**Psychological Foundations of Human Learning**

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| http://cmap.ihmc.us/docs/AusubelAssimilationTheorySmall.pngFigure 1. Key concepts and principles that explain human learning according to Ausubel and Novak.(click on image for a larger version) |

**Early Studies on Learning**

Although writings on learning go back to scholars writing in the 5th century BC, most of these writings were based on personal introspections, rather than on systematic observations. One of the first persons to collect data on animal learning was Ivan Pavlov in the 19th century. Pavlov observed that dogs would respond to various stimuli in predictable ways. He also discovered what he called the *conditional response* illustrated when a dog hearing a bell each time food was presented would later salivate when only the bell was rung. Also working in the early 19th century, Hermann Ebbinghaus was one of the first persons to collect data on human learning. Using himself as a subject, he observed that lists of nonsense syllables could be recalled for varying lengths of time, depending on the lists and how they were memorized. He invented the use of nonsense syllables (triplets of letters that had no common meanings) to avoid the problems associated with memorizing information that was in some way related to what he already knew, thus confounding the memory process.

From the mid 1800’s through most of the 20th century, the study of learning dealt either with research on animal learning, or research on human learning that minimized the effect of prior knowledge on new learning. The assumption was that if *laws of learning* could be discovered with the simpler, more controlled experiments with animals, nonsense syllables, paired word associations, etc., these laws could then be extrapolated to more complex learning tasks in schools and workplaces. As Mandler (1967) observed, *“[This] promissory note turned out to be a rubber check. At least, by 1966, nobody has been able to cash in on it”* (page 6). The extraordinary thing is that this kind of research continued to dominate educational psychology until well into the 1980’s. Part of the reason this *behavioral psychology* persisted as long as it did is that it was buttressed by an epistemology or philosophy of knowledge known as *positivism* or *logical positivism* that held that careful observations would lead to proof or falsification of principles or theories and once proven, the “laws” would endure forever. We see in this history how faulty epistemology sustained faulty psychology, and some of this continues today. We look at epistemology, or the nature of knowledge and knowledge creation, in a complementary document (\*\*\* missing link \*\*\*\*).

**The Rise of Cognitive Psychology**

Although there were some early pioneers in psychology who never subscribed to the dogma of the behaviorists, the politics of psychology and the control of granting agencies made it difficult for researchers with other points of view to get access to grants for their research and publication of their findings, especially in the USA. Piaget in Switzerland, Vygotsky in Russia, and Bartlett in the USA were among these early pioneers. Piaget and Vygotsky published mostly abroad and Bartlett did reach a small, sympathetic audience in the USA. The work of these persons beginning in the early 1900’s laid some of the groundwork for studies on human learning dealing with complex *cognitive processes* that occurred inside the brain, and therefore were not easily observed. The strict behavioral psychologist saw such work as *mentalist* and lacking sound scientific methodology. However, what they may have lacked in experimental rigor they more than compensated for by the high the degree of relevance their work could bear on learning in school and work settings. Gradually the pendulum began to swing in favor of the cognitive psychologist, and they certainly dominate the field today.

Among the early leaders of the “cognitive revolution” was David Ausubel. His *Psychology of Meaningful Verbal Learning*, published in 1963 (Ausubel, 1963), and his *Educational Psychology: A Cognitive View*, published in 1968 (Ausubel, 1968), became the psychological foundations for the research Novak and his students were doing at Cornell University. In the epigraph to his 1968 book, Ausubel states:

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|  | *If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.* |  |

This principle is now recognized as fundamental to understanding how people learn, namely that they *construct new knowledge* by integrating new concepts and propositions with relevant concepts and propositions they already know. What Ausubel described in his early books was the processes by which this integration of new knowledge with existing knowledge occurs. Ausubel’s Assimilation Theory of learning explains how humans build their construct their knowledge frameworks or cognitive structures. The challenge for the educator is to identify with some precision the concepts and propositions the learner already knows that are relevant to the subject matter to be learned, and then design instruction to facilitate the integrations of new concepts and propositions into this learner’s existing knowledge framework or cognitive structure. We shall see how this should proceed, and how concept maps can facilitate the process. The key ideas underlying Ausubel's theory are shown in Figure 1.

We pause to note that the brain is not an “empty vessel” to be filled with information, although much school and university teaching proceeds as if this were the case. Instead, the brain is an extremely complex organ that recognizes and stores signals from our sensory systems including sights, sounds, smells, feelings and proprioceptor signals from our muscles. Most of this information is sent from our sensory systems to an area called*working memory*, and through interactions with knowledge stored in our long-term memory, new meanings are constructed and become part of our *long-term memory* store, or our cognitive structure. One of the reasons we believe concept maps facilitate meaningful learning is that they aid the process of organizing and consolidating information, serving as a kind of “scaffold” for building linkages between new information being processed and information stored in long term memory. We shall discuss this further in later sections. Figure 2 illustrates schematically the key memory systems of the brain.

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| http://cmap.ihmc.us/docs/MemorySystemsSmall.pngFigure 2. Schematic showing the key memory systems in the brain.(click on the image to view a larger version) |

For some decades now it has been known that the hippocampus region of the brain is important in information processing and is considered the site or working memory. In the course of meaningful learning, there is a constant interplay between information stored in long-term memory and new information being received in sensory memory. Recent research has shown that that the hippocampus also plays a role in creativity and imagination. Individuals with damaged to their hippocampus have difficulty in recalling past events and imagining new events (Miller, 2007).

**Ausubel’s Six Principles of Learning**

In his early writings, Ausubel described six key principles of learning, each of which interrelates with the other. These are listed in Figure 1 above. This makes his theory simple in terms of the number of key principles involved, but difficult to master in that one needs some understanding of all of these principles to have a better understanding of any one. Moreover, all of the principles relate to the process of meaningful learning, as contrasted with learning by rote. The distinction between rote learning and meaningful learning is, on the surface, an easy one to understand, but to understand meaningful learning fully is almost a life-long pursuit. In meaningful learning, new knowledge is not added to cognitive structure in a manner similar to filling a vessel with a liquid, sand, or marbles. The new knowledge is *assimilated* into and *integrated* with relevant existing prior knowledge. This is an active process, and only the learner can choose to learn meaningfully. This presents a challenge for the teacher or trainer, both in the instruction and in the assessment of learning. It is this assimilation process that gives the name to Ausubel’s (1968; 2000) Assimilation Theory of Learning.

In the 5th century BC, Zeno of Elea proposed a number of paradoxes. He correctly observed that what new things we can learn depends on what we already know. How then can an infant learn anything? The answer is that the infant is endowed by evolution to observe regularities or patterns in events or objects in her/his environment and later to code the regularities using words. This is a *discovery* learning process where the criterial attributes of the patterns or regularities are not given to the child but rather are discovered by the child through experiences with events and objects observed. It is a remarkable learning feat, and yet every normal child succeeds to begin to learn the concepts and concept labels by age two, and in some cases to use two or three languages to code the same concepts. This is why Zeno’s paradox does not apply to human learning. If every normal child succeeds at this difficult task before schooling, why do so many children have trouble mastering much simpler concepts when they are in school? The short answer is that too often school procedures encourage *learning by rote*, where no substantial meanings for concepts are acquired. Instead, schools need to use procedures that require the student to *learn meaningfully*, that is to integrate the meaning of new concepts and propositions into his/her existing framework of concepts and propositions.

***Subsumption***

This principle holds that new concepts or propositions assimilated into cognitive structure are usually subsumed into more general, more inclusive relevant concepts and propositions. For example, terrier, collie, and dachshund may be subsumed into the concept of "dog”, now broadening and refining this concept further. Subsumption is perhaps the easiest form of meaningful learning, since relatively little cognitive restructuring is required, and usually the relationship between the new idea and subsuming concept is easily recognized. Subsumption also leads to some loss of distinction for the new concept or proposition subsumed, and in time some subsumed concepts may no longer be recalled. However, the contribution these concepts made to development of the subsuming concept largely remains and learning new relevant concepts will be at least to some extent facilitated. A person may forget that maltese is one of the 150 breeds of dogs, but learning about other breeds enhances one's concept of dog.

***Obliterative Subsumption***

As noted above, the process of subsumption of new ideas into cognitive structure results in some loss of identity of the subsumed idea, and this begins the process of *obliterative subsumption*. Over time, specific concepts and propositions subsumed into cognitive structure may no longer be recallable. However, this process is usually much slower than loss of information learned by rote. Moreover, information forgotten after rote learning typically *interferes* with the learning of new similar information, whereas information loss through obliterative subsumption does not have this deleterious effect. In fact, the contribution that the obliteratively subsumed information made to enhancing the subsuming concept or proposition remains and confers facilitation of new, related learning. The important message here is that although loss of some knowledge over time is inevitable either following leaning by rote or learning meaningfully, the loss is slower after meaningful learning and the deleterious effects on new learning that can result from forgetting after rote learning does not occur after obliterative subsumption occurs. Another factor that operates to reduce obliterative subsumption is better organization of ideas in cognitive structure. When knowledge is better organized, and perhaps with more important cross-links, loss of information is retarded, and the power to use the information in new contexts is enhanced.

***Progressive Differentiation***

As new meaningful learning occurs, concepts and propositions in cognitive structure become more precise, more widely applicable in facilitating new learning or problems solving, and better discriminated from similar but distinct ideas. Thus studies comparing the knowledge and problem solving of experts, as contrasted with novices in a field, show that the experts have much better organization of their knowledge and tend to use more general, more inclusive concepts at the outset. Novices often fixate on details and use more specific, less general concepts, frequently leading to faulty “solutions” (Bransford, Brown, and Cocking, 1999). The use of concept maps can facilitate better knowledge organization and improved expertise.

To illustrate progressive differentiation, we show below two concept maps that were drawn from interviews with a child at the end of grade two and the end of grade twelve. This child was one member of a twelve-year study of children’s understanding of basic science concepts. This was also the research study that led to the invention of the concept mapping tool in 1972 (Novak 2005). Figure 3 shows that this child had some understanding of the nature of matter, and also knew that ice can melt when heated. Although Paul had the concept that some things are made of tiny chunks, he did not have the concepts of atoms and molecules, or the names for these concepts. Nevertheless, he had some concepts that could serve to subsume new, relevant learning and he obviously has been trying to understand things he had been told and to organize his knowledge. In short, Paul was a meaningful learner in his early years, and subsequent interviews with Paul indicated he continued to integrate knew ideas he learned into his cognitive structure.

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| http://cmap.ihmc.us/docs/CmapPaulGr2.pngFigure 3. A concept map drawn from an interview with Paul at the end of grade two. |

Figure 4 shows a concept map drawn from an interview with Paul at the end of grade twelve. We see that he has added many concepts and propositions to his knowledge of the structure of matter and the role that heat energy plays. He has not only subsumed much new knowledge under a few more general concepts, but he has very precisely integrated his knowledge and is highly specific and precise in the meanings shown. Again, it is evident that Paul has been a meaningful learning and has built a remarkably good knowledge structure dealing with the nature of matter. His cognitive gains show a high degree of progressive differentiation of basic concepts, especially when compared to his knowledge in grade two.

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| http://cmap.ihmc.us/docs/CmapPaulGr12Small.pngFigure 4. A concept map drawn from an interview with Paul at the end of grade twelve, showing extensive development of his cognitive structure dealing with the nature of matter.(click on the image to view a larger version) |

***Integrative Reconciliation***

This is the process wherebythe learner clarifies ideas that may have been unclear or even contradictory, with the result that concept and propositional framework that is developed is more precise and explicit. For example, in grade two, Paul was not sure what a smell was made of and incorrectly thought it may be made of oxygen or something. By grade twelve, he knows that oxygen is part of air and the smell from mothballs comes from molecules of mothballs that sublime and rise in the air. Other parts of his knowledge structure show evidence of integrative reconciliations to form a highly organized, well integrated, and relatively highly precise knowledge structure.

Integrative reconciliation is a very important result of relatively high levels of meaningful learning. Research has shown that faulty conceptions are rarely if ever corrected when learning is predominately by rote (Novak, 2002). Interviews with students learning science by rote often show that they hold conflicting ideas and are unaware of the contradictions they may express in interviews or in seeking problem solutions. Baron and Goldman (1994) found that students repeat correct answers about insulation provided by different kinds of cups, but then evidence the same misconceptions in a second related unit. The Private Universe Project (Schneps, 1989) has video tapes showing a number of instances where students learn the “correct” answer to a given problem, then later manifest the persisting misconception when interviewed about a related problem. Needless to say, this leads to faulty problem solving, failure to transfer knowledge to new settings, and no facilitation of future related learning. Creative insights are virtually impossible, since the faulty knowledge structures simply cannot function to see new creative solutions to problems.

***Superordinate Learning***

While subsumption is the more common learning process by which new concepts are assimilated into cognitive structure, occasionally a new concept or proposition is acquired that is more general and more inclusive than the previously learned concepts or propositions. For Paul, one clear case of superordinate learning was the acquisition of the concept of molecule. We see in the concept map for Paul in grade twelve that this concept not only holds a superordinate position, replacing his earlier concept of “tiny chunks”, but he has also integrated ideas about energy with this concept, especially concepts dealing with the nature and role of heat energy. He sees that the states of matter are a function of the amount of heat energy stored in molecules. The concept of energy is also becoming more like a superordinate concept and this might have been more evident if the interviews probed more deeply his understanding of energy. As noted earlier, experts differ from novices in the number and quality of superordinate concepts they have developed and their facility in using these concepts in new applications or in new knowledge acquisition. A characteristic of learners who learn mostly by rote is that they have fewer superordinate concepts and these are less fully differentiated. Moreover, rote learners often express faculty or incorrect propositions, or even contradictory propositions when interviewed.

***Advance Organizers***

This principle is perhaps the most recognized of Ausubel’s principles, even though it is seldom well applied. Briefly, an advance organizer is a more general, more abstract segment of instruction that is presented prior to more specific, more detailed instruction to serve as a kind of kind of “cognitive bridge” between what the learner already knows and the new knowledge to be learned. For example, one may suggests that automobiles, like people have “birthdays” and then go on to explain that the date a car left the assembly line is stamped on the name plate of the automobile, along with other information about the automobile. A car’s age is measured from this date, similar to people’s age. All learners are familiar with the concept of “birthday” and can meaningfully link this with the idea of the date of a car’s manufacture.

Concept maps can serve as advance organizers, especially when they have at the top more general, more inclusive concepts that are likely to be familiar to the learners, followed by increasingly less general, more specific concepts and propositions lower in the concept map.

***The Rote – Meaningful Continuum***

It should be obvious from the above discussion that individuals will vary greatly in the quantity and quality of their knowledge structure in any given domain. They also vary in the motivation to seek to integrate new concepts and propositions with existing knowledge and in their metacognitive skills for doing this. Metacognition, simply stated, is knowledge about gaining knowledge and we shall explore this topic more extensively below. The consequence of individual differences in relevant knowledge, motivation and metacognition means that for any given learning episode, individuals may vary from almost pure rote learning to very high levels of meaningful learning. This is illustrated in Figure 5. While the primary determinant of the level of meaningful learning reside with the learner, teachers and coaches can influence this through the kind of instruction provided and the kind of assessments utilized. For example, if learners are required to use concept maps as part of their learning, and perhaps asked to do concept maps in the assessment of learning, these practices strongly encourage higher levels of meaningful learning.

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| http://cmap.ihmc.us/docs/RoteMeaningful.gifFigure 5. The Rote - Meaningful continuum for learning. |

In our view, creativity is achieved when an individual moves to very high levels of meaningful learning in a given domain. Although creative people often also know a good deal of relevant information, the primary characteristic of creative people is their ability to see new integrative reconciliations in their knowledge, and their emotional penchant to search for such new meanings. All of the above principles of meaningful learning are skillfully executed and integrated by the creative person.

**Additional Ideas from Psychology Pertinent to Concept Mapping**

***Developmental Stages***

In the 1920’s, Jean Piaget suggested (1926) that children progressed in cognitive development through a series of stages. From birth to about age two, the child is in the *sensory-motor* stage and responds largely by touching things and reacting to things in her/his  surroundings. From age two to seven, the child is in the *preoperational* stage and can form mental symbols to stand for things or events even in the absence of these. From age seven to eleven, the child is in the *concrete operational* stage where she/he can reason about objects or events but still requires concrete objects and events to reason and draw inferences about them. Finally, by age eleven or older, the child has enter *formal operational* thinking where she/he can reason about hypothetical objects or events and draw inferences in the absence of direct experience with these objects or events. According to Piaget, children cannot reason about atoms or energy changes and their hypothesized actions until they reach the stage of formal operational reasoning.

Although the dominance of behavioral psychology in North America prevented early widespread understanding of Piaget’s work, by the 1960’s, his ideas on children’s cognitive development were widely accepted in education circles in the USA as well as other countries. In some circles his ideas became dogma and it was very difficult to obtain funding for research and projects that considered the possibility that children possessed far greater learning potentials than Piaget’s stages would suggest. This was especially true with the National Science Foundation and other state and federal agencies in the USA. Gradually researchers began to show that children and even infants possessed far greater learning capabilities than was commonly believed and today most cognitive psychologist such as Donaldson (1973), Chi (1983), Carey (1985), Gelman (1999), and others largely dismiss Piaget’s stages of cognitive development as reasonable boundary conditions. In Novak’s 12-year longitudinal study of children’s development of understanding of science concepts such as the particulate nature of matter and the nature of energy and energy transformations not only developed the technique of concept mapping to track children’s understanding but also showed remarkable development of early understanding in 6-8 year old children (Novak & Musonda, 1991). What the emerging consensus is regarding children’s cognitive capabilities is that these are highly dependent on the number and quality concepts and propositions developed in a given domain of knowledge, and the quality of the organization of these concepts and propositions in their cognitive structure. While this view opens up numerous possibilities for the education of younger children, even pre-school children, it also presents an enormous challenge in how to design instruction to optimize meaningful learning necessary for the acquisition new knowledge and development of superior organization of this knowledge. Once again we shall see where the utilization of concept mapping, when properly done, can substantially facilitate individual’s construction of powerful knowledge structures.

***Zone of Proximal Development (ZPD)***

The Russian psychologist Lev Vygotsky was born in 1896, the same year as Piaget, but he died at age 38, whereas Piaget continued to be active and publishing until age 84. Vygotsky saw children’s cognitive development in ways different from Piaget, in that he saw cognitive development as very dependent on the child’s socialization and quality of experiences. Unfortunately, because he died rather young and because he published in Russian, his ideas were not well known and accepted outside of Russia until comparatively recently when the pendulum of cognitive psychology has swung in his direction. One of his key ideas was that a child’s cognitive development proceeds from the current level of understanding to a higher level either with their own efforts or when supported or coached. He called this range of development the *zone of proximal development* or ZPD, where the lower level can be development the learner can accomplish without coaching, whereas the upper level of the ZPD requires social support and coaching to achieve, from a teacher or from a peer student, for example. Another way to look at the ZPD is that this zone defines the cognitive understandings that are still developing for a given domain of knowledge and in time these understandings will mature into more advanced levels. This development can by assisted by various aids, such as Ausubel’s advance organizers, concept maps and carefully planned instructional sequences that build on the initial understandings. This is illustrated in Figure 6.

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| http://cmap.ihmc.us/docs/ZPD.pngFigure 6. Schematic showing Vygotsky’s zone of proximal development. |

Vygotsky’s research showed that learners could be aided in cognitive development by interaction with peers and by coaching by adults. He also stressed the importance of language in cognitive development, an idea that was a precursor to the idea of collaborative learning that has been shown to be helpful. Collaborative concept mapping has been show to greatly facilitate learning.

Another idea that grew out of Vygotsky’s work is that various kinds of props and assists can provide a “scaffold” to facilitate learning (Berk & Winsler, 1995). Perhaps the simplest and oldest form of scaffolding is the use of sample problems that illustrate how to find solutions to a given class of problems. This kind of assistance is even more helpful when the instructor explains the concept(s) involved in the problem solution and how different kinds of problems are related to each other. Graphs, tables, charts, diagrams, videos, and other learning aids can also provide a type of scaffolding, provided that they are presented in a way that helps the learner see relationships between concepts and principles. Again, they key is to facilitate the learner in building a better organized cognitive structure.

***The Problem of Misconceptions***

In the course of everyday experiences, we observe certain patterns or regularities in events or objects and we construct our concepts. However, sometimes we fail to observe some important feature or aspect of the events or objects and thus construct a faulty or incomplete concept. These faulty concepts have been called misconceptions, naive notions, alternative conceptions, and other names. The problem of overcoming misconceptions was noted earlier. The critical feature is that over the years of learning, these faulty concepts become deeply rooted in cognitive structure and it is very difficult for the learner to recognize the faulty structure and reorganize, modify, add or delete concepts and overcome the faulty structure. Ordinary instruction that teaches the “correct concept” notoriously fails to remediate the defects and the misconception persists. One reason for this is that so much teaching encourages rote learning, and misconceptions are essentially unaffected, since the learner is not engaging and restructuring the existing concepts and propositions in the her/his cognitive structure (Novak, 2002). Assessments that require only rote recall of information taught will often fail to detect the existing misconception.

An example of a common misconception is that if three or four heads occur with a tossed coin, the next toss is more likely to be a tail, “since "we are due for a tail”. Assuming the coin is not faulty, the likelihood of a head or tail on the next toss is always 50%. Another common misconception is that summer and winter seasons are caused by the Planet Earth moving closer or further from the sun. In a well-known study done at Harvard University (Schneps, 1989) with 23 graduates, alumni, and faculty, 21 of the 23 thought that summer was when Earth was closer to the sun, and winter occurs when we are further away. This misconception may have its origins in the common experience that we feel more heat from a campfire or light bulb when we are near to it, and this is indeed the case. However, in the case of the Earth, we are actually about 3 million miles closer to the sun when it is winter in the Northern hemisphere (but summer in the Southern hemisphere). The reason it is colder in winter and warmer in summer is that the Earth moves around the Sun with its axis of rotation tilted about 23 degrees with the North pole pointing away from the sun during the Northern hemisphere's winter and toward the sun in summer making the days are longer and the sun shines more directly on the Earth. Of course, at the equator, there is little effect from this tilt in the axis, so temperatures vary much less. A series of four international seminars on misconceptions were held at Cornell University and the proceedings from these seminars are available at: [www.mlrg.org](http://www.mlrg.org/).

The problem with misconceptions is that everyone holds some misconceptions in virtually every domain of knowledge, and we usually do not recognize that we have these misconceptions. Thus we go along learning new things and often it is our misconceptions that subsume the new concepts and propositions, making these misconceptions even more stable and more likely to distort our learning in the future. Over the years, we have found in our research that the best way to help learners recognize and remediate their misconceptions is to engage them in collaborative learning with peers using concept mapping tools. In any case, if we wish to effect high levels of meaningful learning with our students, we must be very careful that we help them recognize and remediate their misconceptions (Ross *et al*, 1991; Novak, 2002). Be cognizant of the fact that this is not an easy task.

***Metacognition***

Briefly, metacognition is thinking about thinking (Flavell, 1979, 1987). Research has shown that learners who are conscious about how they are learning and monitor their learning do better than learners who do not engage in such metacognitive activity. Metacognition is a complex idea and includes *metalearning*; for example, learners who are aware of the differences between rote and meaningful learning and consciously choose to do the latter when they seek to understand what they are learning would be using metalearning knowledge. *Metaknowledge* learning would involve becoming aware of the concept and propositional nature of knowledge and the need for high levels of meaningful learning to enhance creativity and new knowledge creation. Some of our research has shown that learners who have a good grasp on metalearning  ideas and metaknowledge ideas perform better than their less aware peers, especially on tasks that require application of knowledge in new situations (Novak, 1985; Edmondson & Novak, 1992).

Over the years we have found that is not enough to just teach the subject matter of a discipline. If we want our learners to achieve a high level of understanding of the subject matter and ability to apply this subject matter in novel problem solving, we must incorporate metacognitive learning into the instruction. An awareness of the prevalence of misconceptions and an understanding of how to remediate one’s misconceptions is another form of metacognition. As we have learned more about the use of concept maps for teaching and learning, we see that understanding the use this tool is perhaps the most powerful metacognitive learning we can provide to our students (Novak, 1983). A learner who recognizes that her/his inability  to make a good link between two concepts may be due to some misconception about one or both concepts has gained some powerful metacognitive learning.

***The Problem of “Situativity”***

It has been recognized for many decades that students who learn an idea or procedure in one context may fail to use the same idea or principle in another context. In the 1980’s, Lave (1997) reported on studies where students who learned to solve math problems with one set of examples failed to transfer this knowledge where the same type of problem was presented in a different context. She called this context bound learning*situativity*, and the idea has become more popular in the past two decades. Another aspect of situativity is the idea that what we learn and how we learn it is culture-bound. The kind of peer group or learning group we belong to has its own ways of approaching knowledge and knowing that places constraints on how an individual in the group will gain meaning from experiences. Many researchers have shown that this kind of failure to transfer knowledge to new contexts occurs in many fields (see for example Greeno 1998).

From our perspective, the most important factors influencing learning are the concept and propositional frameworks an individual has constructed. To be sure, the learning culture or social milieu the individual has been in will influence the kind of knowledge acquired, the affective connotations associated with this knowledge and the kind of knowledge hierarchies the individual will construct. This is well illustrated by discussions between individuals who hold strong but opposite political positions. They look at the same data, but they draw very different conclusions. It is no easy task to bring individuals from these both parties to some diplomatic solution that parties will agree satisfies their goals and needs. What we have found in our work is that many of the problems that derive from situativity can be resolved or ameliorated when the concept mapping tools are used to work toward a shared understanding and a comprehensive grasp of the principal ideas involved.

***The Problem of Assessment***

From the perspective of Ausubel’s Assimilation Theory, we need to assess what the learner knows at the beginning of an educative experience, and again at the end of the experience. Since the learner’s history of relevant experiences also include the kind of *activities* she/he has engaged in and the kinds of *feelings* she/he has experienced, there must be some effort to assess these also if we seek to optimize the meaningful learning of new materials.

The assessment of what a learner already knows can be done with true-false or multiple-choice questions, and this is perhaps the most common practice. However, much more specificity and can be achieved if concept maps are used as a pre-assessment and post assessment tool. This not only reveals the concepts and propositions the learner holds in cognitive structure; the concept maps also provide some indication of the quality of organization of this knowledge. We propose that the pre-assessment concept map be refined by the student as his or her level of understanding increases while studying the particular subject matter. By using concept mapping software such as CmapTools (Cañas *et al*, 2004), this constant revision of the map is made easier. Furthermore, as the student finds resources that help in that understanding, whether they are Web pages, videos, texts, pictures or other media, these can be linked to the map to document the source of learning. The student's progress is thus reflected in their concept maps, and the teacher can assess the process instead of relying on a single, final, static concept map. By building a portfolio of linked maps, the students can also demonstrate how they are integrating different topics and/or subjects.

Of course, concept maps cannot be used as assessment tools unless the individuals have some developed some skill in the use of this tool. Detailed information on assessment is beyond the scope of this document and there are other good sources of information (e.g. Mintzes, *et. al*, 2000; Pellegrino, *et. al*., 2001).

While it is not easy to assess a learner’s feelings as they apply to a domain of learning, at least some effort should be made to do this. For example, learners can be asked to indicate how confident they feel about different aspects of their knowledge, perhaps by font or color coding concepts and propositions on the concept maps. With respect to assessment of the kind of activities that contributed to their knowledge, concept maps that present procedural knowledge could include comments on the kind of activities that led to understanding of procedures indicated in their concept maps. Any efforts to gain information from learners as to their actions involving learning and their feelings about what they know will be beneficial to the learners, other members of the learner’s team, and to the coach or instructional designer.

**Other Forms of Learning**

***Iconic learning***

Obviously our brain stores more than concepts and propositions. We also store images of scenes we encounter, people we meet, photos, and a host of other images. These are also referred to as *iconic* memories (Sperling, 1960; 1963). While the alphanumeric images Sperling used in his studies were quickly forgotten, other kinds of images are retained much longer. Our brains have a remarkable capacity for acquiring and retaining visual images of people of photos. For example, in one study Shepard (1967) presented 612 pictures of common scenes to subjects, and later asked which of two similar pictures shown was one of the 612 seen earlier? After the presentation the subjects were 97% correct in identifying picture they had seen. Three days later, they were still 92% correct, and three months later they were correct 58% of the time. This and many other studies have shown that humans have a remarkable ability to recall images, although they soon forget many of the details in the images. Considering how often we look at pennies, it is interesting that the subjects asked to draw a penny in a study by Nickerson & Adams (1979) omitted more than half of the features or located them in the wrong place. We believe that integrating various kind of images into a conceptual framework using CmapTools could enhance iconic memory, and we hope research on this will be done.

***Sound Learning***

Human’s ability to recall sounds is also remarkable. Consider the musician who can play hundreds of songs without reading any music. Again we are dealing with memories that are not coded as concepts or propositions. Studies by Penfield & Perot (1963), among others, indicate that regions of our brain that are activated when we hear sounds are the same regions that are active when we recall sounds. While we can locate regions of the brain that are active in learning or recall of information using positron emission tomography (PET) scans, the specific mechanisms by which neurons store this information is not known. A full discussion of memory mechanisms is beyond the scope of this document.

***Spatial or Relational Learning***

Most of us can recall how to get to a place visited often, but we vary widely in our ability to recall a route traveled only once. Similarly, individuals vary widely in their ability to recall the arrangement of rooms in a house they visited, or the position of furniture in a room. Studies by Kosslyn (1987) and others indicate that our brain codes at least two different kinds of spatial relationships. One type deals with determining relationships such as “inside of” or “above”, and another that deals with distances between objects. Novak recalls how his six-year old son recalled the locations of rooms and a hidden staircase in the House of Seven Gables after a single visit, whereas the other members of the family could not. Perhaps this is why his son is now a professional architectural designer. Just how our brains store this kind of information is not known at this time.

***Motor or Kinesthetic Learning***

When it comes to batting a ball or jumping hurdles, we are well aware of wide differences in human motor or kinesthetic learning. This kind of learning involves the muscles of our bodies as well our minds. In many ways, the skills associated with high performance in sports or playing a musical instrument are an excellent illustration of how important it is for us to seek to integrate our thinking, feeling and acting. We have found that several kinds of performance can be enhanced if the concepts that relate to the performance are made explicit in concept maps, and there is a conscience effort to integrate thinking, feeling and acting (Novak & Gowin, 1984).

***Multiple Intelligences***

The obvious differences between individual’s abilities has been explored by Gardner (1983), who has proposed a Theory of Multiple Intelligences. His work has drawn much attention in education and has served to bring awareness to the broad range of differences in human abilities for various kinds of learning and performance. It is good that schools are recognizing that there are important human capabilities other than the recall of specific cognitive information so often the only form of learning represented in multiple-choice tests used commonly in schools and corporations. One reason we encourage the integration of the broad range of activities represented in our New Model is to provide opportunities for these other abilities to be represented and expressed. Nevertheless, we see the organizing opportunities afforded by associating the various activities with an explicit knowledge structure as very beneficial. Time will tell if future research studies will support this claim.

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