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Paper Title: **Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies (LIPHs) Leading to Empowerment of Learners**

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Meaningful Learning: The Essential Factor for Conceptual Change in Limited or Inappropriate Propositional Hierarchies (LIPHs) Leading to Empowerment of Learners[1]

Joseph D. Novak, Cornell University

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Abstract

The construction of meanings by learners requires that they actively seek to integrate new knowledge with knowledge already in cognitive structure. Ausubel's (1963, 1968) assimilation theory of cognitive learning has been shown to be effective in guiding research and instructional design to facilitate meaningful learning. Gowin's (1981) Vee heuristic has been employed effectively to aid teachers and students in understanding the constructed nature of knowledge. Concept mapping has been used effectively to aid meaningful learning with resulting modification of student's Limited or Inapproproate Propositional Hierarchies (LIPH's). conceptual change requires meaningful learning to modify LIPH's. World-wide economic changes are forcing major changes in business and industry placing a premium on the power and value of knowledge and new knowledge production. These changes require changes in school and university education that centers on the nature and power of meaningful learning.

The Construction of Meanings

It is now almost universally accepted among those who study human learning that humans begin construction of meanings at birth and rapidly accelerate the process as they gain the capacity to use language to code meanings for events and objects around them. It is also almost universally accepted that some of the meanings constructed are faulty or limited and this can distort or impede new meaning construction. What is not agreed upon is why these faulty constructions

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arise, and <u>how</u> we can facilitate the construction of valid meanings and the reconstruction of faulty or invalid meanings. This Third International Seminar on Misconceptions and Educational Strategies in Science and Mathematics will present over 300 papers focused on these issues, including a few papers dealing with faulty constructions in the social sciences and humanities.

We must pause to address the question: What are meanings? Since 1964, my graduate students and I, and many scholars around the world who have been receptive to our work, have built upon the ideas of David Ausubel. In his <u>The Psychology of Meaningful Verbal Learning</u> (1963) and later <u>Educational Psychology; A Cognitive View</u> (1968), Ausubel made the clear distinction between *rote* learning where new knowledge is arbitrarily and non-substantively incorporated into cognitive structure (or we might say now, into long term memory, LTM), and *meaningful* learning where the learner chooses conscientiously to *integrate* new knowledge to knowledge that the learner already possesses. Young (pre-school) children are marvelously adept at meaningful learning, but upon entering formal schooling, too often with overwhelming emphasis on rote memorization and verbatim recall of answers for tests, most learners move to predominantly patterns of rote learning. Most Cornell University students achieve their high grade point averages by rote learning--which they do very well (Edmondson, 1989). Unfortunately, most of this "knowledge" soon becomes irretrievable from long term memory, and even if recalled, seldom can the learner utilize the knowledge in new contexts, as in novel problem solving. Thus much of this high "achievement" is really fraudulant or inauthentic (Edmondson and Novak 1992).

The Construction of Knowledge

If meaningful learning involves substantive, non-arbitrary incorporation of concepts and propositions into cognitive structure, we must ask: What is a *concept*, what is a *proposition* and what is *cognitive structure*? Here we must move from psychology to epistemology, the study of knowledge and new knowledge production. Our research group has relied strongly upon the work of Professor Emeritus D. Bob Gowin, who has devoted his career to the study of epistemology in the context of education. Gowin has devised a marvelous heuristic shaped as a V. The shape is arbitrary but it serves to give emphasis and distinction to a number of important epistemological elements that are involved in the construction of new knowledge, or new meanings. Figure 1 shows the general form

of Gowin's Vee, with definitions of the 12 epistemological elements and Figure 2 shows an example of an inquiry as depicted through the Vee. At the "point" of the Vee are the events or objects we are

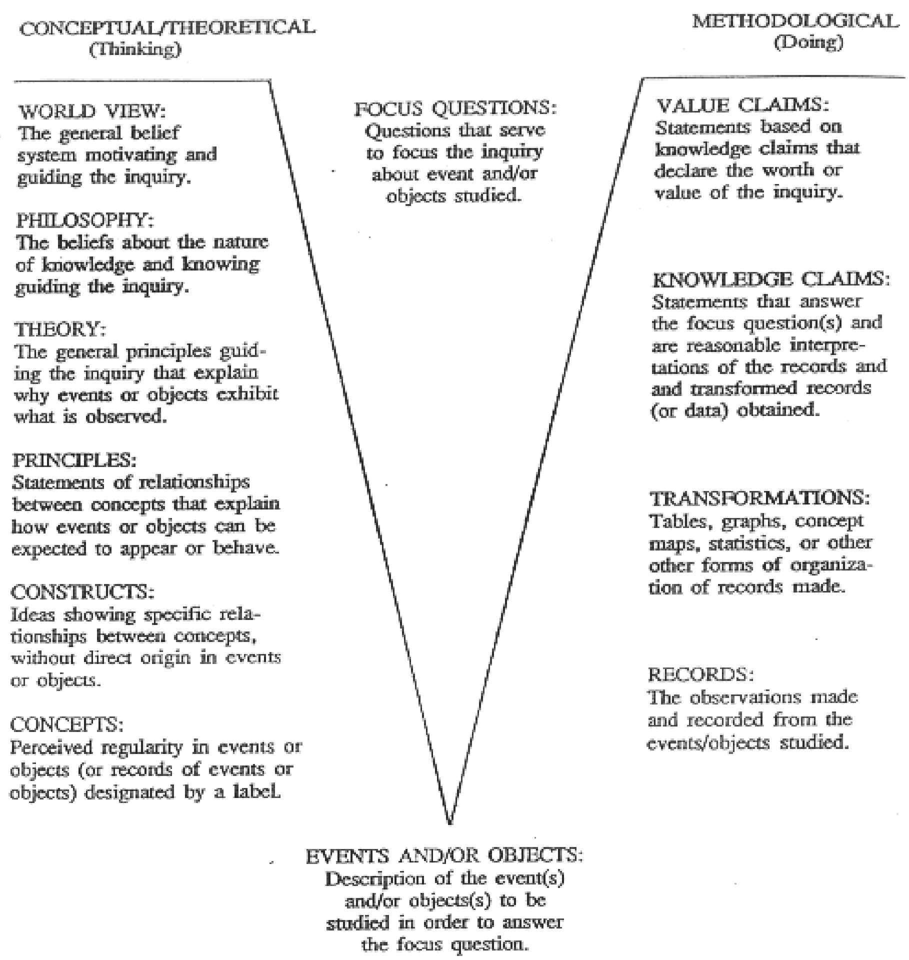

Figure 1. Gowin's Vee showing twelve epistemological elements operating in the construction of knowledge or in an analysis of a unit of knowledge. All elements interact with one another and the process of knowledge construction can be initiated from any element, but most commonly from the focus question and event(s) or object(s) of interest.

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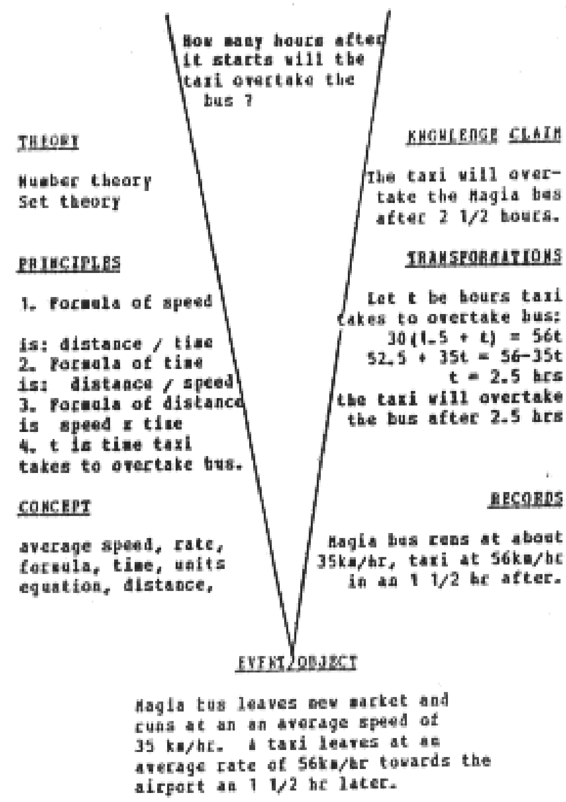

Figure 2. an example of Gowin's Vee drawn by a secondary school student to represent textbook problem (From Fuatai, 1985). Students were not asked to include philosophy or world view or value claims.

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trying to understand. On the left side are those epistemological elements we bring to the study (our conceptual/theoretical framework) and on the right side are the procedural activities we do guided by our conceptual/theoretical framework. In the center is the focus question(s) that frame the inquiry and guide the interplay of all 12 elements as the inquiry proceeds. Meaning making proceeds when a new regularity is perceived in events or objects, or records of events or objects, leading to concept formation. With young children, concept formation is a relatively autonomous event, albeit adults and older children may help to focus the child's attention and to supply language labels. By age three, children can use language to construct the meanings of regularities observed and to acquire new concepts, even relatively abstract concepts such as hot, slow, and love. Of course, all concepts are an abstraction, a representation of reality in our minds, not the reality itself.

The Construction of Concept/Propositional Frameworks

Concepts are combined to form statements or propositions. Knowledge stored in our brain consists of networks of concepts and propositions. The *meaning* of concepts derives from the totality of propositions linked to any given concept, plus emotional connotations associated with these concepts, derivative in part from the experiences during which the concepts were acquired. Piaget popularized the clinical interview as a means to probe children's cognitive processes used to interpret events. We adapted his approach to serve a significantly different purpose, namely to identify the concept and propositional frameworks that people use to explain events. From these interviews we devised the technique of **concept mapping** to represent the interviewer's knowledge (Novak and Gowin, 1984, Chapter 7; Novak and Musonda, 1991). Figure 3 shows a concept map of my ideas the nature of on concept maps. Figures 4 and 5 show concept maps drawn from interviews with two second grade school students and interviews with the same students 10 years later.

Early concept learning tends to be context imbedded and highly meaningful. By contrast, much school learning involves the rote learning of concept definitions or statements of principles without opportunities to observe the relevant events or objects, and without careful integration of new concept and proposition meanings into their existing knowledge frameworks. This rote, arbitrary acquisition of knowledge is encouraged by poor evaluation practices as well as instruction strategies where teacher rewards quick answers to questions that have little or no relevance to direct experiences with pertinent objects or events. But "hands on" experience is not enough; we also need "minds" on experiences (Hassard, 1992). The problem also exists in mathematics, as Schmittau (1991) observed in her study of ways that college

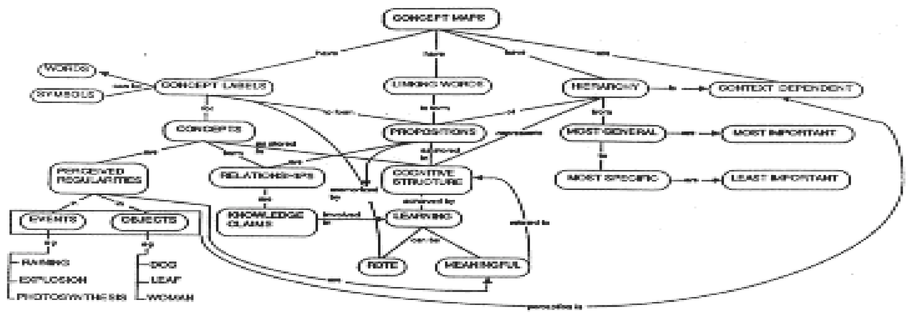

Figure 3. A concept map showing the nature and structure of concept maps.

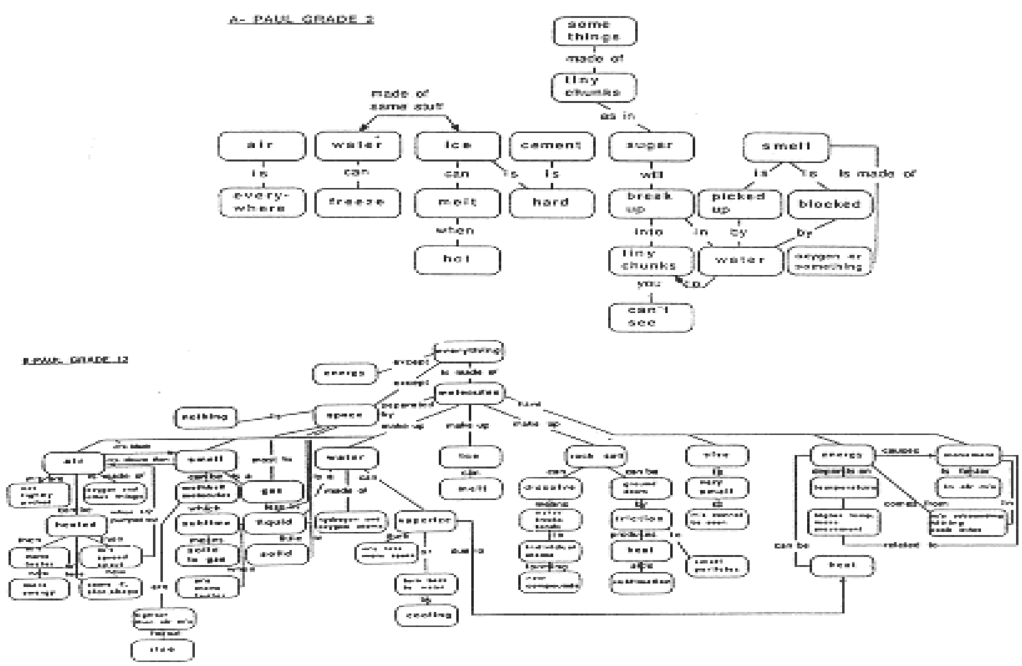

Figure 4. Concept maps drawn from interviews with Paul in grade 2 (Map A) and in grade 12 (Map B). Note the enormous growth and refinement of Paul's concept/propositional knowledge of the nature of matter (From Novak & Musonda, 1991).

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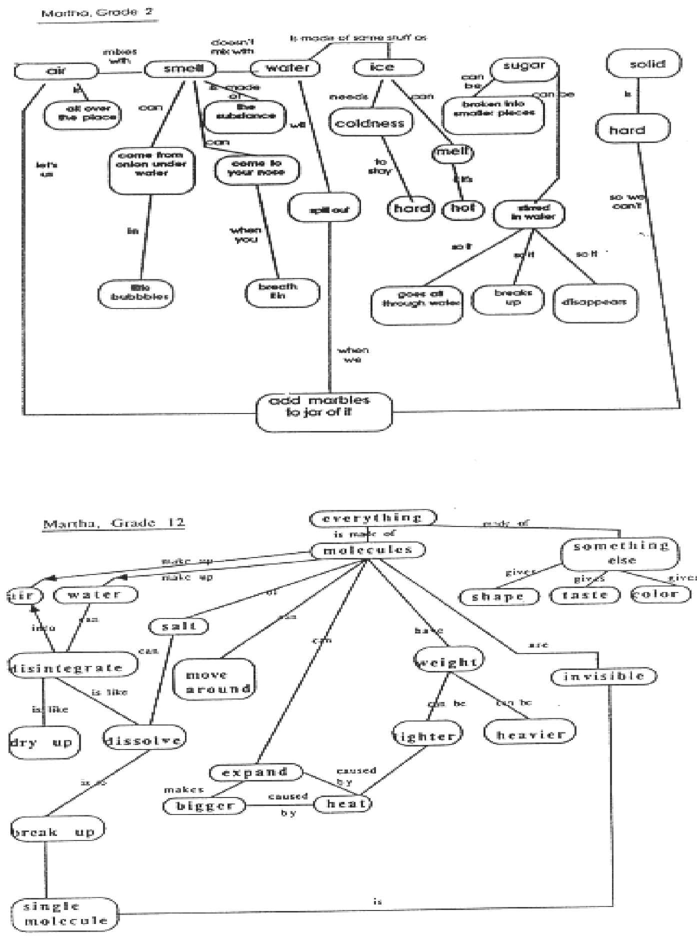

Figure 5. Concept maps drawn from interviews with Martha in Grade 2 and grade 12. Note that Martha's knowledge structure about the nature of matter shows little increase over-all and numerous misconceptions and limited conceptions (From Novak & Musonda, 1991).

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students conceptualize mathematics. Figure 6 shows an example of a concept map drawn by one of her subjects who sees no relevance of algebra and geometry to everyday life and few connections with multiplication that is relevant to everyday life.

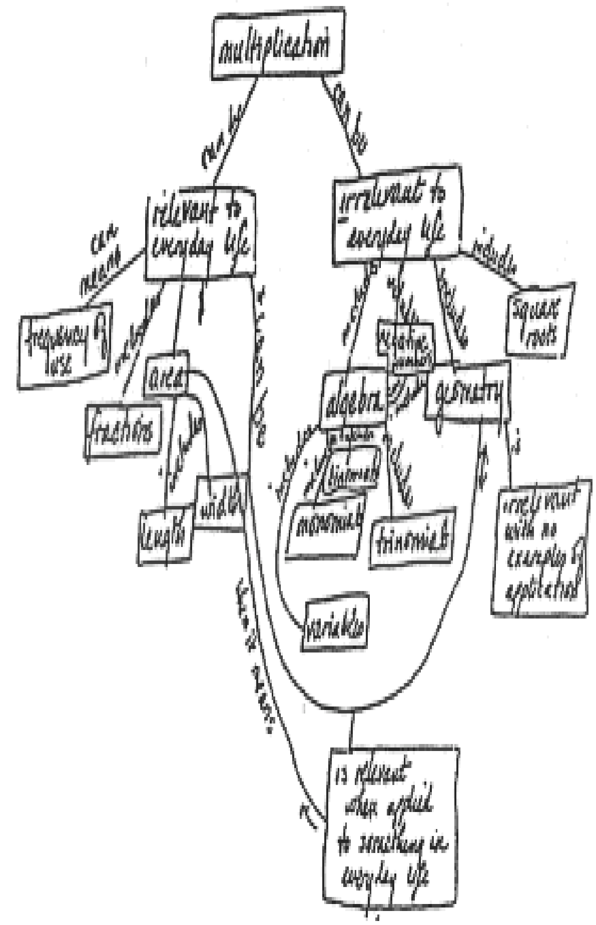

Figure 6. A concept map drawn by a college student showing her conception of multiplication. She does not have an integration of ideas from geometry with multiplication concepts (From Schmittau, 1991).

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The Problem of Faulty Conceptual Frameworks (LIPH's)

Even when classroom learning experiences involve hands-on activities to illustrate concepts and principles, many students fail to construct concept and propositional frameworks that are congruent with what scientists or mathematicians currently believe. Figure 5 shows an example of this in science. One could argue that maturity, innate intelligence and/or the quality of the instructional program are the reasons for the lack of appropriate knowledge acquisition. Our research and the research of others indicates that while the latter are in many cases significant factors influencing achievement, they are probably not the most important factors. For example, in a study with Ph.D. students in chemistry at Cornell University, the number and variety of misconceptions after carefully designed lectures on gas chromatography was similar to that evidenced before the lectures (Pendley, Bretz and Novak, in press). A study with high school physics students showed no significant variance due to scores on Raven's Progressive Matrices Test (a measure of innate ability), but highly significant differences (ANOVA F = 480) between students doing concept mapping when compared with students doing more traditional problem sets (Bacones and Novak, 1985). After carefully designed and executed eighth grade science lessons on the particulate nature of matter, students evidenced a greater number and variety of misconceptions than scientifically accepted conceptions (Bartow, 1981).

What is clearly evident from the studies cited above and hundreds of other studies such as those reported at our First and Second International Seminars (Helm and Novak, 1983; Novak, 1987), and those that will be reported in these proceedings, is that facilitating student's acquisition of powerful and valid conceptual frameworks is not easy. There are innumerable ways to go wrong and no set of instructional strategies that are foolproof. This, of course, is to be expected because we know that meaning building is an idiosyncratic event, involving not only unique concept and propositional frameworks, but also varying approaches to learning and varying emotional predispositions. The challenge is how to help teachers, directly or vicariously, help students construct and reconstruct their individual conceptual frameworks and their attitudes toward science and mathematics in ways that will lead to increasing successes.

There was much discussion at the 1983 International Seminar on the proper label to apply to these cognitive problems researchers have called misconceptions, alternative conceptions, naive notions, pre-scientific notions, etc. Each of these labels has merit, but each also is limited in its description of the origin of the problem, the historical antecedents of the conception and/or the role these conceptions play in the thinking of the individual or the society that holds the belief. I proposed then (Novak, 1983) that we consider an acronym LIPH as a fresh label for these conceptions, representing the idea that problems arise from the Limited or Inappropriate Propositional Hierarchies possessed by the individual. Now, a decade later and hundreds of relevant research studies later, I am more persuaded that the LIPH label is appropriate and powerful. It recognizes that we cannot simply ask learners to expunge a faulty concept meaning they have in their mind and substitute the currently valid label and definition. It recognizes that rote learning is ineffective in reconstructing cognitive frameworks, thus "removing misconceptions" and supplanting them with valid conceptions. It also recognizes that only the learner can choose to learn meaningfully and to consciously and deliberately reconstruct his/her cognitive framework. What is required is often the reconstruction of a significant segment of the learner's concept and propositional framework, and we see in some of the above figures that this does not occur easily even with meticulous instructional effort.

There is one advantage to rote learning: because new information is **not** integrated with existing concepts and propositions in the learner's cognitive structure, misconceptions the learner holds do not operate to distort the new learning. Hence the learner can respond to oral or written questions that are "correct", at least for the few days or weeks that information learned by rote is retained in cognitive structure. This can be satisfying to both teachers and students. However, no constructive modification of LIPH's can occur.

Helping Students to Learn Meaningfully

For almost two decades, we have been developing ways to apply the concept map tool to help teachers help students "learn how to learn". For 16 years we have also employed the Vee heuristic to help students and teachers understand better how to "unpack" knowledge in documents (Waterman and Rissler, 1986) and to construct knowledge (Novak, 1979; Novak and Gowin, 1984). Our research and the research of others have shown that these tools can be effective in facilitation of meaningful learning (Novak, 1990; Novak and Wandersee, 1990). These studies have shown that it is not easy to move science and mathematics instruction from the traditional approaches emphasizing rote memorization to patterns where meaningful learning predominates. The tools are no panacea or "magic bullet", but they can be effective. Concept maps are now appearing in many science books and Vee diagrams are beginning to appear. Mathematics instruction has moved much more slowly toward the use of learning tools, but they can be effective in this field as well (Fuatai, 1985). Figure 7 shows a concept map prepared by a secondary school student in Western Samoa. The real test of the effectiveness of these tools would require school settings where the tools are used in multiple subjects and for a succession of years, but to date I am not aware of schools or colleges where this is being done. Indeed, it is a rare school where the overwhelming and explicit commitment of teachers and administrators is to meaningful learning. Most schools remain a mix of traditional rote learning activities and various efforts by enlightened teachers to emphasize meaningful learning.

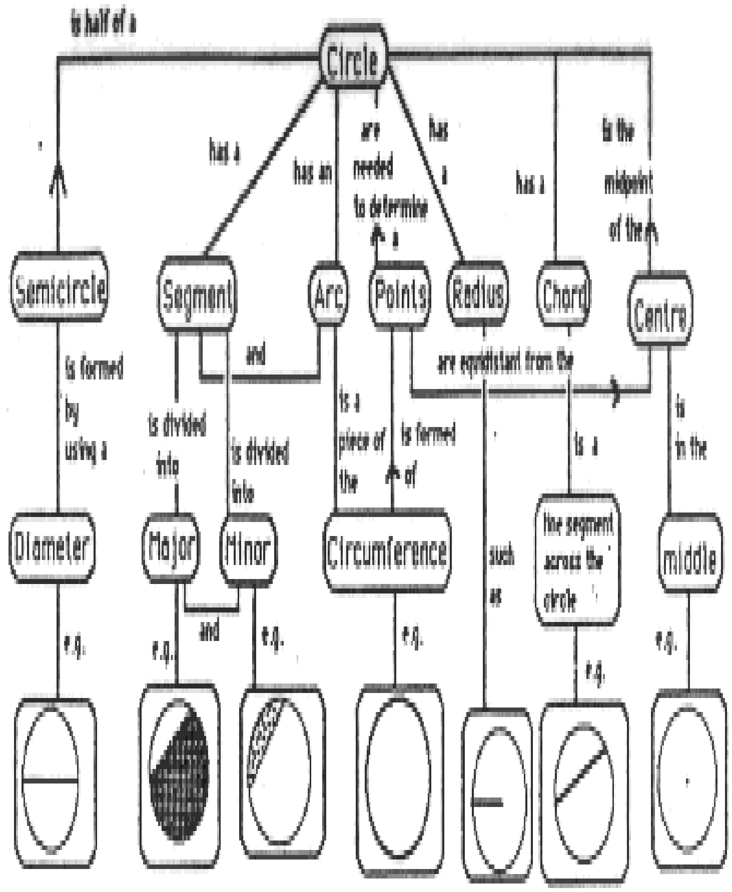

Figure 7. One of the best concept maps prepared by a student from the textbook section dealing with circles (From Fuatai, 1985, p.130).

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Conceptual Change

The issue of how individuals change their conceptual ideas has been much discussed in the past decade. Posner, Strike, Hewson and Gertzog (1982) proposed a theory of conceptual change that has been widely quoted. Instructional strategies and evaluation studies based on this theory have generally shown mixed success. This has led Strike and Posner (1992) to critique the original theory and to propose revisions. Their theory derives from epistemological foundations, especially the work of Kuhn (1970) and Toulmin

(1972), drawing parallels from conceptual (or paradigm) change to changes in an individual's "conceptual ecology". Chi (in press) has developed another model to explain problems in acquisition of valid concepts that emphasizes that a specific class of constructs, namely those that are invented by scientists and involve dynamic interactions of several underlying components. She sees "electrical current" and "evolution" as examples of these constructs.

From my perspective, the more fundamental issue is how an individual acquires knowledge and I see the epistemology of knowledge construction more parsimoniously explained by Ausubel's assimilation theory of learning (Novak, 1993a; in review). Obviously, all knowledge constructed in a discipline is first constructed in some individual's cognitive structure. To understand how knowledge is constructed in any field, it is therefore essential to understand how human beings construct knowledge. To understand how an individual constructs his or her conceptual frameworks, we need to understand the psychology underlying human meaning making.

What becomes central to "conceptual change" from my perspective is the necessity for meaningful learning to occur. This is in principle a simple task, but in practice it may be profoundly difficult. When one is dealing with secondary or tertiary students who have had years of experience with science and mathematics instruction and evaluation that encourages rote memorization of definitions or problem-solving algorithms, it is not easy to get these students to reconsider and revise their learning to meaningful learning strategies. In fact, this task is typically so difficult that I believe the research evidence suggests the use of learning tools such as concept maps and Vee diagrams are essential to achieve high levels of meaningful learning by a high percentage of students. The fundamental challenge to "conceptual change teaching" is therefore to help learner's understand how they must choose to modify their concept and propositional hierarchies and to provide instruction that is "conceptually transparent" to the learners (Novak, 1992). Changing their "conceptual ecology" requires that the learner recognizes explicit ways where their concept/propositional frameworks are limited, inapprorpirate or poorly organized into hierarchies. When this is done, a single learning episode, using concept maps prepared by the learner, can result in restructuring of a student's LIPH and stable alteration of the conceptual framework (Feldsine, 1983). Reconstruction of LIPH's requires negotiation of meanings between students and teachers. It is a social as well as a personal reconstruction.

In our 12-year longitudinal study of concept development, we observed cases (e.g., Paul in Figure 4) where enormous improvements occurred in the student's understanding of the particulate nature of matter, and other cases (e.g., Martha in Figure 5) where from grade 2 to grade 12, no improvement was evidenced even though the students took similar numbers of science courses. Based on the nature of Paul's responses to the interviews, he was obviously committed to meaningful learning in science, whereas Martha was obviously a rote learner, memorizing as best she could and recalling bits and pieces of knowledge, but not forming a well organized conceptual framework.

The long term impact on learning science when high quality, audio-tutorial, science lessons were provided in only grades one and two was remarkable (Novak and Musonda, 1991). Figure 8 shows the differences in valid and invalid conceptions evidenced in interviews over the span of school years for those students who engaged in the audio-tutorial in grades one and two lessons (experimental, Instructed group) compared with those who had only ordinary school science experiences (the control, Uninstructed group). These kinds of data suggest a very optimistic picture regarding the potential effectiveness of science instruction when deliberate and explicit efforts are made to provide instruction that has clear and explicit linkage between the events students are manipulating and observing and instruction in the conceptual ideas necessary to construct the concept and propositional hierarchies necessary for valid scientific understanding of these events. Schmittau has shown (in press) that similar results can be obtained in mathematics.

During this seminar, the Private Universe Project, based at Harvard University, will videotape interviews with some of the leading researchers in science and mathematics education. The powerful videotape created earlier by the Harvard-Smithsonian Center for Astrophysics has already been seen by thousands of teachers and lay persons, illustrating the enormous failure of science instruction, even with Harvard graduates. The new videotapes to be developed by the Project will surely contribute to an awareness of the conceptual problems that arise as a result of ineffective science education.

It may be audacious to say this, but I think we know in principle <u>why</u> learning in sciences and mathematics is so ineffectual for most students and how to remediate this problem. What we lack is the commitment, resources and the political strategies to change schooling in the direction that requires uncompromising commitment to meaningful learning for all students in all subject matter fields. Perhaps some smaller countries will be the first to mobilize their political and educational resources to effect the changes needed to achieve meaningful learning for all students at all ages. I am impressed, for example, with the leadership in Spain and Thailand to move in this direction.

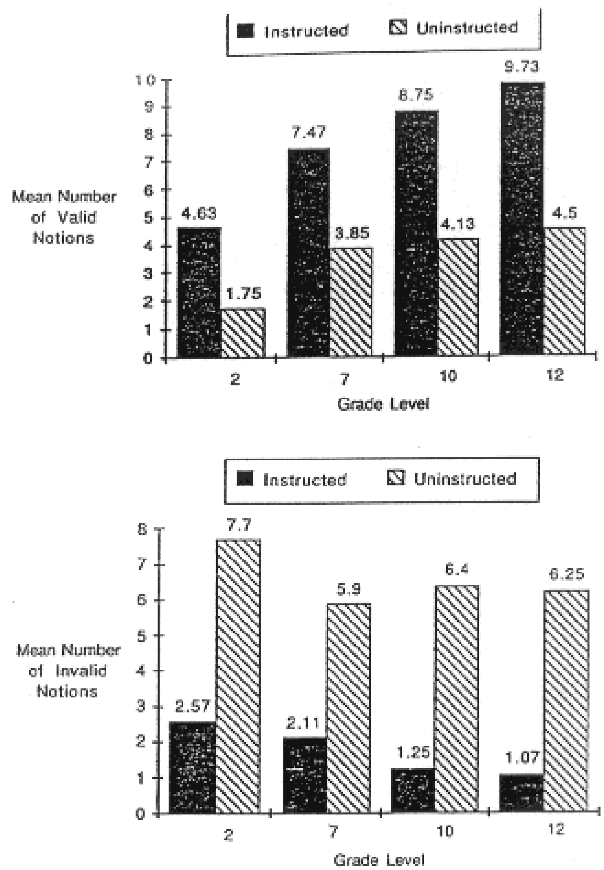

Figure 8. Students receiving audio-tutorial instruction in basic science concepts in grade one and two (ages 6-8), show more valid notions ond fewer invalid notions throughout their school years, compared with students who did not receive this instruction (See Novak & Musonda, 1991).

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A Theory of Education

During my graduate studies at Minnesota in the 1950's, I was employed as a teaching and research assistant in the Botany Department but majored in science education. I was captivated by the way theory guided work in sciences--and by the absence of viable theory in education. It seemed to me then that it should be possible to construct theories that could serve to guide education and I began what has been a 40-year effort to do this. It was evident to me that a viable theory of education needed to be based on a theory of human learning, but all that was available in my studies in psychology was behavioral psychology that seemed inappropriate to me. When Ausubel's (1963) work came to my attention in his *The Psychology of Meaningful Verbal Learning*, our research group moved rapidly to apply his assimilation theory to our studies. Assimilation theory became a cornerstone in my efforts to construct a theory of education (Ausubel, Novak and Hanesian, 1978; Novak, 1993b). Searching for a philosophical foundation for education, I was impressed first with Conant's (1947) *On Understanding Science* and subsequently with Kuhn's (1962) *Structure of Scientific Revolutions*. But it was Toulmin's (1972) *Human Understand* book that presented ideas I saw as most congruent with assimilation theory. Building on Ausubel, Toulmin and Schwab's (1973) work, my first effort to put forth *A Theory of Education* was published in 1977.

Now, 16 years later with dozens more M.S. and Ph.D. studies based on my theory and Gowin's (1981) *Educating* completed, the general outlines of the theory put forward in 1977 remain viable and productive. However, I have sought better to integrate affective ideas and social learning ideas into the theory. What is emerging is a theory of education that can be stated as follows:

Meaningful Learning Underlies the Constructive Integration of Thinking, Feeling and Acting Leading to Human Empowerment for Commitment and Responsibility.

I am working to complete a new book describing this theory which I believe can be useful to guide future studies dealing with topics covered in this Seminar. It is my hope this theory will help to advance the way educators educate, for I believe nothing is more important to the future of mankind.

The Changing Economic Environment

History shows that good ideas floundered for centuries (if not millennia) before societal changes occurred that allowed the ideas to flourish. Toulmin's (1972) idea of the evolution of conceptual ecologies is very apt to this reality. A spherical model of the earth had little social consequence until traders in the west sought to transport spices and silk from the east as trade began to flourish following the Dark Ages. There was little need for workers empowered to take charge of their own meaning making in societies where businesses were managed "top-down" and only top managers needed to be inventive. In the rapidly emerging climate of Total Quality Management(TQM), Just In Time (JIT) inventory systems, and commitment for *all workers* to the "Strategic Intent" of the corporation, all workers, at all levels, need to be capable of constructing and reconstructing their knowledge frameworks. We are beginning to see the pressure for radical improvement of education not from educators but from businesses and industries that need better educated personnel, personnel who can think creatively and can adapt rapidly to changing environments. Even universities are now under pressure from their consumers--the corporations that hire college graduates--to adopt TQM strategies (Marchese, 1993). Just this past June, more than 100 Cornell University professors, staff and administrators traveled to Cincinnati, Ohio to learn from Proctor and Gamble how TQM ideas work, and to explore ways to apply these ideas to improvement of university education. The world-wide economic pressures on corporations are beginning to be transmitted to schools, colleges and universities.

Peter Drucker, one of the revered leaders of the business world, wrote recently:

> The basic economic resource--"the means of production", to use the economists term--is no longer capital, nor natural resources (the economists "land"), nor labor. <u>It is and will be knowledge</u>" (1993), p. 8, emphasis in the original).

Drucker continues for 210 pages of persuasive argument, I believe, to document and build his case. It has long been recognized that knowledge is power, and now Drucker claims that knowledge is the key to the economic well being of every country. I believe profoundly that this is the case.

It is unfortunate that so many of our colleagues from third world countries who wanted to attend this Seminar did not have the resources to do so. We could not assist them. We can and will, however, make available to them the knowledge that will be presented here. Publishing these Proceedings electronically, and making the Proceedings available to anyone in the world who has access to the electronic Internet highway, will do much to help spread the knowledge collected here to rich and poor, albeit electronic access is still limited in third world countries. Knowledge, as with love, is not diminished when it is shared, unlike most economic resources. Those of us gathered here stand at a new threshold of opportunity for improvement of education. We also share the commitment to extend this opportunity to the peoples of the world.

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Figure 1. Gowin's Vee showing twelve epistemological elements operating in the construction of knowledge or in an analysis of a unit of knowledge. All elements interact with one another and the process of knowledge construction can be initiated from any element, but most commonly from the focus question and event(s) or object(s) of interest.

Figure 2. an example of Gowin's Vee drawn by a secondary school student to represent a textbook problem (From Fuatai, 1985). Students were not asked to include philosophy or world view or value claims.

Figure 3. A concept map showing the nature and structure of concept maps.

Figure 4. Concept maps drawn from interviews with Paul in grade 2 (Map A) and in grade 12 (Map B). Note the enormous growth and refinement of Paul's concept/propositional knowledge of the nature of matter (From Novak & Musonda, 1991).

Figure 5. Concept maps drawn from interviews with Martha in Grade 2 and grade 12. Note that Martha's knowledge structure about the nature of matter shows little increase over-all and numerous misconceptions and limited conceptions (From Novak & Musonda, 1991).

Figure 6. A concept map drawn by a college student showing her conception of multiplication. She does not have an integration of ideas from geometry with multiplication concepts (From Schmittau, 1991).

Figure 7. One of the best concept maps prepared by a student from the textbook section dealing with circles (From Fuatai, 1985, p.130).

Figure 8. Students receiving audio-tutorial instruction in basic science concepts in grade one and two (ages 6-8), show more valid notions ond fewer invalid notions throughout their school years, compared with students who did not receive this instruction (See Novak & Musonda, 1991).