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Paper Title: **A View on the Current Status of Ausubel's Assimilation Theory of Learning**
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Abstract: In the three decades since Ausubel put forward his assimilation theory of congnitive learning, many changes have occurred in the field of educational psychology and the emerging fields of cognitive science and artificial intelligence. This paper is not a review of these developments, but rather a statement on the current status of Ausubel's theory as seen from the perspective of our research group. We see his theory largely unchanged in terms of basic concepts and principles, although new epistemological ideas, recent ideas from cognitive science, and new metacognitive tools permit new perspectives on the power and value of Ausubel's theory. Thus a research paradigm rooted in his theory may take on substantively new characteristics with powerful implications for teaching and learning.

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A View on the Current Status of Ausubel's Assimilation Theory of Learning[1]

Introduction

David Ausubel first introduced his theory of Meaningful Learning in 1962 under the title, "A Subsumption Theory of Meaningful Learning and Retention." In 1963, he published The Psychology of Meaningful Verbal Learning, elaborating on the ideas presented earlier. Finally in 1968, a more comprehensive view of his ideas was published in Educational Psychology: A Cognitive View (Ausubel, 1968).

The first formulation of Ausubel's assimilation theory was done in 1938 as a term paper for a psychology of learning course at the University of Pennsylvania. In 1949, he revised and expanded his ideas in a term paper in a course taught by Robert Thorndike at Teachers College, Columbia University. It should be remembered that the late 1930s to the early 1960s when Ausubel was formulating his ideas was also the heyday of behavioral psychology. Not only in the field of psychology in general, but also in educational psychology, behaviorism was the overwhelmingly dominant paradigm, and, along with it, positivistic epistemology was also strongly in control. The views that Ausubel put forward in the early 1960s were strongly in discord with the prevailing behaviorist ideas and Ausubel experienced considerable difficulty in finding publication outlets in respectable journals of psychology or educational psychology. Recall also that Kuhn book, The Structure of Scientific Revolutions, was published in 1962, and the movement toward newer epistemologies was only in its infancy at the time Ausubel's work emerged.

The prevailing behaviorist dominance not only created a hostile climate for many of Ausubel ideas, but also helped to prevent wide acceptance of Piagetian ideas, which had been put forth since the 1920s in Geneva, Switzerland. In fact, it could be said that Piaget was not discovered in this country until the mid-1960s (Ripple and Rockcastle, 1964).

Not surprisingly, Ausubel's ideas on learning made slow progress in the 1960s, even though there was a relatively immediate recognition of the importance of his work in some circles and the beginning of a substantial worldwide acceptance of his ideas outside of North America. Remember also behavioral psychology did not succeed in dominating the thinking in most European and Oriental countries.

Our research group first became familiar with Ausubel's work in 1964 when we began careful study of his Psychology of Meaningful Verbal Learning. The theory put forward explained many of the difficulties we found in interpreting data we were gathering on student problem solving. Working initially with an information processing model of learning (Novak, 1958), we assumed that problem solving was a function of two independent traits, knowledge stored in the mind, and information processing capability. What we found suggested in Ausubel's theory was that these two processes are confounded in the process of new learning which is a function of both the quantity and the quality of cognitive structure organization. This interpretation closely followed the pattern of our research results. Further elaboration of this movement away from information processing models and toward Ausubel's assimilation theory has been presented elsewhere (Novak 1977a).

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[1] A paper presented at the meetings of the American Educational Research Association, San Francisco, California, April 24, 1992.

After moving in 1967 from Purdue University to Cornell University, our research group there proceeded not only in the study of problems associated with science learning but also in the design of new instructional approaches based on assimilation theory. These included the development of an audio-tutorial elementary science program that served as a foundation for many of our research studies with elementary school students. It was from this research dealing with a twelve-year longitudinal study of science concept learning that the technique of concept mapping was developed by our research group (Novak and Musonda, 1991). Since 1974, much of our research and many of our innovative practices in teaching have involved the utilization of the concept mapping as we developed it.

Parallel to developments in cognitive psychology have been important developments in epistemology moving away from positivistic epistemologies and toward realist or constructivist views. Today, virtually all serious researchers in the field of cognitive psychology and science and mathematics education are guided by some form of constructivist epistemological framework. This is reflected in recent monographs published in the Journal of Research Science Teaching (Lynn, Songer, and Lewis, 1991; Bybee, Ellis, and Matthews, 1992), and by numerous papers appearing in the Educational Researcher. The consensus toward constructivist epistemology as the framework to guide inquiry and theory development in cognitive psychology and education in general are strongly supportive of ideas in the assimilation theory. The importance of this epistemology to the current status of assimilation theory will be illustrated.

Key Principles of Ausubel‘s Theory

Ausubel's early work on cognitive learning put forward clear descriptions of a dozen or so major ideas or principles. These are illustrated in Figure 1. First and most important was the emphasis on meaningful learning, which he defined as non arbitrary, non verbatim, substantive incorporation of new symbolically expressed ideas into cognitive structure. The point here is that learners relate new information or ideas to relevant aspects of their current knowledge structure in a conscious manner. For meaningful learning to occur, three requirements must be met. First, the material to be learned must itself have potential meaning. For example, nonsense syllables or arbitrary lists of words have little inherent meaning and cannot be incorporated into cognitive structure in a non-arbitrary, substantive fashion. Secondly, the learner must possess relevant concepts and propositions that can serve to anchor the new learning and assimilate new ideas. Thirdly, the learner must choose to relate the new information to his/her cognitive structure in a non verbatim, substantive fashion. If any of these three elements are lacking, meaningful learning cannot occur, at least in initial stages of a given learning sequence.

Ausubel defines rote learning as arbitrary, verbatim, non substantive incorporation of new ideas into cognitive structure. Information does enter cognitive structure, but with no specific relevance to existing concept/propositional frameworks. Partly for this reason, rote learning may involve interference with previous similar learning, and exhibit some of the difficulties in patterns of recall, including misassociations. Most importantly, rote learning tends to be recalled for only a short time (hours for nonsense syllables, and days or a few weeks for classroom instructional materials) and once forgotten, the remaining traces will confer interference to future similar learning. Unless rote learned material is repeatedly rehearsed to achieve high levels of overlearning, it tends to be more detrimental to future learning than no learning at all.

The fundamental process involved in meaningful learning is the incorporation of new concepts and propositions into a hierarchically arranged framework in cognitive structure. Usually this incorporation involves more specific, less inclusive ideas being subsumed under more inclusive concepts and propositions in cognitive structures. The idiosyncratic

nature of cognitive structure led Ausubel to label this process subsumption, to recognize that meaningful learning is a highly idiosyncratic learning

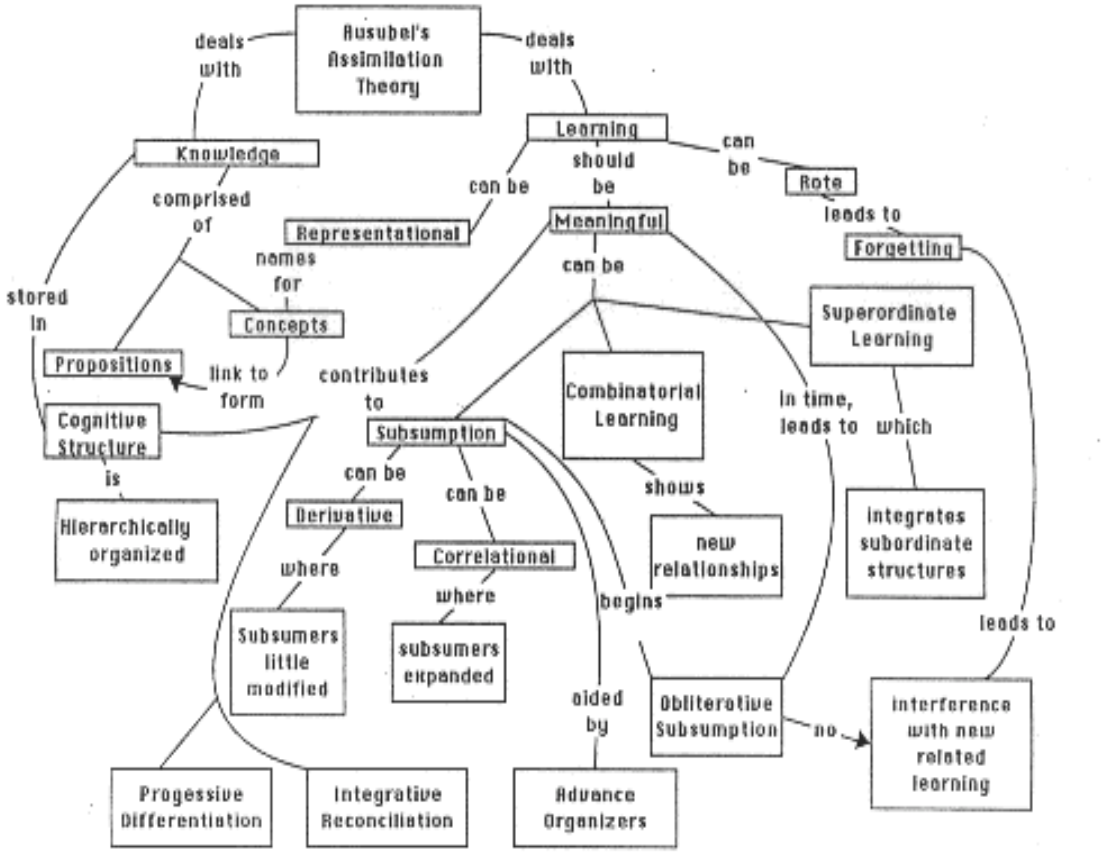

Figure 1. Key Concepts and Principles in Ausubel's Assimilation Theory of Learning as Expressed in a Concept Map.

Figure 1. Key Concepts and Principles in Ausubel's Assimilation Theory of Learning as Expressed in a Concept Map.

process. Nevertheless, students in a given culture possess somewhat similar conceptual frameworks, and, therefore, it is possible to have schools where children are taught in groups and each can still engage in meaningful learning.

Two kinds of subsumption were proposed by Ausubel: derivative and correlative. Derivative subsumption occurs when new concepts or propositions are related to existing concepts or propositions but do not substantially alter the character or the meaning of the latter. For example, as students recognize that giraffes and elephants are also kinds of animals, as are perhaps more familiar dogs and cats, derivative subsumption of these new meanings occurs under the concept of animal. Correlative subsumption, on the other hand, expands the meaning of the existing subsumer and confers new characteristics to the subsumer. For example, as microscopic, unicellular animals are also recognized as related to the concept animal, the latter takes on substantively new meaning. Thus derivative and correlative subsumption occur frequently and easily in most school instruction. Ausubel

sees subsumptive learning as the most common and most important form of meaningful learning.

Another kind of learning described by Ausubel is combinatorial learning. In combinatorial learning, new concepts and propositions are seen as related to previous knowledge and cognitive structure, but the ideas are not simply subsumed under existing concepts or propositions. For example, concepts of mass, force, and energy may be seen to be related ideas in physics, but initial learning may be combinatorial in nature rather than subsumptive. Similarly, ideas of supply, demand, and market may initially be learned in a combinatorial fashion. However, as cognitive development and differentiation proceeds, ideas learned initially in a combinatorial fashion may now take on new meanings as for example, in the equation, f = ma. In the latter case, not only are force, mass, and acceleration seen as related, substantial new meanings inhere in this specific relationship.

One of the challenges for children in their early acquisition of language is the identification of ideas that they understand with appropriate symbolic labels. This Ausubel calls representational learning. It is a principal kind of learning described by Macnamara (1982) in his book, Names For Things. Representational learning can occur in older students and adults as well, and teachers are all too familiar with students learning the names for things or phenomena but not understanding the specific attributes or characteristics of the things or phenomena. Nevertheless, language provides a powerful tool for acquisition of meanings, a phenomenon very much emphasized in the work of Vygotsky (1962). There is a kind of interplay that exists between the acquisition of meanings for concepts and the recognition of the appropriate symbol to represent these concepts. Vocabulary learning can be merely the definitions of certain symbols, without acquisition or understanding of meaning expressed in the definition. Vocabulary learning of this type is at a very low level of meaningful learning.

Although subsumptive learning is most common in meaningful learning, occasionally new concepts or propositions are acquired that have a superordinate relationship with existing concepts and propositions. For example, as students come to understand the mechanisms underlying reactions in chemistry, they move from a mere representational knowledge of entropy toward acquisition of powerful meanings for this important encompassing concept (Cullen, 1983). This kind of learning Ausubel defines as superordinate learning. Superordinate concepts, when acquired with substantial meaning, can serve to interrelate previously held concepts that were not seen as connected in meanings. Therefore, superordinate learning is unusually powerful in developing cognitive organization, the kind of organization characteristic of people who possess expert knowledge in the domain. It is also an important component in creative production, since ideas may be related in new combinations with powerful new meanings. Many of the Nobel prizes awarded have been essentially for individuals who created some new superordinate linkage between ideas that were widely known by their peers in their disciplines, but the relationships were not seen. A classic example of this was Einstein's recognition that mass and energy could be related as expressed in the principle, $E = mc^2$. Although it is less common in terms of day-to-day meaningful learning, superordinate learning is a powerful form of meaningful learning.

Finally, Ausubel introduced the idea of obliterative subsumption, the process that begins in meaningful learning where new meanings are modified as they are incorporated into cognitive structure. This modification and inclusion into more general ideas can over time lead to the failure to recall specific new concepts or propositions previously subsumed, and the process of obliterative subsumption is complete. However, unlike the forgetting that occurs after rote learning, the failure to recall characterized by obliterative subsumption does

not produce interference with future learning, and, in fact, the cognitive restructuring that occurred in the process may substantially facilitate new related learning. Thus, lack of ability to recall details after meaningful learning does not have the negative effect of failure to recall that occurs following rote learning.

Two additional ideas were put forward by Ausubel to describe changes that occur in cognitive structure as a consequence of meaningful learning. Progressive differentiation occurs when concept meanings are gradually clarified and hierarchical organization of concepts and propositions is improved. Integrative reconciliation occurs when explicit delineation of similarities and differences between related ideas is achieved. For example, as one begins to understand better how all of the above ideas explain the process of meaningful learning, the concept of meaningful learning is progressively differentiated. Integrative reconciliation could occur when one recognizes that rote learning and reception learning are not the same phenomenon but represent instead a form of cognitive learning as distinct from a form of instruction.

Ausubel's theory recognizes the important role that experiences both in and out of school play in cognitive development. In many ways, the recent findings in non-school learning (e.g., Saxe, 1988) and the importance of context in learning (e.g., Perkins & Solomon, 1989; Brown, Colling & Duguid, 1989; and the Vanderbilt Group, 1990) was anticipated in Ausubel's subsumptive or assimilation theory and could serve as a powerful explanatory framework for findings in these works.

The above ideas are essentially the key concepts of Ausubel's subsumption or assimilation theory of learning. They remain useful concepts, and we have found them to be productive in our research program. However, through the research we have done with children and adults, we have seen it useful to modify somewhat Ausubel's idea and, to some extent, to simplify the theory. The current status of assimilation theory as viewed by myself and colleagues working with me is described below.

Ausubel and Piaget

In presenting Ausubel's theory to classes or in seminars, I am frequently asked how his ideas are similar or different from Piaget's key ideas of assimilation, accommodation, and equilibration. The fundamental distinction is that Ausubel's theory deals with cognitive learning and how new, specific concepts and propositions are incorporated into the learner's cognitive structure. Piaget's developmental theory deals with changes in generic cognitive capacities characterized by the stages of forms of thinking: sensory motor (0-2 years), preoperational (2-7 years), concrete operational (7-14 years), and formal operational (14+ years), roughly developing in the ages shown. Assimilation of new information is seen as occurring into these general structures or schemata, where a schema can be defined as "a cognitive structure which has reference to a class of similar action sequences, these sequences of necessity being strong, bounded totalities in which the constituent behavioral elements are tightly interrelated" (Flavel, 1963, p. 52-53). Accommodation leads to some modification of existing schema and assimilation and accommodation are seen as "indissociable from each other" (Piaget, 1954, p. 352). Successive experiences lead to a new equilibration of the schema structure allowing for new further assimilations and accommodations. Gradually new cognitive capabilities emerge as a result of the generic modification of schemas leading to formal operational (abstract, hypothetical-deductive) reasoning. Formal operational thought involves propositional thinking which allows the learners to use propositions to understand new propositions. This approaches something close to Ausubel's meaningful reception learning, except that Ausubel is more explicit in the nature of the assimilation processes of subsumption, combinatorial learning, superordinate learning, progressive differentiation, and integrative reconciliation. Moreover, these

processes can be expressed as specific changes in concept and propositional frameworks in cognitive structure, frameworks that we now show in the form of concept maps, as illustrated in this paper. What is shown on a concept map, or a section of a concept map, is not the same as the generalized structure that Piaget would call a schema. In our work, we see the fundamental cognitive limitation of children as derived primarily from the paucity of developed specific concept and propositional frameworks, and not from limited brain mechanisms per se (Novak, 1977b).

Ausubel's Theory Applied to Instruction

In his early writings, Ausubel pointed out the distinction between reception learning and discovery learning. Reception learning occurs when concepts and propositions are presented to learners for incorporation into cognitive structure. In contrast, discovery learning occurs when the learner identifies the content and relationships to be learned and constructs the propositional ideas independently. Discovery learning can vary along a continuum from merely reception learning to high levels of autonomous learning characteristic of original research. Of course, discovery learning can also occur in a trial-and-error fashion where the degree of meanings and meaning-making involved is minimal. Therefore, engaging students in discovery learning experiences does not necessarily lead to high levels of meaningful learning. Ausubel pointed out this important distinction and indicated that discovery learning and rote learning could be seen as two ends of a continuum. On the other hand, rote learning and meaningful learning can also be seen as a distinct continuum, orthogonal to the reception-discovery continuum. Although Ausubel sees rote learning as distinctly different from meaningful learning in that the latter requires non-arbitrary substantive incorporation of new knowledge into cognitive structure, we have found it useful to see this process as a continuum,[1] since students will vary widely, in terms of the number and quality of associations they seek to make between new learning and existing prior knowledge. Also, the quality and quantity of knowledge held, and the degree of commitment to seek integration with prior knowledge, significantly impacts the level of meaningful learning, as does also the quality and organization of the new learning materials. Figure 2 illustrates the idea that meaningful and rote learning are a separate continuum from instruction that may range from reception to autonomous discovery learning. Rote learning may take place in either a discovery or reception instructional mode, and meaningful learning may also occur or fail to occur under any mode of instruction.

According to the principle of progressive differentiation, learning proceeds more efficiently when information to be learned is sequenced in such a way that it proceeds from more general ideas to more specific, more explicit concepts and propositions. Instruction organized in this manner leads to further differentiation of relevant segments of cognitive structure. In a related manner, the principle of integrative reconciliation applies when instruction is organized so that concepts and propositions previously unrelated are brought together in a sequence that integrates their meanings and leads to a sharpening of the distinctions and similarities between previously learned concepts and propositions. For example, when distinctions are learned between speed and velocity, weight and mass, force and acceleration, not only is cognitive structure progressively differentiated, but there are new integrations of meanings, including a distinction between these concept labels in

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[1] This is one area in which I disagree with Ausubel in that I see rote learning as part of a continuum from little association of new knowledge with existing cognitive structure to high levels of integration with a complex, well-integrated relevant conceptual framework. Similarly, we observe students' commitment (set) to learn varying from no effort to relate new learning to their prior knowledge to high levels of energy committed to constructing and reconstructing knowledge integration.

ordinary English language and their precise meanings in physics. It is partly the failure to achieve integrative reconciliation that leads to so many of the difficulties in the teaching of physics, and also the teaching of most subjects. Integrative reconciliation of concepts and propositions in cognitive structure is required for elimination of misconceptions (or "alternative conceptions").

The idea for which Ausubel's theory has become best known is his advocacy of the use of the principle of advance organizers. Ausubel proposed that instruction should be organized in such a way that more general concept/propositional material is introduced in a concise fashion prior to more specific less inclusive propositional material. He proposed that this general, more abstract introduction of ideas served to anchor into cognitive structure more specific information to be learned subsequently. Two requirements for functional advance organizers are they should be relatable to existing concept and propositional meanings in the learner's cognitive structure, and that they should be relatable also

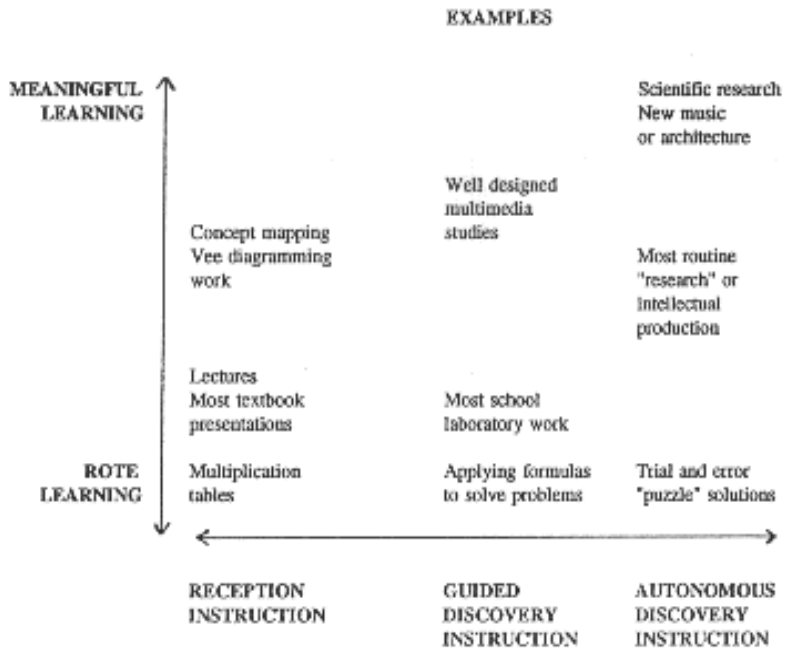

Figure 2. The rote-meaningful learning continuum is distinct from the reception-discovery continuum for instruction. Both reception and discovery instruction can lead to rote learning or meaningful learning. School learning needs to help students move toward high levels of meaningful learning, especially in reception instruction that is the most common. See text for discussion of differences in Ausubel's and Novak's views.

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to the concept and propositional structure of the subsequent information to be taught. Although some of the studies on the use of advance organizers have shown no significant differences or even negative affects, most of these studies fail to recognize the importance of devising advance organizers relatable to existing cognitive structure, the necessity for learners to choose to learn meaningfully, and/or the necessity to evaluate meaningful learning with appropriate test instruments. When all of the necessary conditions for functioning of advance organizers are met, and appropriate evaluation is used, the idea of the advance organizer has shown to be effective in promoting meaningful learning (Ausubel, 1978). Ausubel's key ideas regarding instruction are shown in Figure 3.

Ausubel also views the concept of advance organizer as one of the concepts of assimilation learning theory. Since advance organizers, when properly constructed, serve as a kind of cognitive bridge between the more general existing concepts in the learner's cognitive structure and the more specific knowledge in the learning task, advance organizers directly facilitate other assimilation processes. Thus we can view the idea of advance organizer, when employed, as a component of the meaningful learning process.

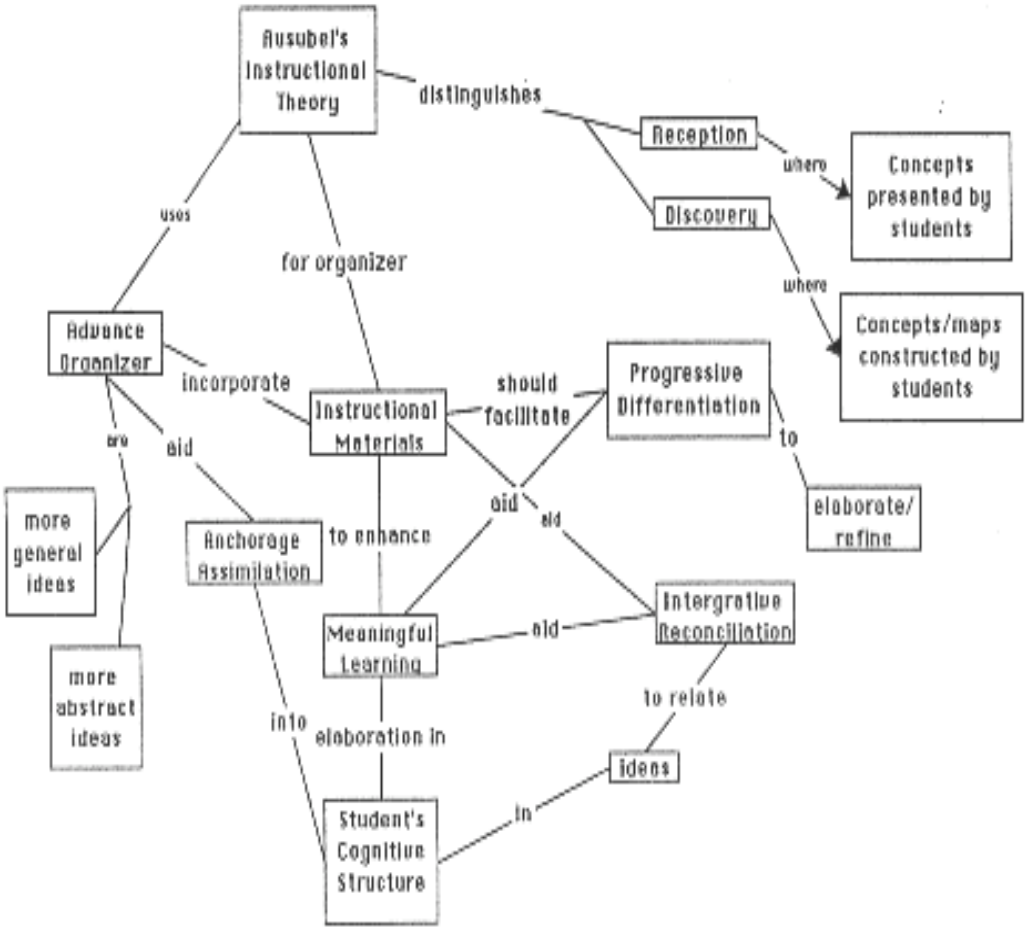

Figure 3. Key ideas in Ausubel's instructional theory building on principles of assimilation theory.

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The Changing Epistemological Landscape

For some three hundred years, the ideas set out by Francis Bacon (1620) regarding the nature of rational inquiry have dominated Western views of science and the scientific method. Bacon properly criticized the tendencies in the early Seventeenth Century to base judgments on ancient writers or on mythological ideas about the workings of the universe. Instead, he wrote a prescription for observing nature and wresting from nature the truths that can better guide human experience. Almost three hundred years later, Karl Pearson (1900) further explicated the dogma for doing science in his Grammar of Science. With the growing popularity of philosophy and philosophy of science, elaborations on the themes set forth by Bacon and Pearson took place with the intent of showing logical systems that could lead to the production of truths about the universe. These philosophies, variously labeled positivism, logical positivism, and empiricism, dominated the thinking of the community of scholars interested in the nature of knowledge and knowledge production. While these scholars carried on their debate with one another, scientists and other scholars proceeded in

their work largely unaffected by the issues and discussions in philosophy of science. However, beginning in the 1940s, scientists themselves began to turn attention to philosophical issues. With work such as Conant's On Understanding Science (1947), a new philosophy of science began to emerge that has had significant implications for the work of scientists and the training of scientists. This was followed by work such as that of Conant's protege, Thomas Kuhn, and his Structure of Scientific Revolutions (1962).

From the early 1960s onward, we began to see a succession of books coming forward with new ideas regarding the nature of knowledge and knowledge production largely rejecting the ideas of the still-dominant positivist writers. Toulmin's (1972) Human Understanding and later writings by Rorty (1979), Popper (1982), Watson (1985), and Miller (1987) put forward ideas that repudiated positivistic thinking. With the cascade of writings by philosophers concerned with epistemology of the last two decades, we have entered what is now referred to as a period of "post-positivism." However, as Wilshire (1990) points out, positivism is alive and well in universities, and so teachers are still being trained under positivistic influence. In many cases, what we observe is hardly more than lip-service to new epistemological ideas, but nevertheless the trend is clear--we are moving toward a new epistemological landscape, albeit the debate continues (Schrag, 1992).

The changing epistemological ideas have importance for learning psychology and also for education in general. Virtually all contemporary researchers on human learning have moved away from behaviorism and into one form or another of cognitive psychology. This psychology recognizes that individuals construct their own meanings and that the construction of new meanings is dependent upon the adequacy of prior conceptual knowledge. However, these ideas date back to antiquity, and what is still missing in the thinking of many people in the field of cognitive science and artificial intelligence is an epistemological commitment to post-positivist ideas. Von Glasersfeld (1984) labels a commitment to the psychology of individual knowledge construction as "trivial constructivism," whereas the idea that knowledge is continuously evolving and that ultimate truths will not be known is what he calls "radical constructivism." Relatively few professional scientists or educators have been committed to radical constructivist ideas, but these seem to be emerging increasingly in contemporary writings.

One of my colleagues, D. Bob Gowin, has been interested in problems of epistemology for most of his professional career. Trained as a philosopher, his early work involved critiques of ideas put forward by other philosophers, but increasingly he turned his attention toward philosophical ideas that could have operational significance in education. One of the thorny problems he observed was the general lack of understanding by students in laboratory settings of the nature of scientific inquiry and the relationship between laboratory work they were doing and the construction of knowledge. This led to Gowin to formulate a series of questions that students could ask regarding any inquiry that would help focus their attention on the conceptual and theoretical elements that were guiding the inquiry and guiding the conclusions constructed in the inquiry. In 1977, Gowin invented a heuristic device to express more cogently the interplay between conceptual/theoretical ideas and methodological elements involved in the construction of knowledge (see Gowin, 1981). Figure 4 shows the current form of Gowin's Vee as we employ it in our own work.

Among the important considerations in contemporary epistemology is the role that feelings and values play in the selection of events and questions for an inquiry and in the construction of knowledge claims. Contrary to the dogma of the positivists, contemporary epistemology sees knowledge making in the sciences (and, indeed, in any field) as highly emotion- and value-laden. The mere decision to inquire into a certain field is already a value decision. Feminist scholars have pointed out that scientific inquiry has been male dominated, often ignoring problems and issues important to women (Keller, 1985; Kerr, 1985). With a growing number of female scientists entering the profession, we now see a

somewhat different perspective emerging on the questions being researched, especially in the field of health sciences.

My own work in this area in collaboration with Gowin has been to focus in on the nature of the learning process as a basis for understanding the process of knowledge construction. Since all knowledge construction is basically a learning event for individuals involved in the process, I believe that a philosophy of knowledge that ignores the nature of human learning ignores the most fundamental elements required to understand epistemology. Building on ideas from assimilation

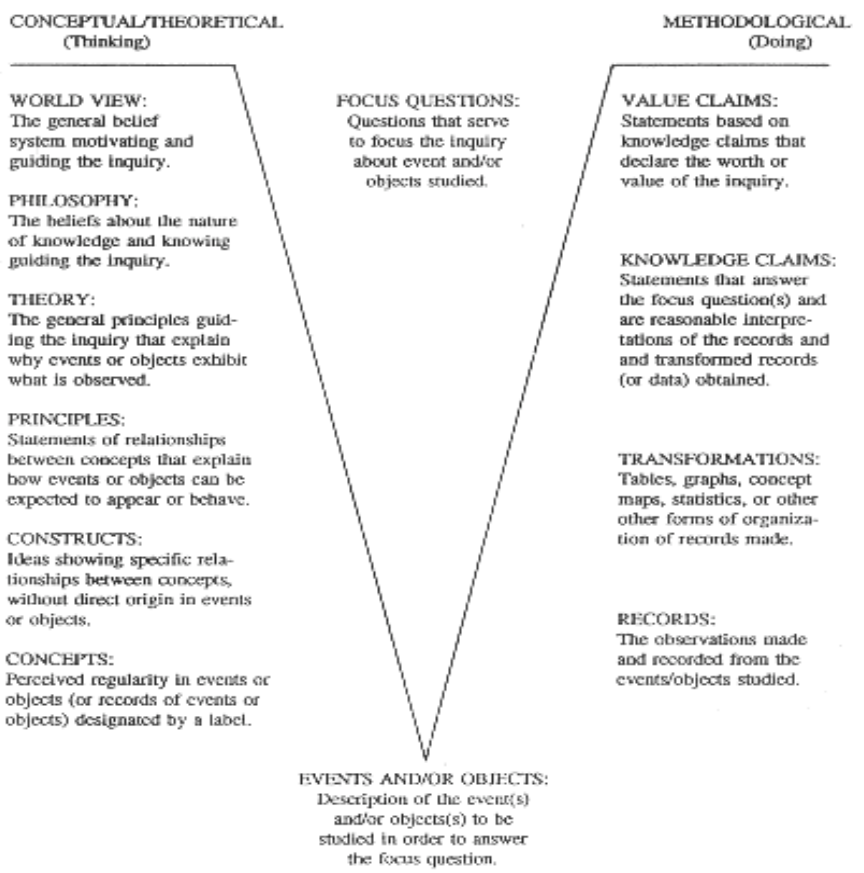

Figure 4. Gowin's Vee showing key epistemological elements which are involved in the construction or description of new knowledge. All elements interact with one another in the process of constructing new knowledge or value claims, or in seeking understanding of these for any set of events and questions.

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theory, our research group has been increasingly looking to ideas that tie the psychology of meaning making to epistemology. Under the label of human constructivism, I have put forward a proposal that seeks a unification of ideas in the psychology of learning and epistemology (Novak, in press). These epistemological ideas significantly alter the ways in which our research group looks at assimilation theory, since we now see a close and inseparable interaction between human learning and human knowledge production. These ideas have been strongly supported both in empirical studies and in an analysis of what scientists do (Kerr, 1985). We also see epistemology as a fundamental problem associated with encouraging meaningful learning in students at all levels, but especially in secondary and tertiary education (Edmondson & Novak, in press).

We see the future of evolving epistemology as increasingly wedding issues of meaningful learning with issues of knowledge production. Furthermore, we see a need for more studies on the nature of affect and values in selecting research questions and guiding inquiry.

Coburn's (1991) monograph on world views illustrates the kind of consideration we think will receive increasing attention in the future.

Current Status of Assimilation Theory

We began intensive applications of Ausubel's assimilation ideas in 1964, both in the design of instructional programs, such as audio-tutorial instruction developed at Purdue University (Postlethwait, Novak, and Murray, 1964; 1974), and in other college and elementary science programs. In every study, our research findings supported the validity of the theory, but also suggested some modifications. For example, in our twelve-year longitudinal study of children (Novak & Musonda, 1991), we found that children were building on their conceptual understanding in patterns that varied from individual to individual, and that could be described as a sequence of additions and elaborations to concept frameworks. Our current ideas on assimilation theory are shown in Figure 5.

Another important aspect of our work that bears on assimilation theory was the development of the concept mapping approach. Working with interview transcripts from our twelve-year study of science concept learning, we found ourselves inundated with transcripts of interviews as we followed children from Grade 1 to Grade 12. By the time the children were in Grade 2, we recognized that some other method was needed for comparing the conceptual understanding of children from one point in time to another. It was this necessity for a better way to represent cognitive structure changes that led to our development of the concept mapping tool (Novak and Musonda, 1991). With the application of concept mapping to interview analysis, we soon found that the tool was also acting as a learning tool for graduate students constructing these maps, and research began involving concept mapping in a variety of instructional settings. These studies strongly supported the important role that Ausubel's concepts of subsumption, progressive differentiation, and integrative reconciliation played in the modification of cognitive structures of children and adults. Moreover, concept maps provided for an explicit way to illustrate changes in cognitive structure that could be described with these principles. Concept maps used in this paper serve to illustrate in themselves some of the changes in views on assimilation theory with the addition of propositions and the modification of some propositional structures.

Following the development of Gowin's Vee heuristic in 1977, we began to see increasingly the important interplay between epistemological thinking and cognitive learning. This led us to pursue more aggressively an understanding of epistemological issues and their relationship with psychological learning issues. The product of this work is represented in a recent paper (Novak, in press).

One of the motivations for initiating our longitudinal study of children's development was skepticism regarding the notion that young children could not learn basic science concepts that tend to be highly abstract, such as concepts about the particulate nature of matter. Our early research on this (Hibbard and Novak, 1975) showed that six-year-old children were capable of understanding these concepts at reasonably high levels. Similar findings by McClelland (1970) in the field of electricity were found with second-grade children (7 - 8 year old children). We began to move toward the idea

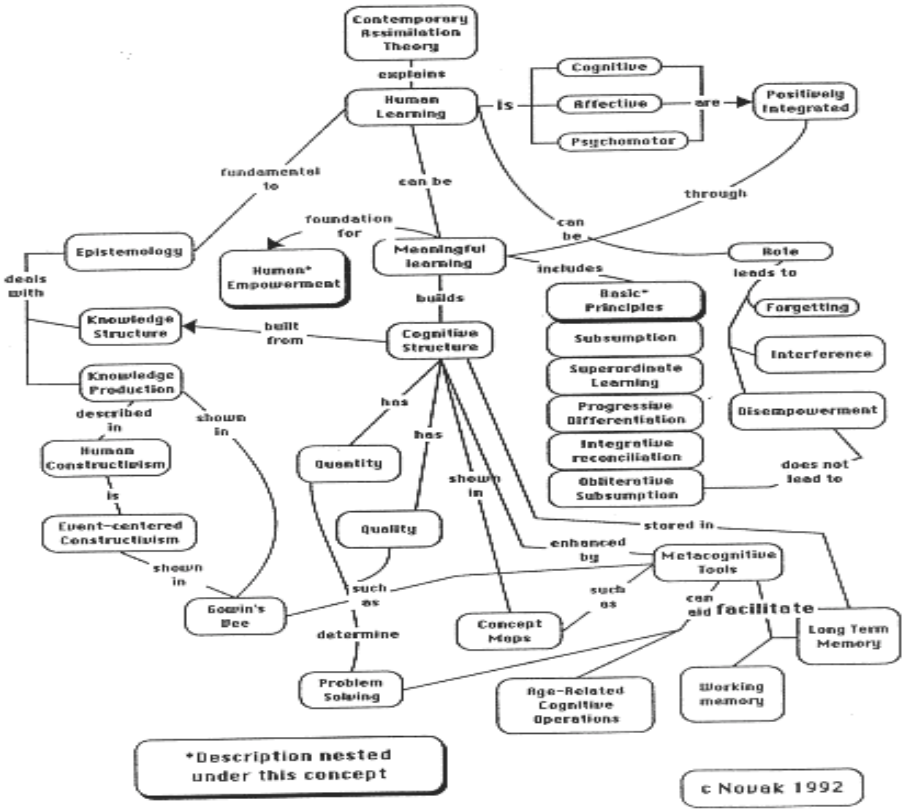

Figure 5. Contemporary assimilation theory as viewed by Novak and associates. Ideas from epistemology, metacognition, and cognitive science have been integrated. Figures 5a and 5b are "nested" under "Basic Principles" and "Human Empowerment, respectively.

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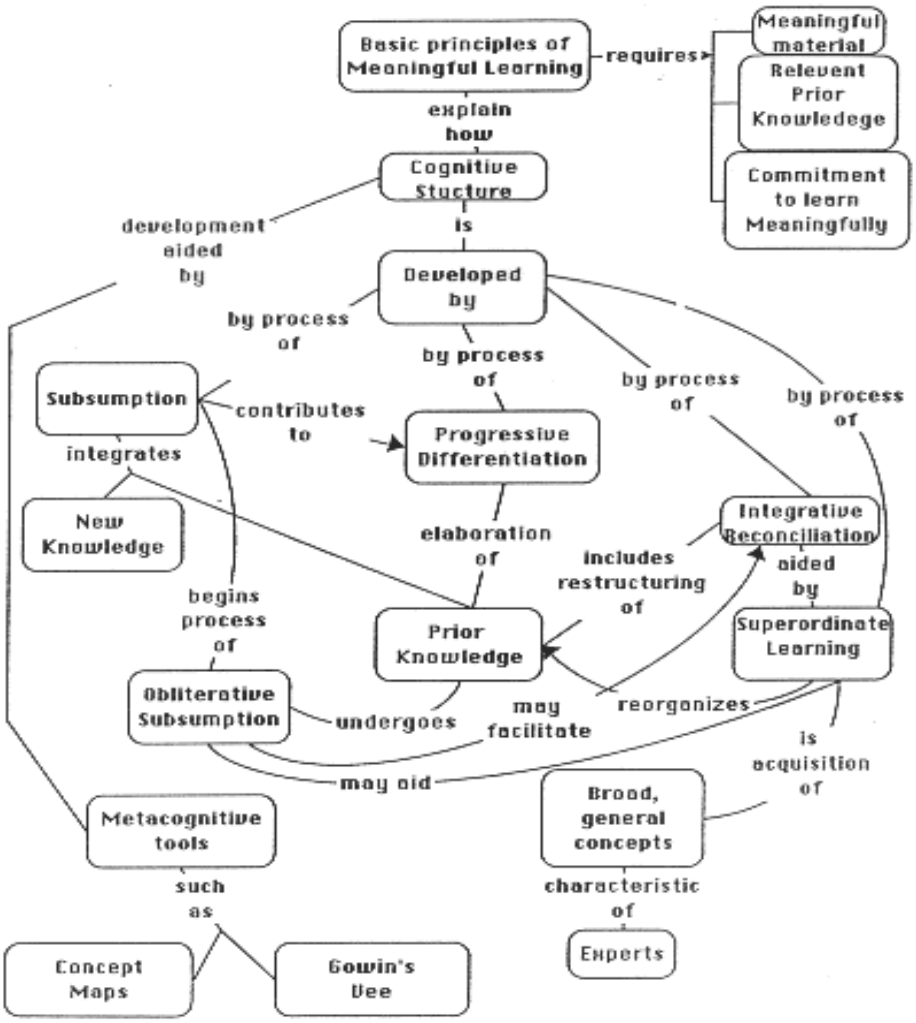

Figure 5a. Basic principles of assimilation theory as represented on a concept map.

Figure 5a. Basic principles of assimilation theory as represented on a concept map.

that limitations in conceptual understanding and problem solving were primarily determined by the adequacy of relevant conceptual frameworks, and not by general cognitive operational stages as proposed by Piaget (Novak, 1977b). Although Piagetian ideas were overwhelmingly dominant in education in the 1960s and 1970s, our own research regarding the learning capabilities of children was widely in disagreement with some of the prevailing dogma in science education.[1] Of course, this situation has changed, and most researchers dealing with cognitive development in children now subscribe ideas closer to those developed in our research program. For example, Flavell, who became well known in 1963

[1] While it is obviously true that developmental changes occur in the brain from birth to senescence, from about age four onward, we see the quantity and quality of relevant knowledge structures and the quality of learning strategies employed as the key limitations. Ausubel stresses instead the declining need for concrete-empirical experiences up to the adolescent years.

for his excellent description of Piagetian developmental psychology, describes the status of cognitive operational stages very differently in his book published in 1985 (see page 114.). Other researchers such as Carey (1985) and Donaldson (1978) take a position very close to what emerged in our own work.

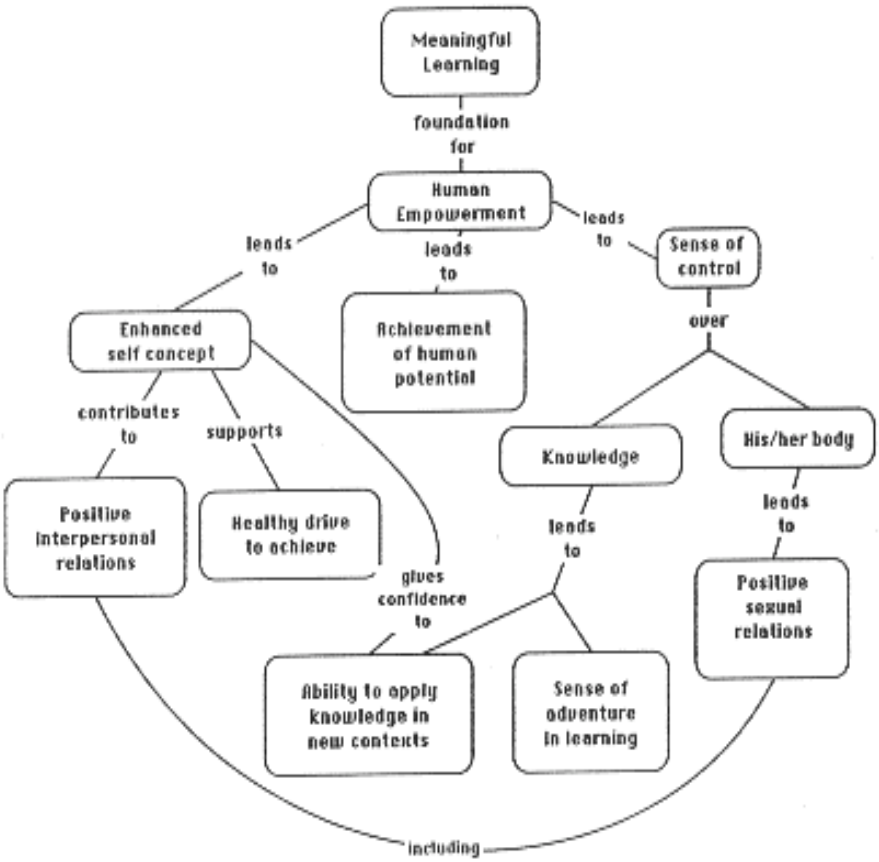

Figure 5b. Concepts/principles leading to human empowerment as seen from current perspectives on assimilation theory.

Figure 5b. Concepts/principles leading to human empowerment as seen from current perspectives on assimilation theory.

With regard to relevant cognitive structure, the question is frequently asked about what happens when learners have no relevant concepts or propositions. In our experience, this is unlikely to be the case for any normal children beyond age three. However, existing relevant concepts may be so general, or so limited in relevance that rote learning could be more efficient in early stages. Furthermore, when an individual possesses misconceptions relevant to the new learning, serious problems arise due to the tendency for the misconceptions to distort the meaning of the new learning. Given that most learners possess misconceptions in any domain of knowledge, it can be seen why rote learning may be preferred by some students, and fostered by some teachers, since students can avoid the difficulties associated with misconceptions if they are in a rote learning mode. However, rote learning contributes

little or nothing to modification of cognitive structure, and the displacement of misconceptions.

Another consideration that has been important in our work and that adds to assimilation theory is the recognition that human memory systems are not a single system but rather at least three systems: (1) perceptual or sensory memory; (2) short-term or working memory; and (3) long-term memory. It is also recognized that the processing of information between sensory input and long-term memory occurs in the working memory. However, as Miller pointed out in 1956,[1] the working memory is severely limited in terms of the number of "chunks" that any individual can process at a given time. It is this limitation in processing capacity that confers a fundamental limitation on human meaning making. Since meaning making occurs in the working memory and since this is a very small conceptual "workbench," there are severe limitations that must be recognized in instructional design as well as the organization of knowledge. One of the reasons we believe that heuristics such as concept maps and Vee diagrams have power in facilitating meaning making is that they serve as a kind of "conceptual jig" to hold in place chunks of related knowledge that must be processed sequentially due to the limitations of working memory. The concept maps and Vee heuristic permit an individual to "hold in place" conceptual elements that are needed for new meaning making, especially in the case of major conceptual integrative reconciliations or in superordinate learning. Moreover, these heuristics function as advance organizers helping to show comprehensive, general, more inclusive concept/propositional relationships, while allowing for clear assimilation of subordinate ideas into the framework. Thus we see the learning heuristics as not only supportive of the assimilation theory but also contributing significantly to the application of assimilation theory principles to instruction and to facilitation of learning.

We now see metacognitive instruction utilizing the tools of concept mapping and Vee diagramming as indispensable for achieving high levels of meaningful learning for the majority of students (Novak, 1990; Moreira and Masini, 1982). When these tools are utilized in instruction, they can then be utilized for evaluation, transcending many of the problems educators face in "authentic" evaluation (e.g., Nickerson, 1989). While concept mapping is now taking root in many instructional programs, including many science textbooks, the application of the Vee heuristic is proceeding more slowly. Nevertheless, we see epistemological issues as inextricably tied to the facilitation of meaningful learning, and we urge researchers to explore further studies that include learning heuristics such as the Vee to facilitate meaning making. At the present time, I am not aware of any other heuristics explicitly designed to express constructivist epistemological ideas complementary with constructivist psychological ideas for meaning making.

In summary, we see assimilation theory alive and well in our own work as well as in the work of others, albeit considerably modified from the form in which it was put forward in 1962. Wittrock and his colleagues, working originally with Ausubel's assimilation theory, have moved toward development of what is called generative learning theory (Wittrock, 1974). As with our own work, Wittrock (1990) and his associates recognized the importance of metacognitive strategies for facilitation of meaning making. Mezirow's (1991) transformational theory of adult learning also emphasizes the importance of meaning making. His work is rooted in similar psychological and philosophical traditions and is

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[1] Miller's work was based largely on learning tasks that were essentially rote in character. However, even with meaningful learning tasks, working memory capacity is highly limited, and sequential, iterative integration of new knowledge with prior knowledge is facilitated by the use of advance organizers and/or concept maps or other metacognitive tools.

compatible with the use of learning tools such as concept mapping and Vee diagramming, although the latter are not suggested. Kelly's (1955) personal construct theory similarly recognizes the idiosyncratic nature of meaning making. These and other theories of human learning all build on similar ideas regarding the assimilative nature of cognitive learning and the strong interplay of thinking, feeling, and acting in human experience.

We have witnessed in the psychology of learning a clear example of what Kuhn (1962) described as a paradigm shift, moving away from behavioral psychology and to various forms of cognitive psychology. Along with this shift in ideas guiding our interpretation of learning, there has also been an epistemological shift away from positivism and toward constructivism, or perhaps even radical constructivism. While the latter seems to be less true for studies done in psychology departments and in the field of artificial intelligence, fields such as science and mathematics education are clearly moving toward radical constructivist ideas. We see a bright future for improving achievement of all learners through the design of better instructional materials and better facilitation of learning using not only assimilation theory and new epistemological ideas, but also learning heuristics that can help students learn how to learn (Novak & Gowin, 1984).

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References

Ausubel, D. P. (1962). A subsumption theory of meaningful learning and retention. *Journal of General Psychology, 66* : 312-224.

Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York: Grune and Stratton.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston.

Ausubel, D. P. (1978). In defense of advance organizers: A reply to the critics. *Review of Educational Research, 48* (2):251-257.

Ausubel, D. P., Novak, J. D., & Hanesian, H. (1978). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston. Reprinted 1986, New York: Warbel & Peck.

Bacon, F. Sir. (1952). *Advancement of learning, novum organum, and new Atlantis*. Chicago, IL: Encyclopedia Britannica.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18* (1):32-42.

Bybee, R. W., Ellis, J. D., & Matthews, M. R. (Eds.). (1992). Teaching about the history and nature of science and technology. *Journal of Research in Science Teaching, 29* (4):325-434.

Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.

Coburn, W. W. (1991). *World view theory and science education research*. NARST Monograph Number Three. Manhattan, KS: National Association for Research in Science Teaching.

Conant, J. B. (1947). *On understanding science*. New Haven, CT: Yale University Press.

Cullen, J. F., Jr. (1983). *Concept learning and problem solving: The use of the entropy concept in college teaching*. Unpublished PhD thesis, Department of Education, Cornell University, Ithaca, NY.

Donaldson, M. (1973). *Children's minds*. New York: Norton.

Edmondson, K., & Novak, J. D. (In press). The interplay of epistemological views, learning strategies, and attitudes of college students. *Journal of Research in Science Teaching*.

Flavell, J. H. (1963). *The developmental psychology of Jean Piaget*. Princeton, NJ: Van Nostrand.

Flavell, J. H. (1985). *Cognitive development* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Gowin, D. B. 1981. *Educating*. Ithaca, NY: Cornell University press.

Hibbard, K. M., &Novak, J. D. (1975). Audio-tutorial elementary school science instruction as a method for studying of children's concept learning: Particulate nature of matter. *Science Education, 59* (4):559-570.

Keller, E. F. (1985). *Reflections on gender and science*. New Haven, CT: Yale University Press.

Kelly, G. A. (1955). *The psychology of personal constructs*. New York: Norton.

Kerr, P. (1988). *A conceptualization of learning, teaching and research experiences of women scientists and its implications for science education*. Unpublished doctoral dissertation, Cornell University, Ithaca, NY.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.

Linn, M. C., Songer, N. B., & Lewis, E. L. (1991). Overview: Students' models and epistemologies of science. *Journal of Research in Science Teaching, 28* (9):729-732.

Macnamara, J. (1982). *Names for things: A study of human learning*. Cambridge, MA: MIT Press.

McClelland, J. A. G. (1970). *An approach to the development and assessment of instruction in science at the second grade level: The concept of energy*. Unpublished doctoral dissertation, Cornell University, Ithaca, NY.

Mezirow, J. (1991). *Transformative dimensions of adult learning*. San Francisco, CA: Jossey-Bass.
Miller, R. W. (1987). *Fact and method: Explanation, conformation and reality in the natural and the social sciences*. Princeton, NJ: Princeton University Press.
Moreira, M. A., & Masini, E. F. S. (1982). *Aprendizagen significativa: A teoria de David Ausubel*. Sao Paulo, Brazil: Editora Mores.
Nickerson, R. S. (1989). Special Issue on Educational Assessment (Editor). *Educational Researcher, 18* (9):3-32.
Novak, J. D. (1957). *A comparison of two methods of teaching a college general botany course*. Unpublished doctoral dissertation, University of Minnesota.
Novak, J. D. (1977a). *A theory of education*. Ithaca, NY: Cornell University Press.
Novak, J. D. (1977b). An alternative to Piagetian psychology for science and mathematics education. *Science Education, 61* (4):453-477.
Novak, J. D. (1990). Concept mapping: A useful tool for science education. *Journal of Research in Science Teaching, 27* (10):937-949.
Novak, J. D. (In press). Human constructivism: A unification of psychological and epistemological phenomena in meaning making. *International Journal of Personal Construct Psychology*.
Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. New York: Cambridge University Press. (Also available in Spanish, Italian, Chinese, Thai, Japanese, and forthcoming Arabic translations.)
Novak, J. D., & Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. *American Educational Research Journal, 28* (1):117-153.
Oliver, D. W. (1989). *Education, modernity, and fractured meaning*. Albany: State University of New York Press.
Pearson, K. (1900). *The grammar of science* (2nd ed.). London, UK: Adam and Charles Black.
Perkins, D. N., & Solomon, G. (1989). Are cognitive skills context bound? *Educational Researcher, 18* (1):16-25.
Piaget, J. (1954). *The construction of reality in the child*. New York: Basis Books.
Popper, K. R. (1982). *Unended quest: An intellectual autobiography*. LaSalle, IL: Open Court Publishing Co.
Postlethwait, S. N., Novak, J. D., & Murray, H. T., Jr. 1972. *The audio-tutorial approach to learning* (3rd ed.). Minneapolis, MN: Burgess.
Ripple, R. E., & Rockcastle, V. N. (Eds.). (1964). *Piaget rediscovered*. Ithaca, NY: Cornell University, Department of Education.
Rorty, R. (1979). *Philosophy and the mirror of nature*. Princeton, NJ: Princeton University Press.
Saxe, G. (1988). Candy selling and math learning. *Educational Researcher, 17* (6):14-21.
Schrag, F. (1992). In defense of positivist research paradigms. *Educational Researcher, 21* (5):5-8.
Vanderbilt Group in Cognition and Technology. (1990). Anchored instruction and its relationship to situated cognition. *Educational Researcher, 19* (6):2-10.
von Glasersfeld, E. (1984). An introduction to radical constructivism. In P. Watzlawick (Ed.), *The invented reality* (pp. 17-41). New York: Norton.
Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: MIT Press (edited and translated by Eugenia Hanfmann and Gertrude Vakar).
Watson, W. (1985). *The architectonics of meaning: Foundations of the new pluralism*. Albany: State University of New York Press.
Wilshire, B. (1990). *The moral collapse of the university: Professionalism, purity, and alienation*. Albany: State University of New York Press.
Wittrock, M. C. (1974). Learning as a generative process. *Educational Psychologist, 11* :87-95.

Wittrock, M. C. (1990). Generative processes of comprehension. *Educational Psychologist, 24*
(4):345-376.