complex as it could get.

We can also make distinctions on the basis of depth, or more specifically, the degree (or level) of complexity. The scope distinction between vocational and professional education implicitly assumes a degree of complexity distinction. This is reflected in the belief that the operator of the machine does not really need to know the design or architecture of the equipment in order to efficiently operate it. Manual and procedural skills are essential but the understanding of blueprints is not. However, something could come along and jolt this existing belief and induce some kind of hypothesis of the sort that knowledge of blueprint reading might significantly improve the operator's productive efficiency. If this is the case, then we may begin to notice that the boundary between vocational and professional learning has become a little fuzzy as a result of this reassessment. However, the degree of complexity of the knowledge learned need not blur the distinction between formal and informal education. It may require an individual with a very high IQ, but it is quite conceivable that a person that does not have a formal education could learn enough informally to effectively deal with problems in, say, electromagnetic wave propagation in the domain of electrical engineering. Thus, when we explicitly add complexity to our classification scheme we find that we are now dealing with a three-dimensional array (cubic matrix) instead of the two-dimensional one.

So where are we terms of our discussion? In metaphorical terms, learning and knowledge can be conceived of as a cubic matrix (classification schema) within the context of a human mind. This is an 'artifact' within my mind. Hopefully, you will absorb it as an artifact in your mind as well as you read and reflect on this paper. This last statement points out that learning involves more than just mental, or cognitive, artifacts. Learning is a process as well as a generator of mental artifacts. Learning is essentially a mind-expanding process. To understand

this learning process, we will have to understand how the human mind works in terms of relating our mental artifacts with our behaviors (activities). Thus, our discussion of learning would not be complete without some discussion of how the mind works (i.e. the most current theory of mind). But before we proceed in that direction, let me use the cubic matrix conception of learning and knowledge that we just described in this section to provide some kind of meaningful interpretation to the academician's statement presented earlier.

Is 'To Learn How To Learn' Meaningful*?*

Our categorical distinctions of learning (based on categories of knowledge) do not allow for meaningful phrases of the sort 'to learn how to learn.' In terms of our artifact and the logical way of reasoning, that phrase is *contradictory* if it refers to a single agent. We can accept the phrase 'learning about knowledge' which specifies knowledge as the content of educational theories. But this second phrase, as it stands, is ambiguous. There are different kinds of learning based on different kinds of knowledge involved. Thus for learning to be meaningful, we need to specifically state what kind(s) of knowledge is (are) being alluded to. For example, are we concerned with the knowledge associated with using basic math or are we concerned with the knowledge associated with formulating and solving differential equation models in some scientific domain such as theoretical physics? Why do we need to make this kind of definite specification? Because the first kind of learning is essential for success as a McDonald's employee, but the second kind of learning is essential for success as a theoretical physicist. Is our social objective more of the first kind of success or of the second kind? If the weight is placed on the second, then the social implications are that there should be more academic emphasis placed on the second kind of learning relative to the first kind of learning in order to fulfill social expectations.

Do teachers learn? Yes they do. (Or at least, they have many opportunities to learn.) What could they learn? Well, they could learn about different sorts of knowledge just like everyone else can. Hey, wait a minute, that's too vague, let's be more specific! Well, as an example, a high school science instructor could learn more about knowledge generated in the various domains of natural sciences by taking college level courses in these disciplines in order to enhance his level of expertise in natural sciences. Also, this same instructor could learn more about the theories underlying teaching practices in secondary education by taking graduate level courses in education. Furthermore, this same instructor could learn on the job about the formal educational process, which involves instructors teaching and students learning in an academic setting. Thus, while the teacher is doing teaching in the context of the academy, the teacher could also be undertaking self-learning (classroom based research) even though this takes place within the walls of the academy. This in class learning of how students learn about some subject matter within the academy, however, must be construed as *instructors* learning about how *students* learn about a subject in an academic setting and not as *students* learning about their

own learning process (contradictory). Thus, in our cubic matrix way of thinking, instructors could conceivably *teach* and *learn* simultaneously in their own classrooms. However, they would necessarily have to teach and to learn *different kinds of knowledge*.

We should also point out that high school students could also simultaneously teach as well as learn within the context of the formal educational structure. This becomes quite obvious when we make note of the use of in-class student tutors. The complexity of a subject matter enables us to establish a measure of expertise (understanding) regarding knowledge about this complex subject matter. While the instructor has a higher level of expertise than all the students do (by virtue of taking college level courses on the subject matter), as the students learn in response to the instructor's teaching, some students may begin to develop a higher level of expertise relative to other students in the class. This gap in the levels of student expertise can be utilized in the form of student tutoring (teaching) in order to achieve more homogeneity in student learning.

So we are now at the level of complexity where we can now meaningfully say that in the formal educational structure, instructors teach and learn and students learn and teach. And this depiction of the academy is not as simplistic as when we first described its activities in terms of sociological roles in the earlier Framework of Analysis section. Notice also that we have broken out of the mental 'box' (mindset) of 'either/or' kind of reasoning. Agents in the academy can teach *and* learn and not necessarily teach *or* learn. This more in depth perspective of what goes on in the academy is attributable to the treatment of learning and knowledge building as a *complementary* cognitive concept rather than as *autonomous* cognitive concepts.

Alternative Theories of Knowledge and Ambiguity

In the two prior sections we presented a conceptual and theoretical perspective that inferred learning was related to knowledge and that all forms (the scope and depth schema) of knowledge were artifacts of the human mind. However, we did not deal with the question: How does the human mind work in terms of knowledge building and relating knowledge (internal cognitive entities) with human behavior (external)? Before we do so, let us probe the most complex aspects of knowledge itself. That is to say, let us try to examine the very foundations of the knowledge that is taught and learned in the academy. It is in regards to this very deep aspect of the content (knowledge) that we must allow for alternative theories of knowledge and where we will encounter the concept of ambiguity. But we may have opened ourselves up to an impossible task. This is because the object of our inquiry (knowledge in the context of mind) has such an extremely wide scope (about all kinds of human activities) as well as a exceedingly deep level of complexity associated with it. The philosopher of science, William Bartley III (1990), has used the metaphor of the ocean's depth, "unfathomed knowledge," in the title of one of his books.

Therefore we are (or at least the author is) faced with the dilemma as to how to go about discussing the subject of knowledge: local setting or global setting? Well, I have decided that we will neither resort to local setting or to global setting but to both. And we will proceed in an eclectic fashion in terms of modes of inquiry. Note that intellectual laziness does not motivate this decision. In fact, intellectual honesty does so. Under the circumstances, maintaining only an analytical mode of inquiry is just not warranted (too restrictive) relative to the scope and depth of our object of inquiry in this section. We need to be open or receptive to any and all modes of inquiry; i.e. we need to adopt what the physicist Basarab Nicolescu (1996) calls a "transdisciplinary" mode of inquiry. Furthermore, we have left learning as a middle-level concept in terms of complexity but the concept of ambiguity will be examined as a very deep level concept. Thus, to establish any kind of meaningful relationships between the two concepts one must be able to transcend the gap or space between the two levels of complexity. It is my hope that the readers of this paper can bridge the complexity gap.

To use a metaphor that should be understandable to educators: Who 'certifies' the knowledge that is taught in the academy? Of course there is no formal certification process comparable to teacher (competency) certification. But there is an informal process based on the concept of authority. Then who are the authorities and by what criteria are they deemed to be in a position of authority? Without getting involved in any extended discussion, it used to be that philosophers and religious leaders were deemed to be the people in the position of authority because philosophers were the seekers of Truth and religious leaders were the receivers and gatekeepers of some kind of Divine Truth. The tug-of-war between religion and philosophy manifested itself in education in terms of the distinction between parochial and public schools. Lately, scientists have tended to displace philosophers and religious leaders as people in the position of authority by virtue of the "power" of their scientific knowledge [Sir Francis Bacon (1620)] rather than the Truth status of their knowledge. Underlying all of the historical changes in terms of authority has been a tension among alternative theories of knowledge in the global setting. And this social competition among concepts, theories, doctrines and ways of knowing (modes of thought) relating to knowledge and the human mind has had an external impact on the (academic) theories of education, which are for the most part formulated in terms of a local setting.

While the history of intellectual thought on knowledge is extensive, we can 'cut to the chase' by focusing our attention on the Truth status of knowledge. The Truth status, stated in a simplistic manner, refers to the deepest aspect of our knowledge about anything. We are at the deepest level of complexity as far as knowledge is concerned, i.e. at the foundations of our knowledge. Can we know anything with absolute certainty or not? (In terms of colloquialisms: 'a sure thing,' 'no ifs or buts about it,' 'no two ways about it,' etc.) If not, we must be prepared to confront (or embrace) *uncertainty*. Here is where we have the concept of *ambiguity*. In lexical

terms, “ambiguity” is the noun for “ambiguous,” which comes from the Latin verb *ambigere*. The Latin word can further be divided into *ambi-* (English translations: “on both sides” or “around”) and *agere* (English translation: “to drive”). Thus, if something is “ambiguous,” it is “doubtful or uncertain.” [Dictionary Source: *Merriam-Webster*]

There are two extreme conceptual perspectives on the Truth status of our knowledge. We can have knowledge about some things in our lives that is absolutely certain, but this kind of knowledge is not created by the human mind (consciousness). Rather, it is the kind of knowledge that is received by the human mind via divine intervention. In other words, we can have some forms of *absolutely certain* knowledge, but it is by the ‘grace of God’ (i.e. some Supreme Being) and not by any of mankind’s doing. Any knowledge derived by human modes of inquiry (such as reasoning) is necessarily ambiguous. To return to the certification of knowledge metaphor that was introduced earlier in this section, the only authority of Truth is God. The other extreme perspective is there is no God (or ‘God is dead’) and that all of mankind’s knowledge has been and will forever be created by the human mind, i.e. consciousness. Consequently, all knowledge is necessarily ambiguous (uncertain) and Truth is an illusion.

Of course, these polar conceptions of Truth represent the boundaries of the path down which mankind’s intellectual development has been travelling. During the era referred to as the Enlightenment, Western philosophical thought led to the development of the concept of Universal Ideas. These universals were principles that could be derived and comprehended by human minds via formal analytical thought. The concept of Universal Ideas did not appear to be inconsistent with the concept of Divine Truth. However, there was no way that humans could establish the one-to-one correspondence between Universal Ideas and Divine Truth. Nevertheless, the Enlightenment Era created an intellectual environment (modernity) which fostered advances in the creation of other forms of human knowledge (derivatives of Universal Ideas). But at the same time individuals who wanted to believe that there was some unknowable God whose Divine Truth apparently supported mankind’s quest for Universal Ideas were accommodated.

Thus, there was no need for a recurrence of the dreaded Inquisitions of the Middle Ages. For a hierarchy of Truth status was created (Divine knowledge, universal knowledge, and derivative knowledge) that accommodated the existence of knowledge seeking mankind and the belief in the existence of a God. Unfortunately, the intellectual environment is now radically changing. The concept of Universal Ideas is being intellectually discredited and the polar position that only the human mind creates knowledge is gaining social acceptance. Within the new intellectual environment that is evolving (postmodernism), science is ascending over religion and philosophy, ambiguity is the “preeminent characteristic” [Richard Brown (1995, p. 2)] and there is a growing quest for new forms of social unity in the face of increasing multiplicity (relativism).

How Does the Mind Work?

Let us now return to the discussion of the process aspect of learning. It was mentioned earlier that knowledge building results in cognitive, or mental, artifacts but that learning was more than just the product, it was also the process of creating cognitive artifacts. The product and process conceptualization of learning, as associated with knowledge building, can be formulated in terms of a problem-solving exercise. The human mind is set upon the task of identifying, defining and solving a new problem. Note that I said a new problem. Going back to 'setting out garbage,' the reason I did not initially consider that particular activity as either a problem-solving or knowledge building kind of activity was because for me it was based on knowledge already learnt, i.e. a problem already solved. However, we must remember that knowledge is a stock variable as well as a flow variable. Once we have learnt something anew (flow), it becomes part of our mind, or consciousness (stock). In this sense, learning is a mind-expanding kind of process. And thereafter, much of our daily routine activities is based on stored knowledge and does not involve problem-solving activities where we are learning new knowledge. Nevertheless, both categories of activities involve the operation of our minds. Consciousness is an all-encompassing property of human existence, although it may often seem like we are doing something unconsciously.

What we have said in the previous paragraph represents nothing novel as far as the history of educational philosophy is concerned. The pragmatist and educational theorist John Dewey (1910) has already expressed the distinction between process and product and also between unconscious and conscious behavior. Focusing on the human thought process, or "thinking," he also argued for some appropriate balances in educational practices. However, Dewey's comprehension of how the human mind worked was very limited relative to what we know today via contributions from such recently created disciplines as cognitive science and neuroscience and from changing scientific paradigms in other disciplines, such as physics, biology and psychology, as well. To keep the focus of this paper narrowly on education, let us concentrate on the question of: What is thinking? In effect, we will be entering a third order exploration of thinking (cognition) utilizing some of the insights (knowledge) gained recently in these other disciplines.

We have already undertaken what the philosopher John Searle (1983, p. 156) calls a "second order" investigation of the question: What is thinking? Thinking occurs when the mind creates and utilizes knowledge and where learning is involved. Thus, instead of speaking about thinking *per se*, we were earlier discussing a cubic matrix schema of knowledge and relating it to learning and we were also making a distinction between artifact and cognitive process. These earlier endeavors all fall under the rubric of "thinking" in Dewey's sense. Thinking is a cognitive activity, i.e. part of our consciousness. However, we generally think along very narrow or

restricted modes of cognitive process (mindset). Thinking is usually associated with analytical modes of thought; i.e. the mind operates along the lines of logical reasoning and classification, or in terms of a *reductivist* strategy of knowledge building. However, thinking need not be only associated with rational modes of thought. A cognitive revolution is taking place that is leading to a third order understanding of thinking. Our consciousness is equally capable of holistic modes of thought such as artistic creation [Susanne Langer (1988)] and/or dialogic reasoning [Gordon Wells (1999)], or in terms of a *constructivist* strategy of knowledge building. And it is the mind's holistic capacity that appears to enable Western thinkers to resolve many seemingly intractable paradoxes lately.

You can think of paradoxes as an extremely complex form of problems that require some solution. There have been significant paradoxes in philosophy, theology, mathematics and the sciences. Generally, the resolution of a paradox (problem solving) culminates in a significant advance in human knowledge along a broad front (different domains of knowledge). A long-standing paradox regarding the human brain and the human mind appears to be on the verge of such a resolution. And this is sending shock waves to all the fields of human knowledge (i.e. the subject matter taught in schools). For the past two centuries or so, scientists have adopted a reductivist strategy of knowledge building and utilized a deductive reasoning mode of thinking as their bases of determining scientific causation. Furthermore, the underlying logic of deductive reasoning went all the way back to the Greek philosopher Aristotle. The Aristotelian system of logic is a bivalent system based on the following three axioms: (1) The axiom of identity, i.e. A is A. (2) The axiom of non-contradiction, i.e. A is not non-A. And finally, (3) The axiom of the excluded middle, i.e. we cannot have *both* A is A and A is not non-A simultaneously.

The reductive, Aristotelian way of thinking (mindset) fostered a subject-predicate mode of mental inquiry, i.e. the mind inquires about the brain and also an either/or (duality) pattern of reasoning. With the advent of scientific medicine, the brain could be analyzed along with the body's other various components. But the totality of human body components could not explain the soul nor could classification of the parts of the brain explain the mind. This allowed for the separation of religion and philosophy from the sciences. The mind was a metaphysical phenomenon and therefore should be subject to philosophical inquiry and along similar reasoning, the soul belonged to the purview of theology. The Enlightenment philosophers really confused the issue between science on one side and philosophy and theology on the other side. Bishop George Berkeley (1710), in particular, argued that there was no objectivity beyond the mind; or if there were, mankind would not be able to *know it* since we can know only through the mind.

How is the mind-brain paradox being resolved? Interestingly the impulses for change are coming neither so much from medicine (brain) nor philosophy (mind) but from new technological developments (computer science) and new scientific paradigms in physics and psychology and

metaphors from biology and zoology. And much of this interdisciplinary thrust regarding our understanding of the human mind is manifested in the new field of cognitive science. Science has gained the dominance in our quest to understand how the mind works. And in so doing, science is becoming the higher authority that certifies the relevant knowledge that, socially speaking, 'ought to be taught' in the academy. What are the essential features of the scientific paradigm of mind? How do we think?

The new scientific paradigm relaxes the restrictions that Aristotelian (bivalent) logic places on modes of thought, accepts the concept of 'emergent' phenomenon, and relies a great deal on the evolutionary process and biological metaphors to explain the essence of the human mind which is consciousness. The evolving scientific paradigm of mind places more emphasis on constructivist strategies of knowledge building rather than reductivist strategies. The bias of bivalent logic was that it fostered a mode of thinking that focused on the 'being' rather than the 'becoming,' by virtue of not allowing the excluded middle. The logical purist would say that this leads to *contradictions* or *impossibilities*. Maybe so, but it also hinders consideration of *possibilities*. Consider the analogy of the opposites (duality): black *or* white. White is not black and black is not white. If we also allow for black *and* white, (the excluded middle) it appears that we have a contradiction, or at least an ambiguity. However, out of this possibility emerges shades of gray. We now have an entire *spectrum of alternatives* ranging from black at one end to white at the other end. In a similar fashion, the mind is now being conceived of as what the neuro-psychologist and 1981 Nobel Prize winner, Roger Sperry (1995, p. 42), called an "irreducible emergent phenomenon" that complements the brain. And from the deepest ambiguities (possibilities) of our minds (i.e. consciousness) emerge reality (meaningful ideas) or at least our knowledge of reality. Thus we construct our social identities and our knowledge of nature via our individual consciousness and our consciousness is part of some evolutionary process that determines the growth of the human species and possibly the development of the universe in terms of physicist John Wheeler's (1981) provocative participatory anthropic principle.

Ambiguity and Current Teaching Practices

While our aim is to make an explicit connection between the concept of ambiguity and theories of learning, in this section of the paper we will make some observations regarding current teaching practices in the formal school system. This is based on the premise that teachers still have a significant control over what and how students learn in their classrooms. Our four observations will be confined to areas where ambiguity appears to be an important aspect of student's learning of subject matter (knowledge about something). The four observations are: (1) inquiry-based teaching or discovery learning of science in elementary and secondary schools; (2) ill-structured or ambiguous problem solving in secondary schools and colleges; (3) making

probability theory and quantitative reasoning part of the liberal studies core on the university level; and (4) the development of hypertext learning via the Internet.

Inquiry-Based Teaching

Suppose we let riddles serve as a model for all kinds of problems; and riddle solving as an analogue for problem solving. Suppose also that there is a long history of riddle solving and also that a group of experts (professionals) on riddles' structure and solutions (the RSS experts in technical jargon) has developed. Here is a multiple choice test question based on the above mentioned facts: In terms of the knowledge of riddles, how is this subject matter taught (expected to be learned) in a typical classroom setting? Answer options: (a) Students are taught to memorize a list of riddles and their answers. (b) Students are taught the rules (principles) of riddle solving as devised by experts and are expected to be able to apply these rules after they graduate. (c) Students are taught the rules of riddle solving and provided some practice (laboratory or fieldwork) regarding how to apply the rules. (d) Students are encouraged to discover what riddles are all about by constructing and answering each other's riddles and reflecting on their riddle solving experience. (e) All of the above. Of course, the correct (in the positive sense) answer is (e). Knowledge about something is taught differently at different levels of schooling (stages of learning); and even at any given school level, knowledge is taught differently because instructors individually adhere to *different* learning theories.

However, if proponents of inquiry-based learning could have their way, option (d) would be the way in which mathematics and scientific knowledge are taught in the schools. Advocates of inquiry-based learning do not believe that reliance on options (a), (b) and even (c) are adequate to prepare students for the life they will lead after their formal education. Gerald F. Wheeler, executive director of the National Science Teachers Association (NSTA) is quoted in a *Business Week* (12/13/1999) science and technology article as saying: "Drilling students with lectures and a long list of facts just doesn't produce a thinking adult." Also quoted in the same article is Reeny D. Davison, executive director of Allegheny Schools Science & Technology Inc. (Asset) that trains teachers in the new techniques of inquiry-based learning. According to Davison: "When you expose kids to the concept of variables—what influences what and how—it makes them really perceptive and analytical. They learn concepts that stay with them for life."

Essentially, inquiry-based, or discovery, learning is attempting to reinvigorate learning in the schools by making learning relate to life in general, i.e. enabling students to relate to life in a reflexive and vital manner. The active learning option (d) is favored over the passive learning options (a) and (b). Although inquiry-based learning may seem like a very novel theory of learning, it is not. John Dewey (1899) advocated this theory of learning via his Progressive School movement of the early 1900s. Interestingly Dewey demonstrated a very good appreciation for the role of ambiguity in learning. Let me quote from his volume, *How We Think* (italicized words are mine and not Dewey's):

> Alertness of observation is at its height wherever there is "plot interest." Why? Because of the balanced combination of the old and the new, of the familiar and the unexpected. We hang on the lips of the story-teller because of the element of mental suspense. Alternatives are suggested, but are left *ambiguous*, so that our whole being questions: What befell next? [John Dewey (1910, p. 193)]

And continuing to quote Dewey:

> When an individual is engaged in doing or making something (the activity not being of such a mechanical and habitual character that its outcome is assured), there is an analogous situation. Something is going to come of what is present to the sense, but just what is *doubtful*. The plot is unfolding toward success or failure, but just when or how is *uncertain.* [John Dewey (1910, p. 194)]

Ill-Structured Problem Solving

At the level of a research university, some gifted and well-prepared undergraduate students are provided with the opportunity to participate in frontier type problem solving endeavors via collaborative research programs. In that context, students are immediately exposed to all the ambiguities of creating new knowledge in a specific scientific domain. However, for the most part, just like the elementary, middle and high school students, college students are taught mathematics and the sciences in the classroom. And in most cases, the classroom is a large lecture hall where teaching is done in the format of Alison King's (1993) metaphor: "sage on the stage." Just as in the lower levels of the academy, a vigorous debate is taking place at the collegiate level regarding active learning verses passive learning. And unfortunately, the debate seems to be centered on a bivalent (either/or) mode of thinking and in many cases this is leading to some very drastic changes in teaching practices. Instead of having an 'all or nothing' situation where large lecture classes are abolished in favor of small groups of students discovering the essence of scientific concepts and principles, one can opt for a strategy of *incremental* changes in teaching practices which attempts to *balance* all of the learning options discussed in our riddle model.

One area where incremental changes in teaching practices can be implemented is problem sets. Many disciplines already rely on a problem solving approach to teaching students about the disciplines' concepts, models and social relevance. One such discipline is economics. The engineering fields also offer good examples. The issue with respect to the use of problem sets in academia is not so much the matter of not enough or too much, but with respect to what kind of problems students are expected to solve. Most of the problems that students are expected to solve are well-structured problems as opposed to "ill-structured" ones. [David Jonassen (1997) and Gilbert Suzawa (2001)] The well-structured problems may enable students to gain mastery of techniques of analysis, but provide students with a very narrow perspective of

the theories involved. It is only when students are made to confront ill-structured problems that they gain some tolerance for ambiguity and begin to recognize the limitations of their theories.

Mastery of analytical techniques with no accompanying appreciation for ambiguity could be very dangerous from a social perspective, especially when we are dealing with policy considerations. Economist W. Brian Arthur (2000, pp.) makes the case in terms of the following account:

> When a decision maker faces a situation of high complexity, say Bosnia in the mid-1990s, applying theory prematurely—a set of precise but narrowly applicable metaphors—can be dangerous. Let's say he is in the State Department looking at Bosnia and has been in graduate school in political science, doesn't have much experience and is full of theories. His reaction may be to shoehorn Bosnia into a pre-constructed framework. But in this situation it is better to wait and observe. And in observation to invoke a variable set of pictures on which he may conjure up a richer set of associations. (break in quote) Eventually from such pondering and perusal—from dreamlike association—a composite set of hypotheses or composite picture may emerge. It's at this stage that theory might apply. Premature association without going through the richness of a wide set of pictures may be disastrous. Where I come from, Belfast—another complicated situation—we say: "If you're not confused, you don't know anything."

Probability Theory and Risk Assessment

In this paper, we have not investigated theories of probability or techniques of risk assessment. However, there is an overlapping relationship between uncertainty and risk, and therefore we should not totally ignore the domain of risk analysis and its foundations in terms of mathematical theories of probability. Simply put, risk taking is basically one of mankind's systematic ways of trying to dealing with ambiguity. Consider a primitive situation where you find yourself at a split in your path. You are not certain as to whether the right fork or the left fork will get you to your desired destination. To help you make your decision, suppose you commit to flipping a coin with the decision rule: heads you go right, tails you go left. Well here you have the beginning of probability theory or statistical analysis of decision-making. Imagine what the art of coin flipping and relating it to decision-making would be like after centuries of knowledge building by the human mind? For a historical perspective of such an intellectual development, refer to the volumes by Peter Bernstein (1996) or Stephen Stigler (1986).

Probability theory and risk assessment enters into educational debates more as a curriculum matter than a teaching or learning practice matter. Nevertheless, because of the association between risk assessment and ambiguity let us briefly make an observation regarding recent curriculum reform at Harvard University. In 1997 the faculty of the College of Arts and Sciences at Harvard University voted to revise the Quantitative Reasoning requirement of the

Core Curriculum. In a Letter to the Faculty dated January 26, 1998 (pp. 2-3), Dean Jeremy Knowles states:

> The new requirement comes at a time when quantitative methods such as surveys and statistical analyses are being used more and more to shape and to convey information Our graduates must be able to penetrate he numbers and the claimed conclusions of data used in public discourse, and to understand the issues of a more quantitative world, The Quantitative Reasoning requirement will be analytical in focus, comprising courses across many fields, each of which will embed the elements of numerical analysis and application. The new Core sub-committee is working to recruit courses in a range of fields, such as risk analysis, demography, evolution, logic and econometrics.

I'm not sure if curriculum reform at Harvard would be applicable to curriculum reform at the secondary education or elementary education levels. However, Andrew Lo, a professor of finance at Massachusetts Institute of Technology, believes that basic concepts of probability theory should be taught to elementary school students. And preliminary research results of Bonnie Halper-Felsher, an assistant professor of pediatrics at University of California at San Francisco, indicate that children of varying ages lack a uniform understanding of the language of probability and therefore may not be able to adequately protect themselves from risky situations.

Hypertext and the Internet

We all know about the Internet. One cannot spend any twenty-four hours time span without some reference to this marvelous communications network where information, of all sorts and from any location, is abundant and can be accessed at very low cost. We not only hear about the Internet, many of us use it regularly, e-mailing friends and colleagues, searching the information network, the World Wide Web, for research data and references, getting the latest stock prices to see how rich we are, etc. In fact, it is largely due to the rapid rate of technological progress in Computing and Information Technology that pressure is being placed on the educational establishments for reform in teaching and learning practices. The basic contention being that the current educational practices are not adequate in terms of preparing students to work and live (as adults) in a society where knowledge of all sorts are expanding exponentially and economic, social and moral boundaries are shifting almost as rapidly. Technological change cuts two ways. On the one hand it may stimulate social pressure for educational reforms, but on the other hand it can provide the means for implementing changes in teaching and learning practices. In this observation, I would like to focus on the development of the hypertext.

The basic idea for the hypertext predates the invention of the Internet. In an article published in the *Atlantic Monthly*, Vannevar Bush (1945) introduced the idea of a "memex" or what he conceived of as an interactive library. The memex was in effect a card catalog (index) that was supposed to be interconnected and cross-referenced with all the books in the library.

Thus, instead of being a static card catalog, the memex would allow a reader to enter the system at any point and read through the information contained in the library in any sequence that she pleased. The idea was very interesting, but the technology did not exist back in 1945 to make the idea a practical reality. Also prior to the development of the Internet, Theodor Nelson (1981, p. 2) published a definition of the word "hypertext" that he coined as "a text that branches and allows choices to the reader." At the present, the concept of hypertext is a juxtaposition of the basic ideas of Bush and Nelson. Hypertext is essentially a reader determined, nonlinear form of writing where information can be accessed at any point and organized in any number of ways by the reader/writer. Advocates of hypertext learning and knowledge building argue that this is very much in sync with the way that our minds work and therefore may greatly facilitate the process of learning.

A hypertext strategy for accessing the information networks on the Internet will probably prove to be a highly effective learning tool in the 21st Century. In fact, I did some preliminary research for this paper employing such a strategy. I still consider myself to be a novice at hypertexting, so I will not offer any advice in this paper. For some insights from experts, I recommend starting with Nicholas Burbules and Thomas Callister, Jr. (1996) or George Landow (1992). As to particular knowledge domains where hypertext learning may prove to be fruitful, let me quote Burbules and Callister (1996, p. 30):

> This process of actively selecting and assimilating new information in light of personally coherent cognitive frameworks meshes the potential of hypertext with constructivist learning theories, especially schema theory. This link is particularly strong when we consider knowledge domains that are complex and indeterminate; domains requiring a high degree of "cognitive flexibility" and a tolerance for ambiguity.

Besides the development of hypertext learning, there are also explorations taking place in regards to distance learning and computer simulations of complex processes and behavior in many knowledge domains at the collegiate level. Unfortunately, we are not able to discuss these developments in this paper.

Conclusion

In the conclusion of this paper, I would like to say a few words regarding the apparent attitude that many educators have regarding the concept of ambiguity (uncertainty) and what attitude I believe they *ought to* have. In doing so I will quote a social scientist and a humanist. And I will reserve the very last words for novelist Richard Ford since we have not adequately represented the artistic perspective of the possible relationships between ambiguity and theories of learning in our discussion so far.

Instead of having a positive attitude towards ambiguity, many educators appear to have a negative attitude, or even an aversion, towards ambiguity. This is evidenced by the propensity to use the phase 'tolerance for ambiguity' or to disambiguate all their pronouncements in the classroom. The hypothesis of this paper is that ambiguity is an essential property of all human knowledge and as educators who teach mankind's knowledge to students, we should 'embrace' ambiguity rather than just 'tolerate' it. Embracing ambiguity means being more open to alternative ideas, never being very narrow in our thinking as we practice the art of teaching (even though we may be scientists as well as teachers). Kenneth Arrow, 1972 winner of the Nobel Prize in economic science, has this to say on this matter:

> The sense of uncertainty is active; it actively recognizes the possibility of alternative views and seeks them out. I consider it essential to honesty to look for the best arguments against a position that one is holding. Commitments should always have a tentative quality. As may be supposed, I have always enjoyed satire and irony, as well as logical paradox; Swift and Russell are favorite authors. [Kenneth Arrow (1992, p. 47)]

Kenneth Arrow's words are echoed by those of humanist Robert Grudin, a professor of English at the University of Oregon, who in an essay on dialogue states: "Unless they are understood in a context that includes irony, ambiguity and contingency, conclusions are always wrong and assertions always mistaken." [Robert Grudin (1996, p. 211)] Unfortunately, a majority of educators are not like Arrow and Grudin. Their attitude towards ambiguity is quite negative, if not downright hostile. And this is reflected in their teaching practices and students in turn do not learn the subject matter in an appropriate manner.

Richard Ford's *Independence Day* (1995) was the first novel to win both the Pulitzer Prize and PEN/Faulkner Award. The main character of the novel is Frank Bascombe. Bascombe was first introduced in Ford's earlier novel, *The Sportswriter* (1986). Richard Ford's narration of Bascombe's daily life has been hailed as a celebration of the "hum of the human spirit." Ford himself seems to prefer literary critic Lionel Trilling's notion of the "buzz of implications," [Ford (2000, p. 157)] which is the difficult-to-describe *other* dimension to life which Trilling felt accompanied life as we live it but disappeared once the present was lost. At any rate, the character Frank Bascombe serves as a symbol of redemption and possibility, a source of hope for all of us.

After completing a term as a temporary college instructor of creative writing, Frank Bascombe has this to say about teachers and explaining:

> In my view all teachers should be required to stop teaching at age thirty-two and not allowed to resume until they're sixty-five, so that they can *live* their lives, not teach them away—lives full of ambiguity and transience and regret and wonder,

> be asked to explain nothing in public until very near the end when they can't do anything else. (Richard Ford, *The Sportswriter*, p. 223)

Two other significant quotes follow on the same page of the novel. "Explaining is where we all get into trouble." And "Some things can't be explained." Frank Bascombe's words convey a powerful message to educators. We cannot neglect the unexplainable human spirit, or existential 'Being,' in each one of us. As teachers, we should strive to be heroic teachers. Or in philosophical terms: "Philosophy should aim not for academic authority but rather for heroic teaching; its goal is not certainty but liberation." [Robert Grudin (1996, p. 109)]

REFERENCES

Arthur, W. B. (2000). "Cognition: The Black Box of Economics," in D. C. Colander (ed.), *Complexity Vision and the Teaching of Economics*. Northampton, MA: Edward Elgar Publishing Inc.

Arrow, K. J. (1992). "I Know a Hawk from a Handsaw," in M. Szenberg (ed.), *Eminent Economists: Their Life Philosophies*. Cambridge: Cambridge University Press.

Bacon, F. (1620). *Novum Organum.*

Bartley III, W. W. (1990). *Unfathomed Knowledge, Unmeasured Wealth: On Universities and the Wealth of Nations.* La Salle, IL: Open Court.

Bereiter, C. (1998-9). "Education and Mind in the Knowledge Age," a manuscript maintained by S. Hazlewood at website. Ontario Institute for Studies in Education/University of Toronto, Canada: CSILE/Knowledge Building Team.

Berkeley, G. (1710). *A Treatise on the Principles of Human Knowledge.*

Bernstein, P. L. (1996). *Against the Gods: The Remarkable Story of Risk.* New York: John Wiley & Sons, Inc.

Brown, R. H. (1995). "Postmodern Representation, Postmodern Affirmation," in R. H. Brown (ed.), *Postmodern Representations*. Chicago: University of Illinois Press.

Burbules, N. C. and Callister Jr., T. A. (1996). "Knowledge at the Crossroads: Some Alternative Futures of Hypertext Learning Environments," *Educational Theory*, 46, pp. 23-50.

Bush, V. (1945). "As we may think," *Atlantic Monthly, 176, pp. 101-106.*

Dewey, J. (1899). *The School and Society*. Chicago: The University of Chicago Press.

_____ (1910). *How We Think.* Boston: D.C. Heath & Co. (Unabridged republication by Dover Publications, Inc. 1997)

Ford, R. (2000). "The act of contemplation," *Forbes ASAP* (October 2, 2000), pp. 157-158. Ford is the author of the novels: *Independence Day* (1995) and *The Sportswriter (1986).*

Grudin, R. (1996). *On Dialogue: An essay on free thought.* Boston: Houghton Mifflin Company.

Jonassen, D. H. (1997). "Instructional Design Models for Well-Structured and Ill-structured Problem Solving Learning Outcomes," *Educational Technology Research & Development*, 45. pp. 65-94.

King, A. (1993). "From Sage on the Stage to Guide on the Side," *College Teaching*, 41, pp. 30-35.

Landow, G. P. (1992). *Hypertext: The Convergence of Contemporary Critical Theory and Technology.* Baltimore: Johns Hopkins University Press.

Langer, S. K. (1988). *Mind: An Essay on Human Feeling*, abridged edition. Baltimore: The Johns Hopkins University Press.

Nasaw, D. (1979). *Schooled to Order: A Social History of Public Schooling in the U.S.* New York: Oxford University Press.

Nelson, T. H. (1981). *Literary Machines.* Swarthmore, PA: Self-published.

Nicolescu, B. (1996). *La transidiciplinarit■---Manifeste* (Transdisciplinarity—A Manifesto). Paris: ditions du Rocher.

Popper, K. R. (1979). *Objective Knowledge: An Evolutionary Approach,* revised edition. London: Oxford University Press.

Searle, J. R. (1983). *Intentionality: An Essay in the Philosophy of Mind.* Cambridge: Cambridge University Press.

Solomon D. L. (2000). "Philosophy and the Learning Ecology," paper presented at the Presidential Session on In *Search of the Meaning of Learning* at the International Conference of the Association for Educational Communications and Technology, Denver, CO, October 25-28, 2000.

Sperry, R. W. (1995). "The Impact and Promise of the Cognitive Revolution," in R. L. Solso and D. W. Massaro (eds.), *The Science of the Mind: 2001 and Beyond.* New York: Oxford University Press. (This article is an abridgement of a Distinguished Centennial Address presented at the 99th Annual Convention of the American Psychological Association, San Francisco, CA, August 1991.)

Stigler, S. M. (1986). *The History of Statistics: The Measurement of Uncertainty before 1900.* Cambridge, MA: The Belknap Press of Harvard University Press.

Suzawa, G. S. (2001). "Learning Economic Principles via Ambiguous Problem Solving Exercises," paper to be presented at the 12th Annual Conference on Teaching Economics, Robert Morris College, Moon Township, PA, February 22-24, 2001.

Wells, G. (1999). *Dialogic Inquiry: Towards a Sociocultural Practice and Theory of Education.* New York: Cambridge University Press.

Wheeler, J. A. (1981). "Bohr, Einstein, and the Strange Lesson of the Quantum," in R. Q. Elvee (ed.), *Mind in Nature.* New York: Harper and Row.