Conceiving of Concept Maps To Foster Meaningful Learning: An Interview with Joseph D. Novak

Liberato Cardellini
Dipartimento di Scienze dei Materiali e della Terra, Università Politecnica della Marche, 60131 Ancona, Italy; *libero@univpm.it*

Joseph Novak's career in teaching has spanned over four decades; he is now professor emeritus of Education and Biology at Cornell University, visiting senior scientist at the University of West Florida Institute for Human and Machine Cognition, and president of Joseph D. Novak Knowledge Consultants, Inc. He is the author of 26 books, including *Learning How To Learn (1),* translated into 9 languages; 29 book chapters; and over 100 articles published in professional journals. He has consulted for several corporations, federal agencies, and for more than 400 schools and colleges in the U.S.A. and abroad. In July 1995 Professor Novak resigned from active teaching at Cornell and subsequently has been working with corporations using concept mapping for research and development efforts to create and transfer knowledge and information in corporate environments; he also teaches clients how use concept mapping to capture and archive expert knowledge. Perhaps this interview will capture some of his expert knowledge for *Journal* readers.

Joseph D. Novak (photograph by L. Cardellini).

Teaching People How To Learn Can Change the World

Liberato Cardellini: How and why did you become a teacher?

Joseph D. Novak: As a young child, I somehow developed the belief that the world could be a better place, and I wanted to find a way to help achieve this. I thought I might become an inventor, since I was always tinkering with things. When I began college, I was a mathematics major, and considered the field of secondary education. But in my sophomore year, I recognized that while I had a *conceptual understanding* of sciences, my mathematics was based mostly on *procedural knowledge,* and I did not want to try to go back and relearn all of my mathematics from a conceptual perspective. Thus I trained to be a science teacher. After a year-long internship in secondary school science teaching, it was evident to me that the educational *system* was stifling, and a teacher would have little chance to change the system. I was offered a teaching assistantship in the botany department at the University of Minnesota and I eagerly accepted the appointment. However, it was my growing conviction that I could do more to "change the world" as an educator than as a botanist. Much to the chagrin of my botany professors, I chose to do Ph.D. studies in education, while continuing graduate studies and some research in sciences, a necessity for continuing my appointment in the botany department. I enjoyed my university teaching in the sciences, and although frustrated with much of the coursework in education, I persisted in my goals of trying to find better ways to educate people. This search goes on today in my teaching and research as I try to find better ways to help people learn how to learn.

How and when was the concept map idea born?

One objective early in my career was to research learning ideas, especially as they related to learning science. Contrary to popular views of Piaget's work that indicated young children could not do "formal operational" thinking, while observing my own children and conducting studies of elementary school children I saw evidence that children could grasp and use very abstract concepts, including science concepts such as the nature of matter and energy. What they needed was very careful, systematic instruction dealing with these science concepts, with much appropriately guided hands-on experiences, and careful introduction to the vocabulary of science.

We chose to use *audio-tutorial instruction (2)* to teach basic science concepts to children in grades 1 and 2 (ages 6–8). We interviewed these children periodically to observe changes in their understanding of science concepts, including occasional interviews until they reached grade 12 (17–18 years old). We also followed a group of children in the same schools who did not receive the audio-tutorial instruction in grades 1 and 2. It soon became evident that we were being overwhelmed with interview transcripts and a better method needed to be found to represent children's understanding and to observe changes. After reflecting on the problem for some weeks, our research team came up with the idea of representing the knowledge shown in the interviews as a hierarchical concept and propositional structure. Thus was born in 1972 what we called concept maps. Details of the study, which spanned almost 20 years from initial lesson development to final publication, can be found in the literature *(3).* Highly significant differences in students' understanding of the concept of the particulate nature of matter were found when students receiving audio-tutorial instruction in grades 1 and 2 were compared with students not receiving this instruction in early grades, and this difference grew over the twelve years of their schooling. This study demonstrated two important findings: Young children could begin to learn basic abstract science concepts as early as ages 6–7; and Ausubel's theory that future learning would be strongly affected by early concept acquisition was supported.

Concepts Are Building Blocks of Knowledge

Before we discuss concept maps, could you clarify what you mean by a concept and explain how this differs from the ideas of other authors?

I define a concept as a perceived regularity (or pattern) in events or objects, or records of events or objects, designated by a label. When joined together with appropriate linking words, concepts form statements or *propositions* describing some aspect of the universe, naturally occurring or constructed by humans. Most authors of other forms of representation do not clearly define concepts or propositions, which I regard as the building blocks for all knowledge. Other writers may show nodes linked to other nodes; often the links are not labeled to show the relationship between the two nodes, the items in the nodes may or may not be what I define as concepts, and they are usually not hierarchically arranged.

Concept Maps Are Relevant to All Learning

How are concept maps related to other forms of learning?

Since their early development in 1972, concept maps have been used to represent knowledge in virtually every field of study *(4),* including mathematics, dance, poetry, sports, history, and so forth. Because I believe all learning is rooted in the meaning frameworks that individuals develop, concept maps are relevant to all learning. In skill learning, extramanual or other manipulative practice is needed, yet this proceeds better when individuals have a good conceptual understanding of the skill. Similarly, visual learning, such as recognizing birds and gaining information from photos, for example, is also facilitated when accompanied by appropriate conceptual understanding; of course physical and visual experiences can also enhance conceptual understanding. Many studies show the advantages of concept maps in chemistry *(5–9)* and in the chemistry lab *(10–13).*

How is concept mapping related to intelligence?

If "intelligence" is defined as scores on a written intelligence quotient test, then concept map quality correlates poorly with that definition. If "intelligence" is defined as capacity to apply knowledge to problem solving in novel settings, then concept map quality correlates highly with this kind of "intelligence" *(14).* One reason people can act intelligently in one area and stupidly in another area is that intelligence is limited to those areas where we have developed well-organized knowledge structures and also metacognitive skills. People vary in both their innate capacity and experiences needed to develop such frameworks and skills in different areas, which is the basis of what Howard Gardner calls "multiple intelligences". However, instead of the 7 or 8 "in-

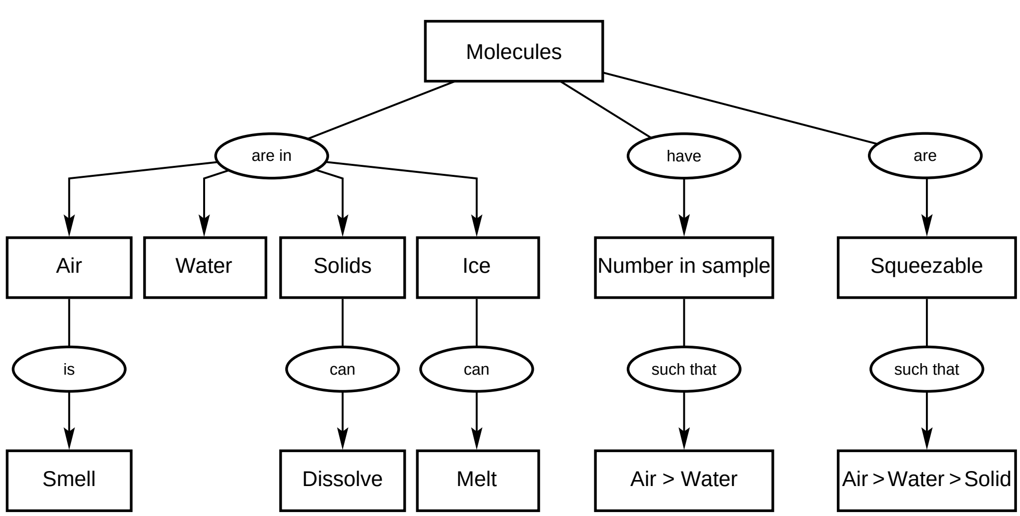

Figure 1. Concept map drawn from Amy's interview. At the time of the interview Amy was seven years old.

telligences" Gardner identifies *(15),* there are probably as many "intelligences" as there are areas in which individuals may develop powerful knowledge structures linked with skills of hand and eye and any associated emotional considerations.

How can concept maps be used to show what a learner knows?

When used prior to instruction, concept maps can show what knowledge a learner possesses that can serve to anchor new learning of concepts and propositions. Concept maps can also reveal misconceptions that the learner has that may negatively influence new, related learning.

Figure 1 shows a concept map drawn from an interview with a seven-year-old child dealing with the nature of matter. It illustrates that while Amy has acquired some basic concepts and propositions, her knowledge is also flawed. She thinks that molecules are "squeezable" with air > water > solid. She wrongly believes that a sample of air contains more molecules than a sample of water, and she equates air with smell (from moth balls used in the interview). Nevertheless, Amy has acquired knowledge from the audio-tutorial lessons she studied and has a foundation for building a better knowledge of the nature of matter.

Concept Maps Aid in Constructing Learning

Could you offer useful suggestions for constructing concept maps?

We have found that it is helpful to begin by identifying a "focus question" to guide us in building a map about some event, text passage, or problem to be resolved. For example, we might ask: What conditions are needed for water to boil? We then identify 15–20 concepts that are pertinent to answering this question (either as an individual or as a team), and rank-order these from most important, most general to least important, most specific. We begin the map with the general concept and then link this to two or three less general concepts with appropriate linking words to form propositions. We proceed to add other concepts and propositions, forming a hierarchy, restructuring the map as we proceed to add clarity and precision to the propositions in our map. Finally we search for "crosslinks" or relationships between concepts in different sections of the map, for the crosslinks may reveal creative insights that can aid in answering the focus question. More concepts and propositions can be added as the map is elaborated and further refined.

You promote concept maps widely; how much are they actually used?

Although we have reported on the value of concept maps for teaching and learning since the early 1970s, there has been a slow yet increasing rate of adoption in the use of concept maps in textbooks, study guides, teaching methods books, and more recently in publications dealing with the capture and use of expert knowledge in corporate and governmental settings. One of these projects was done by NASA and is available online at *http://cmex.arc.nasa.gov/CMEX/Map%20of%20Maps.html* (accessed May 2004). Description of another project focusing on the variety of uses of concept maps, this one sponsored by the U.S. Navy, is available online at *http://www.ihmc.us/research/projects/Cmaps/* (accessed May 2004).

CMap software for building concept maps is available free for non-profit use at *http://cmap.ihmc.us/* (accessed May 2004); this software has been downloaded by people in more than 140 countries. Concept maps, especially when used with CMap software, are ideal for distance learning programs and are being used increasingly in such programs, including distance learning modules used by U.S. Navy personnel.

Meaningful Learning Is Constructed and Supported

You make a sharp distinction between rote and meaningful learning. What are the advantages of meaningful learning?

Rote learning by definition is arbitrary, non-substantive storage of knowledge in cognitive structure without effort on the part of the learner to integrate new knowledge with relevant, previously learned knowledge. This kind of learning may have some advantages when assessment requires verbatim recall of specific information or definitions. Since this is often the case in much school assessment, students tend to learn by rote. Thus only meaningful learning requires *integrating* new knowledge with existing knowledge, and thus only meaningful learning can result in building more powerful knowledge structures and remediating misconceptions that may exist *(16).* Only meaningful learning allows extensive transfer of knowledge to novel settings and supports progressively greater skill development in attacking and solving novel problems. The latter is what the real world is all about.

I have used this tool in my teaching and have noticed that some students have trouble making maps. Why?

Although all people are meaningful learners before they begin school, too often school practices encourage rote learning and many learners become habituated to this type of learning. Making concept maps requires that a learner seeks to develop an understanding of the key concepts and their relationships to one another—to learn meaningfully. Research has shown that rote learners have difficulty doing this at first, although I have never found a person who could not build good concept maps after some time with appropriate instruction, practice, and constructive feedback. The time required to make this shift varies with individuals, yet is seldom more than three or four weeks of practice with appropriate feedback. It is also helpful when learners can use CMap software, which allows for individual or team construction of concept maps, synchronously or asynchronously, and in the same location or anywhere that Internet access exists. We have had elementary schools students in one country work successfully with students in other countries to build concept maps collaboratively, not only sharing knowledge about the topics of study but also sharing cultural differences that enrich the learning process *(17).*

New technology for creating concept maps developed at the University of West Florida Institute for Human and Machine Cognition (*http://www.ihmc.us/* [accessed May 2004]) permits easier and better concept map construction, thus facilitating learning, knowledge capture, and local or distance creation and sharing of structured knowledge, especially when utilized with the Internet.

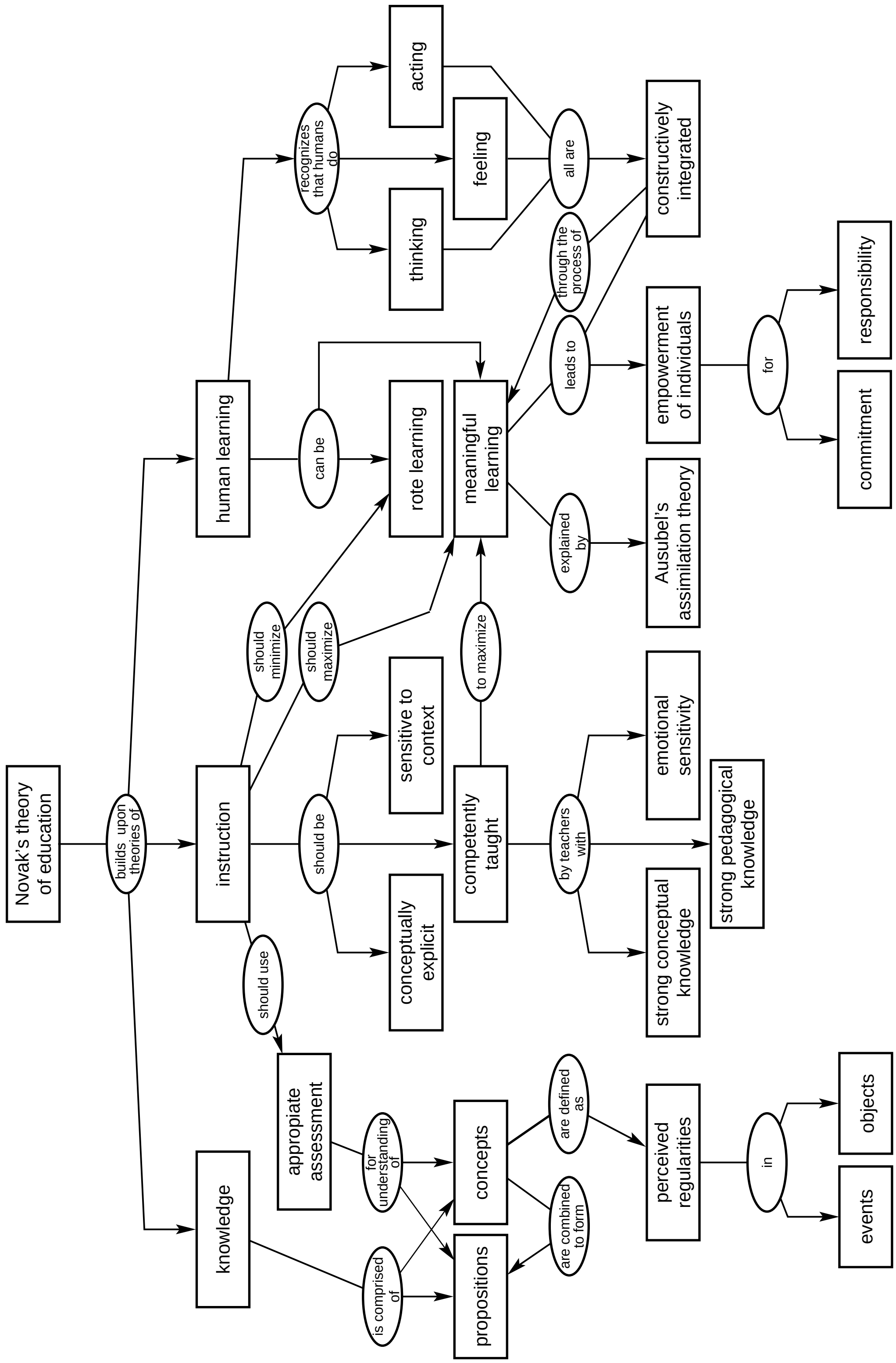

Figure 2. A concept map summarizing Novak's theory of education.

You coined the term "human constructivism". In what way is it different from other forms of constructivism?

von Glasersfeld described what he called "trivial constructivism" and "radical constructivism" *(18).* Trivial constructivism recognizes that every learner must construct for himself or herself the meaning of knowledge; that is, teachers cannot "give" students knowledge. It is basically a *psychological* idea. "Radical constructivism" recognizes that our interpretation of events and objects is controlled by the concepts we use to observe these events and objects, and as the latter evolve over time, new answers may emerge from observation of the same events or objects. The history of science is filled with such examples. The radical constructivist sees no point in time when we will have all the "right" answers. Constructivist ideas come from the theory of knowledge and it should be recognized as related to but also distinct from the psychological view.

My "human constructivism" tries to merge the two views through the recognition that meaningful learning underlies both the individual's construction of new learning, and also the advance of understanding in a discipline that derives from individual and collective progress in building more comprehensive, more parsimonious meanings for events and objects observed. Moreover, I recognize that feelings play an important role in meaning making, and that thinking, feeling, and acting are all integrated in the process of new meaning construction. Since my view integrates both the psychological process of meaning-making and the epistemological process of new knowledge creation in a discipline, I see "human constructivism" as more comprehensive and also more parsimonious than other views of constructivism *(19).* Figure 2 summarizes my theory of education in a concept map.

New Learning Needs To Be Conceptually Integrated

"Integrative reconciliation" and "superordinate learning" are some terms from your books. Could you clarify their meaning?

As meaningful learning progresses and new concepts and propositions are integrated into cognitive structure, confusion sometimes arises that needs to be clarified. For example, a student may learn that a mole of a given substance always has the same number of molecules, but moles of different compounds can have very different weights. The learner has to integrate the ideas of differing atomic weights, differing numbers of atoms in similar compounds, and thus differing molecular weights for different, albeit similar, compounds. As the learner gradually integrates the meanings of atomic weight, molecular weight, moles, molar volume, and associated concepts and experiences, perhaps in a laboratory setting, integrative reconciliation takes place and the distinctions and relationships among the above concepts become clear, prior conflicts of meanings are clarified, and a coherent cognitive structure is formed. Integrative reconciliation of related concept and propositional meanings has occurred.

Most meaningful learning progresses through the process of *subsumption*, where more general, more abstract concepts subsume the examples illustrating different variations of the same general concept. For example, learning that sulfuric acid, acetic acid, and other examples are all hydrogen ion donors that characterize what we call an acid would be an illustration of subsumptive learning. Occasionally, however, a new more general, more inclusive concept is learned and this then subsumes existing concepts in cognitive structure and confers new meanings to these. For example, when the concept of entropy is introduced to explain why chemical reactions proceed in the manner they do, when the idea that energy is required to reduce entropy, or to increase order in a system, and that much of chemistry can be explained by the idea of entropy, superordinate learning of the entropy concept occurs.

It is not easy to teach in a manner that results in this kind of superordinate learning and many chemistry students complete a first course in chemistry without acquiring this concept. In a similar way, many biology students complete a course in biology with only the vaguest idea of the meaning of evolution, even though the concept may be discussed in various aspects of the course. One of the challenges we face in the sciences is helping learners understand the few dozen truly superordinate concepts that can confer deeper meaning to the thousands of subordinate concepts that are taught. Concept maps have been shown to facilitate learning of superordinate concepts *(20).*

Meaningful Learning Resolves the Learning Paradox

How can your theory help to solve the "learning paradox" (21)?

Over two thousand years ago, the Greek philosopher Zeno recognized that what we can learn depends on what we know. But if this is true, how can we learn new things? This came to be known as "Zeno's paradox". What Zeno failed to recognize is that humans can see new regularities in events and objects, or records of events or objects, and can use language to label these regularities and to relate them to other regularities. In short, he failed to understand how what Ausubel calls "discovery learning" *(22)* can lead to new concept formation, and indeed this is the primary process by which infants acquire their first concepts. However, once a framework of elementary concepts is built, this can be used to acquire new concept and propositional meanings. This is why we have schools and universities. Zeno — and too many others — did not understand the process of meaningful learning and how it solves Zeno's paradox.

Concept Maps Are Useful in Business Settings

You now work with corporations. What are the analogies between education and business?

As I point out in my book *(23),* corporations must also learn to empower their people to be better meaningful learners. There is great global competitive pressure for corporations to change the way they do things, but I and others have found that corporations can be as resistant to new ideas and methods as are schools and universities. Nevertheless, I believe some corporation somewhere will seek to demonstrate what profitability can derive from empowering its people by using these tools and ideas. This could then serve as a model that might spread rapidly, given the nature of global competition and new technological capabilities for communicating these ideas. Work we are currently doing with the electric power industry is winning acceptance and may serve as a model for effective use of concept maps in corporations for capturing expert knowledge, designing better *education* (not training) programs for employees, and facilitation of creative application of knowledge.

Why do corporations find concept maps so useful?

Virtually all of the work in corporations is done by teams of people. One of the great problems teams have is to gain a shared vision of what the problem is and a shared *conceptual* understanding of the problem. My experience with corporations, and also with government groups, is that concept maps can be exceedingly valuable to achieve this shared understanding. As I state in my theory of education, "Meaningful learning underlies the constructive integration of thinking, feeling, and acting leading to empowerment for commitment and responsibility". Since this will determine corporate success or failure sometime in the future, corporations may help us to bring the same ideas and actions into schools and universities.

There exists a huge gap between what we now know to improve learning (and the use of knowledge) and the practices currently in place in most schools and corporations. There are promising projects underway that may help to achieve accelerated advances. These include projects in schools at all educational levels, including projects in Columbia, Costa Rica, Italy, Spain, and the United States, and collaborative projects with corporate organizations and distance learning projects. Results to date have been encouraging and suggest that we may be moving from the lag phase of educational innovation to a phase of exponential growth.

Students Can Construct Meaningful Learning by Using Concept Maps

As Novak has outlined in this interview, concept maps are tools for organizing information in such a way as to encourage a deep level of integrated knowledge. Students who use them acquire meaningful, interconnected learning and, as a bonus, "learn how to learn" more effectively. The maps help students to make sense of what they are trying to learn. Joseph Novak, you have shown by your research that education can be improved with the use of concept maps and the technique is beginning to benefit learners on an increasingly larger scale. It has been an honor for me to have shared your views and insights. On behalf of the chemistry education community, I wish to thank you for this interview.

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