# Why the Theme of this Symposium is the Wrong Question

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This paper represents a work in progress rather than a polished, well organized and logically argued whole. In the presentation at the symposium, I essentially want to raise some ideas and stimulate debate during the symposium, and afterwards in the hall, the bar or wherever seems appropriate!

Educational research has for years operated under the assumption that it could produce theory and research findings that would serve as the basis for engineering solutions to educational problems. Even Jerome Bruner has argued that instructional theory must be prescriptive; that is, provide specific recommendations for educational practice. In this paper I will argue against the prescriptive model, and, by reference to my own work in hypermedia, present the case for semiotic models of the teaching/learning process. In brief, I will claim eductional research should provide tools for teachers and learners to accomplish tasks which are embedded in their own lived experience.

In this written outline, I can only present a summary of some of the questions I hope to raise and some of the discussion I anticipate.

The theme of this symposium is "What Sorts of Teaching Enhance Learning for What Sorts of Pupils?" and my deliberately contentious title asserts that this is the wrong kind of question to be asking. Reading much more in to the theme than was probably intended by its author, I claim that questions of this sort assume that the teaching/learning process is amenable to some version of an engineering solution, where efficiency and effectiveness can be optimized by some careful matching of pupil to teaching method. This assumption is ubiquitous. Our textbooks, our teacher training curricula, our representations to the public, and so forth are almost entirely based upon the notion that educational research will produce generalizations that can be be used rather directly to optimize learning. Sometimes these generalizations (or enduring truths, as I like to call them) are, in the vernacular of the Analysis of Variance, main effects - for example, pupils should be required to make active responses during learning. Sometimes we qualify the rule as an interaction - for example, highly anxious students perform best in structured environments whereas low anxious students do well in less structured settings.

Theories which represent extreme versions of this assumption are to be found in the world of instructional design and development. Distinguished educators such as Gagne (1985), Merrill (1983), and Reigeluth (1983) have

argued persuasively that we need an instructional psychology that, in contrast to the descriptive science of psychology, is prescriptive, in the same sense that engineering is the applied, prescriptive field for physical science. In other words, unless our scientific endeavors lead to clear rules or guidelines for educational practice, then we are shirking our responsibilities as psychologists dedicated to the improvement of educational practice.

Jerome Bruner (1966), normally thought of as a critic of the engineering approach, has argued that prescriptive; that is, provide

I contend that this approach is fundamentally flawed because its is based upon false (or, at least, debatable)premises. Some of these premises are:

1. Knowledge is external to a learner and can be represented in some format akin to a task analysis or semantic map. Our job as educators is therefore to package this knowledge in some optimal format.
2. Instruction is primarily a process of efficient communication where

knowledge in some optimum format is efficiently and effective transferred to the pupil.

3. The effectiveness of the teaching/learning process is best measured by assessing the success of this communication process, whether the knowledge as prespecified has been acquired by the pupil.
4. The context in which learning should take place is that which minimises disruptions to the communication process - for example, where students can concentrate without disruption. The context per se is irrelevant to the knowledge being acquired.
5. At its heart, learning is an abstractive process. Concrete experience is very useful in illustrating the abstractions and algorithms which make up mature thought, but it is abstractions which free one from the immediacy of experience and allow generalized thought. These abstractions are most conveniently represented in linguistic and/or mathematical codes.
6. Learning is fundamentally an individual act and is best conceptualized from an individual perspective. Group learning may sometimes be an effective pedagogical strategy, but nothing more. In instruction we are dealing with individual selves, not collectives.

I could go on but perhaps these are sufficient to provoke the debate. If these premises are accepted, then I agree that a prescriptive approach to instruction is not only desirable but mandatory. If we can reliably identify some bit of knowledge as a concept, then a prescription like "Give at least three positive and three negative examples" is appropriate. But lets consider a different set of assumptions, those derived from the emerging social constructivist/semiotic view of learning. I have taken these from a recent paper (Cunningham, McMahon & O'Neill, 1992)

The following section is taken from Knuth & Cunningham (1991 and is an introduction to one (admittedly extreme) version of constructivism

Constructivist Assumptions

Constructivism argues that instruction is more a matter of nurturing

the ongoing processes whereby learners ordinarily and naturally come to understand the world in which they live. In this view, knowledge is an active process of construction, not the receipt of information from external sources. The role of teaching and other instructional media shifts from one that seeks to maximize the communication of fixed content and/or skills to one in which students are led to experience the knowledge construction process: to construct interpretations, appreciate multiple perspectives, develop and defend their own positions while recognizing other views, and become aware of and able to manipulate the knowledge construction process itself. An important aspect of this approach is the insistence that learning take place embedded in the contexts to which it is most relevant in everyday life and with which the students are personally involved.

As promised, in this paper we will take a rather extreme view of constructivism, one that questions the very notion that the environment can be "instructive" in any real sense of that word. For our view, we will draw upon the writing of the Chilean biologist, Humberto Maturana. Our purpose is not to reject other versions of constructivism (or behaviorism, cognitive information processing, etc., for that matter) but to assess the implications of this view for existing and possible new instructional systems. In other words, would instructional design and the use of technology look different based upon Maturana's notion of autopoiesis? In what way can we design instruction that is synomorphic with this process? But first, a few words about Maturana.

Maturana (e.g., Maturana & Varela, 1987) begins with the seemingly simple question "What is the organization of living systems?"; that is, what characterizes systems as living as opposed to non-living? After years of research and thought, Maturana has concluded that the single most important characteristic that distinguished the living from the non-living, in regard to their unitary character, is autopoiesis (a term he coined). In brief, an autopoietic unity is self organized and structurally closed. Their behavior and internal processes are governed by their internal organization (embodied in a particular structure) that must be maintained (conserved). That is, their structure can and will change as a function of internal processes and environmental influences, but the basic unity of the organism and its adaptation must be conserved. With respect to humans, the following, highly integrated points may be noted:

1. Humans are structurally determined systems; that is, they are autonomous and recursively organized living systems that behave as a function of their organization and particular structure (Goolishian & Winderman, 1988). Instead of responding in a cause-effect manner to objective environmental stimuli, living systems, when perturbed by structured patterns of energy, respond in their own idiosyncratic way -- they determine their own response. Thus, there are no cause-effect relationships between the world and the learner, and the patterns exhibited by the perturbed living system do not reflect the structure of the perturbing stimuli. Behavior, whether internal or external, emerges within a context in which the human organism conserves its adaptation and

organization.

2. Living systems are informationally closed. Humans cannot take in information from the outside world and map it onto mental symbols that are then manipulated and processed (e.g., see Newell & Simon, 1976). Rather, people are always immersed in a sea of structured energy that is interpreted and made sense of by an active observer. For example, light, that enters our eyes and perturbs the structure of our nervous system by triggering chemical changes, is organized by our nervous system into edges, light-dark gradients, bars, intense spots, etc. (Marr, 1982) that our cognitive system actively interprets. In other words, we "objectify" our "subjective reality"; "objects [that] we think we see and study are [actually] products of the activities of our own nervous system" (Efran & Lukens, 1985, p. 24). Light energy from the environment can "trigger" but not determine the visual experience.

Notions such as these have led Maturana to argue that if we want to understand human learning we need to focus on the interactions within the learning system, not on the structure of the environment. Winograd & Flores (1986, p. 44) make the same point: "...it is the structure of the perturbed system that determines, or better, specifies what structural configurations of the medium can perturb it."

3. Organisms are structurally coupled to the medium in which they are embedded. That is, living systems survive by fitting with one another and with other aspects of the surrounding medium in a manner that conserves their organization and adaptation. Life is a succession of dynamic interactions or activities in which people are structurally coupled to each other and/or the world (Leont'ev, 1981) and in which there are no stops and starts but rather continuous activity. "People do what they do because of how they are put together, and they do it in connection with (but not on direct instruction from) the medium in which they exist, which includes other people." (Efran & Lukens, 1985, p. 25).

4. Humans are observing systems who describe, distinguish, and delineate in words and symbols. Without the observer, for example, the very notion of behavior in response to external "instructions" from the environment ceases to exist. It is the human observer who imposes some sort of conceptual system upon the phenomena he/she observes and thereby brings forth a world that includes those phenomena. We do not perceive an objective universe but rather it is through observing that humans are capable of generating meaning. Further, all kinds of cause- effect thinking are just verbal formula we use to make sense of our experience.

What do Maturana's notions of the learner imply for instructional designers? Efran & Lukens (1985, p.23) highlight Maturana's belief that instruction in the traditional sense is simply not possible. They suggest that "you do not change organisms -- you design an environment in which organisms thrive, respond, and change themselves." The idea that we can prescriptively design instruction is based on the belief that it is possible to predict a learner's behavior, a concept that has been convincingly argued against by Maturana. He believes that we cannot determine a student's learning, that is directly produce the behaviors we want, when we want them. When we believe we are doing a pretty good job of instructing, students may simply be accommodating to the situation in which

they find themselves, acting in the way they think we want them to act (i.e., in terms of the world that we have brought forth with them) so as to

conserve structural coupling and adaptation. Whether this is "instruction" in the sense that most of us feel is important, is open to question.

Some Principles of Constructivism

Winn (1989, p.40) expresses a sentiment that a number of you may be feeling at this time. If Maturana is correct, the very existence of traditional instructional design is threatened: "Indeed, the very idea that instruction can be designed in the first place must be abandoned unless one subscribes to the belief that how students will react to instruction can be predicted with reasonable accuracy." But the idea that humans are structurally closed need not inevitably lead to the notion that they can not be "influenced," and influenced in predictable ways. The ideas underlying constructivism suggest that we shift from designing environments that instruct to designing environments that influence the structure of autopoietic unities in ways that conserve organization and adaptation. Thus, while the organization of, say, the human nervous system is fixed, its interconnectivity allows for nearly infinite structural flexibility. Through structural coupling with its environment (that includes other beings), the organism literally brings forth the world in which it finds itself, a world constrained by the organization of the environment and by its own organization. But within those limits, an incredible variety of "worlds" are possible.

The key to understanding the relevance of this view for human instructional design is to recognize the importance of a uniquely human form of structural coupling with the environment: social coupling through language. In a very real sense, the environment is entirely independent of us. Living systems are organized to generate internal regularities like neuronal activities and their interconnections that conserve adaptation. The environment is a source of perturbations that the organism may "select" in order to preserve autopoiesis. In other words, throughout its phylogeny and ontogeny, organisms have come to select those aspects of the environment that are or can become structurally coupled to its internal organization, and by doing so have brought forth a world in which autopoiesis is conserved.

In humans, these structural couplings include social couplings brought forth in a network of conversation and dialogue, a unique dimension of operational closure that permits us to experience what we have come to call consciousness: the experience of "mind" and "self" and its reciprocal, "other". The mind is not located in the brain -- it along with consciousness and notions of self and other exist in the domain of social coupling that we continuously weave, through the linguistic interactions that we generate with others. And it is through this means that we generate ourselves as describers and observers of the world in which we find ourselves. It is perhaps natural to assume that this world is the same for everyone, an objective world that exists as a point of reference independent of each of us. But the same linguistic couplings also allow us to see not the world, but a world that we bring forth with others. And we

can see that many worlds are possible, that the world can change if we live differently. In Maturana's words, "the knowledge of knowledge compels". (Maturana & Varela, 1987, p. 245).

This is the essential insight of constructivism: to know not only that we know but how we know. To emphasize this point, we would like to state and briefly discuss seven constructivist principles that are consistent with Maturana's views. In the section to follow, we will review some "tools" that purport to be in the constructivist mold and evaluate the extent to which they embody these principles.

1. All knowledge is constructed.

Among the most quotable phrases from Maturana is the following: "Everything said is said by someone". (Maturana & Varela, 1987, p. 26) This sounds obvious, but consider its implications. Every distinction, every observation that we make brings forth a world. Every reflection is a human action by some particular person in some particular context. And this bringing forth of a world (knowledge) is essential if we are to understand it. But often we take this world as objective, independent of us -- its constructedness is hidden. Scientists, for example, are often perceived as investigating phenomena in the physical world. They aren't. They are investigating the distinctions and observations of themselves or other scientists, based upon a social and linguistic domain that specifies what they say and do. Scientists bring forth a world through their structural coupling in the same manner as we all do, and the constructedness of this world is no less than that brought forth by humanities scholars, for example.

One goal of instructional design derived from this principle might be to allow or encourage the experience of the "constructedness" of our knowledge of the world, a feature that is usually invisible to us in our ordinary daily interactions. By inviting students to adopt the perspectives and roles of a variety of individuals, we attempt to show them that different people can have different views of a situation and that these views can have a sense or logic independent of their own views. Truths that the students hold are shown to be only one of many possible truths.

A rather interesting way to provide such experience is to introduce the concept of metaphor. Lakoff and Johnson (1980) have argued convincingly that much, perhaps all of our thinking is metaphorical in nature. The strategy is to probe a student's existing metaphor for a particular situation, then show how changing the metaphor can change one's view of that situation. For instance, many teachers and students tend to view the classroom as a workplace, where tasks have to be completed in exchange for some sort of reward (e.g., a good grade in the course). Even the language we use to talk about classrooms is embued with this metaphor: homework, classroom management, reading gains, teacher accountability, and so forth. In consequence, learning tends to be regarded as a phenomena that takes place in classrooms, not elsewhere, much as work takes place in the workplace.

But suppose we adopt a different metaphor, say, the classroom as providing a consulting service. Now the agenda of tasks to be completed

shifts from ones imposed by the teacher to ones generated by the students themselves. The classroom becomes one of only many places where work on this task takes place. The role of the teacher and other students shifts; they are now sources of insight and assistance, not authoritarian wisdom or competition. No doubt you can think of other differences that would emerge from such a shift in metaphor.

Another useful strategy is to expose students to cultures different than their own. Exposure to different cultural practices varying from the mildly odd (in most of Europe, for example, one shakes the hand of a friend upon meeting, but not a stranger, while the opposite is true in the U. S.) to the extreme (some Africans are circumcised at puberty, while in the U. S. this is done soon after birth) invites students to reconsider the inevitability of their own cultural practices.

2. Many worlds are possible, hence there will be multiple perspectives.

The notion that we bring forth worlds through our structural coupling leads directly to the issue that no one else sees the world exactly as we do. Of course, because the organization of human autopoiesis and the environment in which it exists are determined, it would be unlikely to find extreme differences where, for example, we would see the trees as made of green cheese. But these commonalities should not obscure the differences. There is great comfort in the certainty that one's view of the world is correct, but this certainty is obtained at the expense of failing to consider the perspective of others. Instead of assuming there is a fixed reference point (i.e., an external world) to which we can anchor our knowledge in order to affirm its validity, we have to accept the fact that our experience will be a mixture of stability and change, of regularity and conflict.

In constructivist instructional design, our aim is to find a way to bring forth worlds with others that accommodate or at least reflect the views of others. Few issues in the world have a single "correct" resolution. But young children (and many adults as well) tend to think that knowledge is either right or wrong, that all valid questions have answers, that authority figures (e.g., teachers, textbooks, etc.) have the answers to these questions and that experts know the truth or have ways to figure it out (Perry, 1970). Instruction designed under constructivist influences should again reveal the constructedness of knowledge, that any "truth" begins with a set of untested assumptions that can be examined to evaluate the adequacy of the position taken. What we take as "true" in a situation is very much a product of a process of negotiation, often taking the form of some sort of dialogue. Positions are something we commit ourselves to, not something we adopt because (or certainly not only because) an authority figure decrees that we must.

Multiple perspectives are most commonly encountered in dialogue with other individuals. Certainly not all forms of dialogue will accomplish this goal. If one member of the group is "certain" about her position (i.e., is an expert, or simply dogmatic) and the others not, that member will usually dominate. If the group contains more than one "certain" individual, none of whom are willing to compromise their beliefs, then once

again the dialogue will be unproductive in terms of this goal (although others in the group who are less certain may benefit). What we are interested in here is the situation where a group member is willing to reconsider his beliefs in terms of another's position and try to find a new view that accommodates them both. Surely not all views are equally accommodatable (we can not imagine finding common ground between our views and those of the KKK, for example). But the development of the realization that our view is only one of many and that an attitude of acceptance toward other views allows for the growth of our views, is fundamental under constructivism.

3. Knowledge is effective action.

According to Maturana, "every act of knowing brings forth a world ... [so] all doing is knowing and all knowing is doing". (Maturana & Varela, 1987, p. 26). This is a key point. Knowledge is effective action. We observers regard an action as effective in a particular context. There is no real distinction between knowing and doing. Behavior is a result of the organism's attempt to conserve its autopoietic organization. The environment does not cause behavior, it only triggers it based upon the structural coupling between the unity and the environment.

This idea resonates nicely with the notion of situated cognition that is so passionately endorsed in the educational literature today (e.g., Brown, Collins, & Duguid,1989). So much of what passes for education these days is relevant only to a single context - the school. Study after study shows a lack of transfer of knowledge acquired in the classroom to the real world (e.g., Bransford et al., 1990). Thus, while students are able to complete the word problems at the end of the chapter in their science textbook, they are unable to use that knowledge to calculate the time it will take them to travel to Grandmother's house at a certain speed and distance. Instruction derived from a constructivist framework must be designed to address issues and be embedded in contexts with which the students are familiar and about which they care. For knowledge to be "effective action", the context of its embodiment must be veridical to the world in which the child finds him/herself.

To be sure, we can manipulate the process of negotiation through which worlds emerge to insure that the school context is a source of "perturbations" to which the child must adapt (to the extent that autopoiesis is conserved). So much of what we ask students to learn is of our choosing. They experience little ownership of the ideas, little sense that they are an active participant in their own learning processes. We feel that the students must come to feel some personal sense of responsibility for the products of their thinking, where their views are heard and respected by others in the situation. In other words, students must come to see that the tasks they are performing will help them accomplish the things they want, will empower them to take more complete control over their lives, to know how they know. In essence, we are suggesting that the children become the observers of their own behavior, the judge of the extent to which their knowledge is effective action.

4. Human learning is embedded within social coupling.

Humans learning is a distinction made by observers of effective action in a particular context. Our commonsense notion that to learn means to

internalize some object from the environment is simply wrong. Actions emerge based upon the structural changes brought about by interactions between the autopoietic unity and its environment. The most interesting of these, from the perspective of humans, are social couplings based in language. In a very real sense, human learning is human languaging, the exchange of conversation and dialogue. Even where language is not present in an interaction, its influence is still present in the distinctions and differentiations that are used in the interactions (i.e., in the world brought forth).

The importance of discussion and dialogue for instructional design has been recognized recently with the rediscovery of Vygotsky's (Vygotsky, 1978) views of cognitive development and Freire's (Freire, 1970) pedagogical writings (see Cunningham, in press, for an elaboration of this point). Many of the examples given so far have focused on dialogue as an important pedagogical strategy for constructivist instructional design. This is no accident because dialogue is a major medium for providing experience in the knowledge construction process. While the individual learner is the only one who can construct his or her unique understanding of the world, this understanding emerges in a social context. Concepts take on meaning through a process of social negotiation. The differentiations that a person makes in the world -- mother versus father, democracy versus dictatorship, computer versus teacher, etc. -- arise from the contrast of one thing with another in some sort of social experience. Language is the key to understanding the development of these processes in humans.

While it is possible to "have a conversation" with oneself (and even desirable in some circumstances), dialogue between individuals is the primary mechanism that allows the social construction of meaning. According to Vygotsky, it is the internalization of social speech into inner speech, that is, the ability to engage in a socially appropriate dialogue with oneself, that allows one to plan and monitor cognitive progress. Inner speech, Vygotsky maintains, is developed by participating in social dialogue.

5. Knowing is not sign dependent

This particular principle is not explicit in Maturana's writing but we think it is consistent with it, and essential. His emphasis on social coupling through language could lead some to characterize his views as logocentric; that all knowing is languaging. Certainly, learning and cognition, and ultimately living, is always embedded within a social context mediated, in part, through language. Language is one of the most powerful means through which humans become structurally coupled to each other, each acting as perturbations for the other. In addition to language, however, human interaction also involves the formation and interpretation of other complex sign systems (e.g., speech, gestures, writing, music, etc.). We use many sign systems to socially construct our world (Goolishian & Winderman, 1988) , a world in which we come to believe in the objectivity of our observations.

Multiple sign systems should be exploited in terms of what they can

contribute to the knowledge construction process (e.g., see Howard Gardner's (1983) discussion of multiple intelligences). Within the computer context, for example, many modes of representation can be captured (e.g., graphics, photographs, animation, video, sound, etc.) and each of these can be assessed in terms of what they can reveal and what they might obscure. In another example, Michael Roth (1990) makes sure that his science students experience multiple ways of representing their experiences while conducting laboratory experiments (e.g., verbal description, equations, pictures and diagrams, demonstrations, tables of numbers, graphs, etc.), all the while encouraging them to point out the strengths and weaknesses of each mode, what is foregrounded in one representation, obscured in another.

The important point to stress here, and the aspect that we think is most compatible with Maturana's views, is that the use of varieties of sign systems can enhance still further our understanding of the constructedness of knowledge, the value of considering multiple perspectives, and so on for each of the other principles listed here. No doubt we become aware of and reflect upon these factors in large part through language. But we must avoid the conclusion that only language can provide the structural social coupling through which we bring forth our world.

6. World views can be explored and changed with tools.

This is another principle not explicitly discussed by Maturana but with which we believe he would find sympathy. Writing long before the advent of computers, Vygotsky (1978) defined tools as "mediating" devices

that allow humans to manipulate their physical world for the purposes of labor. (It was labor that necessitated the development of tools in the first place.) Thus, "man uses the mechanical, physical, and chemical properties of objects so as to make them act as forces that affect other objects in order to fulfill his personal goals" (Marx, 1936, cited in Vygotsky, 1978, p. 54). Thus, for example, a hammer mediates the achievement of the physical goal of driving a nail into wood.

According to this definition, the object of tool use is always external to the user. Although using a tool certainly affects the user psychologically (for instance, with experience a hammer becomes a transparent extension of the hammerer), the purpose of tool use is to affect the physical world. On the other hand, that which is used by humans to purposefully affect one psychologically is designated by Vygotsky (1978) as a "sign." For example, when one ties a knot in a handkerchief as reminder to do something, the person has created a sign that is intended to affect the person psychologically, i.e., to remember something.

Sign usage by humans is so ubiquitous that it, like tool usage, quickly becomes transparent. The two year old son of one of the authors (RK) is still aware of the signification of traffic lights: "Green says stop, daddy?" In contrast, his four year old son, who has internalized traffic light sign systems simply says, "Go, daddy, the light is green!" The function of the traffic light is to psychologically affect the driver by acting as a perturbation. The driver then, due to structural coupling, is "reminded" of and takes appropriate action -- to go (or to honk if the

driver ahead misses the sign!)

According to Vygotsky, the characteristic common to both tool and sign use is their mediating nature. In order to achieve a physical goal, humans use tools to mediate its achievement. (Except for the most rudimentary tasks such as digging in the sand with one's hands, all physical goals require the mediating use of tools.) Similarly, signs act as mediators for mental activity, that is, activity that would be nearly impossible (or at least significantly more difficult) without employing signs. Further, the creation and use of sign systems (such as certain computer applications) allow humans to engage in mental activity not otherwise possible (Pea, 1985).

One distinct difference between tools and signs should be highlighted. That is the cause-effect relationship of the mediating device to the intended object. As observers, it is easy to point to the effect that the hammer will have on the nail -- the result is predictable and only depends on the use and observation of the tool, not on the the nail's "knowledge" of the hammer. On the other hand, signs work only if the observer has prior experience and knowledge of the sign system. An Eskimo who has never been to a village would be able to be perturbed by a traffic light changing color but would have absolutely no idea of what it signifies. In other words, the Eskimo, due to history, is not structurally coupled with that particular sign system. Thus, as Maturana points out, the sign does not instruct the observer; any response is determined entirely by the structure and history of the observer. Whether or not the sign has its intended effect is solely determined by the Eskimo's ability to perceive the sign in conjunction with his prior knowledge of and experience with traffic light sign systems.

Perhaps it was because that, during his time, tools were used almost exclusively for physical labor and signs for mental activity, that Vygotsky was adamant about their distinction. Since the mid-fifties, however, the nature of work (at least in western nations) has shifted from industrial to informational. Even before the launch of Sputnik, the number of white collar jobs outnumbered blue collar jobs in the United States for the first time in history (Naisbitt, 1984). And, since 1984 over half of the US GNP was generated through information/service related jobs. This means that the object of labor is no longer predominantly physical, but rather has shifted toward the various means and purposes of knowledge development.

Because of this qualitative change in labor, its requisite change in the nature of tools, and the ubiquitous use of sign systems, we have broadened Vygotsky's definition of tool to include all mediating devices that can potentially affect both physical and mental activity. The tools we will describe below are of this character.

7. Knowing how we know is the ultimate human accomplishment.

This is perhaps the most important principle of all and has naturally arisen in discussion of previous goals. Providing experience in the knowledge construction process is an important goal, but the outcome we hope will eventually occur is awareness of the constructedness of much of our knowledge and active control over that construction process: To know

how we know. In other places (e.g., Cunningham, in press) this has been referred to as the development of reflexivity. There is no higher educational goal.

If reflexivity were to come to serve as a primary goal in our school curricula, the subject matter of each of our courses would be the mind itself. A course in history would emphasize not simply history, but how historians know, the sign structures or systems of belief that historians use in their discipline, and skills and tools used to construct knowledge. What are the potential effects of those beliefs on the historical analyses that are regarded as acceptable? Or take physics. How do our assumptions about the nature of matter influence our experimental methodologies, and vice versa? How do the various forms of representing our knowledge of the universe influence our theories?

One consequence of an emphasis on reflexivity in our courses would be to coalesce the various subject matters, revealing the unity underlying them and rendering their separate treatment ill advised. More classes would be taught by teams of teachers, say a mathematician, a geographer, and a historian. The systems of belief of each of these disciplines could be juxtaposed so that, for example, the logic used to fashion some particular analysis could be examined against the tools provided by another discipline. We could ask questions like the following: Is adding amendments to the U. S Constitution like adding 3 apples and 2 apples, or can we think about a mathematics in which not only the number of elements but their character is represented? What does it mean to count people, as the U. S. Design and Census is currently doing? Is our use of mathematics value neutral? Does it have a historical dimension?

One hears quite a lot these days about the development of critical thinking and reflection in students, and we would agree with this emphasis. But we want to stress that reflexivity is not a skill existing independent of the learner that must somehow be transferred inside (e.g., the SQR3 method of reading, the method of loci, etc.). Rather we argue that reflexivity must emerge naturally as a function of all the other principles we have mentioned (experience of constructedness, multiple perspectives, tool use, etc.).

## Conclusion

In this paper, I have argued for a point of view that denies the possibility that specific concrete prescriptions for educational practice are possible. What then is our role as educational psychologists or researchers? Rather than prescriptions, we can offer frameworks, structures like computer software which can serve as scaffolds or ZPDs, tools for supporting ongoing processes of knowledge construction. Synomorphy is a term coined by Roger Barker, an eco-environmental psychologist which stresses the closeness of fit between entities. For example, a glove is highly synomorphic with a hand but not with a foot. It should be noted that humans cannot simply decide which aspects of the environment to perceive and which to ignore. Humans by nature live in a relatively narrow band of perceivable energy; without special tools, we can't "see" infrared or ultraviolet light nor hear ultrasonic vibrations. Further, we can't interact at the level of bacteria nor at the level of solar systems. It quickly becomes obvious that there are infinite worlds

possible, each depending on an enormous array of observer properties -- the worlds that humans can bring forth because of their particular properties are but one relatively narrow subset among the possibilities.

Our purpose here is not to argue for one metaphor or the other (although we certainly favor the second over the first). Our point simply is that under constructivism, a primary aim is to provide the students the opportunity to experience the constructedness of their world view.

It can be argued that even hands can be classified as tools, but that is another story.

An illustrative example of an existing tool that clearly serves both

mental and physical activity is the use of computer-assisted design/computer-assisted manufacturing (CAD/CAM) systems. A designer uses a CAD/CAM system to design, that is, to manipulate three dimensional graphical representations of an object which is to be manufactured. The image is not the object but rather stands for it; thus it is a sign (either an icon or a symbol) of the object. The designer works with this sign system by manipulating it along many dimensions, by making decisions, by considering ramifications, by checking it with specifications, by imagining it in relationship to other components, and so on. In other words the CAD/CAM system allows the designer to engage in creative, complex mental activity which would arguably be impossible without it. At this point no physical object has been created with the tool. The image is simply a particular arrangement of symbols that helps the designer think about the real object. Once the design is complete, however, the designer can use the CAD/CAM system to transform the design into a physical object. The designer "tells" the CAD/CAM system to "read" the image and to create the specified object. The tool has clearly served two purposes: (1) it has allowed the designer to think in new ways about designing; and (2) it has allowed the designer to actually affect the physical world by creating the object.

In a recent paper (Knuth & Cuningham, 1991) I presentedthe paper I drewI have reproduced a section of that paper below, but it can be skipped if this background isn't desired:

Assumptionsifprescribingprovide frameworks within which ongoing constructivist processes can operateˇˇ

Rather than prescriptions, constructivism offers broad guidelines for instruction, suggestions for features of settings which can support ongoing processes of semiosis. Some constructivist assumptions and their associated guidelines are:

hence instruction should provide experience with this constructednessThe constructedness of our worlds, hence learning should occur in its relevant context

mbedded within social coupling hence instruction should emphasise the social dimension

. Hence instruction should make available a variety of representational codes

thislytrac In the long run, these abstractions are capable of being simulated on a computerfor example, umould provide experience with the ion process 1992 to count people, as the U. S. periocically does, coaching techniques and so forth that So the only prescription I have to offer is "Warning! Prescriptions can be hazardous to your pedagogy!"

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