Chapter I

Developing the Foundations to Help People Learn

Why Young Children Learn So Quickly

If you have had the experience of interacting with a child between the ages of one and four, you have witnessed how quickly these children acquire the names for objects and events they are experiencing. They also demonstrate their ability to pronounce these names, albeit their pronunciation may not be perfect at first. Usually, mommy and daddy are among the first words learned, but a dog’s name or the name of a favorite toy might also be learned very early. The name of a favorite food or drink may appear very early. Children add about ten to twenty new words a week between the ages of 18 to 24 months. By age four the average child can use about 4,000 words correctly. Most adults know the meanings of 20,000 to 35,000 words.

The most difficult thing any person will have to learn in their lifetime is to speak and understand the language. And yet, all normal children do this by age four! Why then do so many children have trouble learning in school when they were so successful as young children? This book will help to answer this question and to provide some solutions to this problem. We will also discuss what we can do to help people learn in any setting, from the classroom to the job setting to the research laboratory.

In my work as an educator and researcher for the past sixty plus years, I have found that it is critically important for teachers and learners to understand that most words are names for concepts. We define a concept as a perceived regularity or pattern in events or objects, or records of events or objects, designated by a word or symbol. When children learn the meaning of most new words, they are really learning the meaning of concepts. They are learning what pattern or regularity they are for. Concepts are the building blocks of knowledge in every domain of knowledge.

When young children acquire names for concepts, they are almost always observing the events or objects to which the word label is being applied. They are seeing and experiencing things such as dogs, or liquids,
birds, or trees. Or they may be experiencing events such as running, fishing, cooking, or bathing. These concept labels have meaning for the children. They are engaged in meaningful learning. By contrast, so much of school learning involves rote memorization of definitions of words or statements for which the child has no direct experience. We label this kind of learning rote learning, and this kind of learning can lead to many kinds of educational problems. A continuing theme in this book will be that we must find better ways to enhance and facilitate meaningful learning in schools or work settings, and to minimize as much as possible engaging people in rote learning.

New concepts are created by creative people who observe a new pattern or regularity in some specific kind of thing or event. They describe and define this regularity and give it a name. For example, I am typing this book on a laptop computer. These had not been invented when I was a student. Macnamara (1982) saw in his studies of how children acquire "names for things" that either the perception of a regularity or the name (word) for a regularity may come first, but facility in proper use of the word requires that both the word label and its associated meaning be integrated. Since meaning is always context-dependent, the meaning of a concept label will always have some idiosyncratic elements, for no two people experience an identical sequence of events (contexts) in which a given concept label is applied. Whorf (1956) was one of the first and most prominent researchers to recognize that the cultural context in which a person lives shapes the meaning of that person’s concepts. (Novak, 2010, p. 43).

Important as it is to understand the meaning of concepts in any domain of knowledge, learning a set of concept names does not lead to an understanding of the meaning of these concepts. We also must learn valid propositions that incorporate these concepts. Propositions are two or more concepts connected with linking words to form a meaningful statement. Thus, we really never learn the meaning of a concept in isolation but, rather, through learning sets of propositions that include that concept. So, the young child learns that sky is blue, water is wet, dogs can bark, etcetera, etcetera.

We might compare the world of language with the world of chemistry. The universe is made up of about 100 kinds of atoms or elements. Two or more atoms may combine to form a molecule. The possible combinations of atoms are essentially infinite, and there is no end to the number of new molecules a chemist may invent. Similarly, there are just twenty-six letters in the English language, and words are made up of one or more letters. When creative people see or invent some new pattern or regularity, they
make up a word to label this new concept. Consider for a moment all the new words invented to describe new patterns in objects and events in the digital world.

So, the fundamental challenge we face in helping people learn in any domain of knowledge is to help people build an understanding of the key concepts and propositions of that discipline. We also want to help them to understand how new knowledge can be created in that discipline. There has been so much written about how to help people learn that we also need to sort out which ideas are valid and may be powerful, and which ideas are of little value or just plain wrong. For me, this has been a lifelong journey – and the journey will continue as long as I am able to pursue it. We are continuing to find better ways to help people learn. And new technologies are opening up new possibilities that we need to consider.

We are usually at our best in new learning when we are also engaged in some physical activity. If we are progressing well with our learning, we also experience strong positive feelings. Recall your experience when you figured out how something works or a winning strategy for a game. Thinking, feeling, and acting are all integrated in a positive way in any successful learning experience.

![Image of three children](https://doi.org/10.1017/9781108625982.002)

**Figure 1.1** The author’s three children, Barbara (7), William (6), Joseph (8), 1965. Raising children was a joy for me; they also taught me so much!
I have discussed in some detail in my biography three things that have been helpful in my search for understanding how people learn and how to facilitate learning. First, my experiences as a parent raising three children have not only been a great joy but have helped me discern those ideas I was taught that made sense from those perspectives that did not. Second, my wife for more than six decades has been both a constant supporter and the best critic of my work. Third, as a child, my dad played a very important role in building my confidence. He insisted that his son Joe was capable of doing anything he sought to do. I will also indicate in this book instances where these people helped me discern sense from nonsense – and there is much of the latter in the literature!

**Can Education Become a Science?**

I majored in science as an undergraduate and also completed classes and intern teaching to become a certified science teacher. As a graduate student, I was a research and teaching assistant in the Botany Department at the University of Minnesota. I also completed the requirements for a Ph.D. degree in Science Education. I was fascinated by the methods scientists used to create new knowledge and the important role that theories play in the advance of science. By contrast, I learned of no real theories or major principles that could guide educational practice and knowledge creation in education that would lead to better educational practices. It was my conviction that human learning and educational practices could be considered as belonging to the class of animal behavior and therefore should be amenable to the same kinds of tools and theory building that have been so successful in the sciences. I came to believe that if education were ever to become a science, it must be based on a valid theory of learning. I was convinced that behavioral psychology was not viable as a theory to guide education and educational research.

Throughout my undergraduate and graduate education at the University of Minnesota from 1948 to 1957, the only theory of learning I was taught was behavioral psychology. The fundamental idea of behavioral psychology is that since we cannot observe directly what is occurring in the brain, we must study only the manifest behaviors of animals and humans. We cannot therefore attempt to speculate on what is going on in their brains. Furthermore, behavioral psychology largely ignores the important role that feelings play in everything that people choose to do.

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1 This biography is available at no cost at: [www.ihmc.us/joseph](http://www.ihmc.us/joseph).
Any theory that ignored the role of feelings, in my view, was quite simply inadequate at best and possibly dead wrong!

In the sciences, many kinds of studies deal with phenomena that we cannot observe directly, but only through the use of instruments. For example, almost everything we know about the structure and function of atoms is derived through observations with instruments. So, concepts in this field are created primarily from patterns in records we make, not from observing events and objects with our own eyes. From my perspective, behavioral psychology simply did not make sense as a theoretical model, nor did I think it was a viable theory to guide research on human learning. One lesson I learned from my dad’s teaching was that if something just does not make sense, it is probably wrong. For a few years, I and my graduate students searched for a better theory of human learning to guide our work.

**Learning to Understand and to Implement Ausubel’s Assimilation Theory of Learning**

My first job was in the Biology Department at Kansas State Teachers College. I taught undergraduate and graduate biology courses and supervised a small group of master’s degree students interested in research on biology teaching and learning. In 1959, I accepted a joint position as Assistant Professor in the Biology and Education Departments at Purdue University. My primary responsibilities were to build a nationally recognized program for training biology teachers and to conduct research with MS and Ph.D. graduate students interested in improving biology education. I inherited a few Ph.D. students from my predecessor who held this position before he was killed in an automobile accident. Within two years, I had built a team with eight–ten Ph.D. students.

Not only was behavioral psychology the dominant theory for learning during my school years, but it remained the dominant theory until the late 1980s. I saw no value in behavioral psychology as a theory of learning for a science education research program. I and my team of graduate students were delighted when we learned about David Ausubel’s Assimilation Theory of Learning first published as a journal article in 1962, and as a book in 1963. So, beginning in 1963, we finally had a theory of learning that made sense to us! Much of the success my students and I achieved in coming to understand human learning and finding new ways to facilitate such learning derived from rejecting behavioral psychology and embracing Ausubel’s new Assimilation Theory of Learning.
Although Ausubel’s learning theory contained only seven major principles, it was not easy to understand, since each of the principles is closely connected with the meanings of the other six principles. I discussed earlier in this chapter the differences between rote learning and meaningful learning. Ausubel has written more precisely than any other cognitive psychologist I have studied. His theory includes the important differences that occur when a learner acquires information by meaningful learning as contrasted to learning by rote memorization. His theory includes the principle of subsumption that occurs in meaningful learning when new examples of concepts are subsumed and integrated into a relevant existing, more general concept. For example, this is the case when a child learns that another kind of animal they never saw before is also a member of the dog family. Repeated subsumption of new instances or examples of a concept lead to a refinement and enhancement over time of this subsuming concept. Ausubel called this process progressive differentiation. The subsuming concept becomes more complex and inclusive, but also more explicit and more precisely understood. A young child might confuse a cat as another kind of dog. But she/he will soon differentiate these kinds of animals and recognize that while they can both be pets (another concept), they are distinctly different. Even as a young child, these kinds of subsumptions and progressive differentiations take place effectively with all normal children.

As a child’s learning progresses, she/he may learn that some people have parrots or canaries as pets, and maybe hamsters and white rats. A new superordinate concept of household pet may be forming, perhaps including cold-blooded animals such as turtles, fish, and snakes. Over time, some details of these expanded concepts may be forgotten in the process Ausubel called obliterative subsumption. There is a difference between obliterative subsumption that may occur after meaningful learning and forgetting that occurs after rote learning. In the case of obliterative subsumption of concept details, the contributions that obliteratively subsumed concepts had made to the meaning of the superordinate concept largely remain and these can be quickly relearned. No such cognitive benefit occurs in the forgetting that occurs after rote learning. Figure 1.2 summarizes these seven Quasiabelian learning principles, shown in shaded ovals.

One way to move toward better understanding of these principles of learning is to try placing examples of concepts of objects or events that interest you as specific examples of each principle. For example, you might use cars as another example, or events such as parties or travel.

When we memorize new information, that is when we learn by rote, that information can be stored almost anywhere in our frontal cortex (see
When we learn information meaningfully, this new information becomes integrated with related concepts and propositions stored in our cortex. Ausubel called this a subsumption process. When this occurs, both the original anchoring concept and the added subsumed concept are modified in a positive way. Ausubel describes this as assimilating new knowledge into existing relevant concepts. Thus, his theory of learning is often called Ausubel’s Assimilation Theory of Learning. For the young child, almost all learning takes place when they are interacting with objects or events and thus most of their learning is meaningful. By contrast, so much of school learning involves memorization or rote learning of information that has few or no ties to the real world of objects and events already known by the learner.

I recall when my son Joe was about two years old and we were driving in the countryside. My son saw a cow in a field that we passed and he shouted out: “doggy, doggy.” I said no – it is really a cow that is much bigger than a...
dog. It only looks smaller because it is far away. I guess this explanation
made sense to my son; he never made this mistake again – and he
assimilated a new idea about dogs and other animals that might look like
dogs when viewed from a distance. The idea that things viewed some
distance away look smaller than they really are is a pretty powerful concept,
and we have observed this often in our work with children.

From 1963 to this day, Ausubel’s Assimilation Theory of Learning has
been useful to me and my research groups and to my students. As our
work progressed, it became increasingly evident that meaningful learning
was not a simple alternative to rote learning. Since meaningful learning
requires that the learner must make the effort to integrate new concepts
and propositions with relevant concepts and propositions she/he already
knows, the quality of meaningful learning is dependent on both the quality
of relevant concepts and propositions the learner holds and also the degree
to which the learner makes an effort to integrate new knowledge into her/
his existing relevant knowledge. Both of these aspects can vary greatly from
learner to learner and for different learning tasks. Sitting and listening to a
lecture is a very poor way to engage in a high level of meaningful learning.
Actively working with and discussing with a team of students a new idea or
a new way of doing something can be a great way to engage in high levels

Figure 1.3  The brain. Information we learn is stored in the outer convoluted folds of
the frontal cortex of our brain. Feelings and actions, we experience during meaningful
learning are stored in lower regions of the brain, but all are connected by nerve cells
and blood vessels.
of meaningful learning. Throughout this book I shall try to illustrate that working and thinking with others is a great way to help people learn.

When I began college at the University of Minnesota in 1948, one thing I had hoped to learn was how people learn and create new things. From my readings, it was clear that people who create new things and new ideas are intelligent, and they work very hard. The book that I read in 1949 that had perhaps the most important influence on my thinking was James Conant’s, *On Understanding Science*. Conant argued that what makes advances in the sciences is that people invent new conceptual schemes, and then they work to refine, modify, and improve these schemes. Sometimes they see that a given conceptual scheme begins to have too many problems or inconsistencies, and then comes the challenge to create a new, better scheme. Conant also suggested that the process goes on forever, and we will never invent the perfectly correct conceptual scheme!

As a college freshman, I did not know at the time that Conant’s ideas were far from the mainstream of the thinking of philosophers and psychologists. Overwhelmingly in these fields, the popular belief was that through careful observations and experimentation, we can eventually establish laws, and these laws will endure forever. These kinds of thinkers were called positivists or logical positivists. The University of Minnesota was the international center for logical positivism. I did a graduate philosophy course with one of the world leaders, Professor Herbert Feigl. Professor Feigl and I had several friendly debates in his office – which he easily won by sheer years of professing. Nevertheless, I thought the kind of philosophy I was searching for would be better than logical positivism.

All the psychology courses I took at Minnesota were based on behavioral psychology, and this psychology was tightly wedded to positivist thinking. For various reasons, I thought that the logical positivists and the behavioral psychologists were just plain wrong in their assumptions, their methodologies, and their thinking! The confidence my dad helped to build in me as a child gave me the guts to insist that the behaviorists and the positivists were just plain wrong and people like Conant in philosophy of science and Ausubel in psychology were on the right track. Be certain of this, my views were far from the mainstream in the 1950s through the 1970s. Fortunately, the tide of thinking had turned in my direction by the mid-1980s. The changes in thinking in psychology in the 1970s and 1980s became what some call the “cognitive psychology revolution,” bringing the thinking in psychology much more in line with Ausubel’s 1963 ideas.

There were other scholars who were critical of behavioral psychology as early as the 1920s. I simply was not exposed to any of their work in my

Almost simultaneously, the thinking about the nature of knowledge and knowledge creation began to shift toward constructivist views, more similar to Conant than to Feigl and other positivist’s ideas. The current views are congruent with the kind of thinking my students and I had been using since the early 1960s. I have describe my intellectual journey up to my current work in a book that can be downloaded and read at: www.ihmc.us/joseph-novak/.

In 1977, David Ausubel invited me to collaborate on a revision of his 1968 book, *Educational Psychology: A Cognitive View*. My job was to revise the chapters dealing with Ausubel’s Assimilation Theory of Learning, and some other sections of the book. In the course of working on these revisions, I got to know Ausubel very well and we had numerous conversations about his theoretical ideas and possible modifications. The revised second edition was published in 1978. (Ausubel, Novak, and Hanesian, 1978). The sale of the English edition was dropped by the publishers (Holt, Rinehart, and Winston) after five years when annual sales of the book dropped below their required level, but the Spanish translation published by Editorial Trills in Mexico continues to sell today. The international rise of cognitive psychology was yet to come. My colleague, Ulrich Neisser, published his *Cognitive Psychology* in 1967, and this became a classic in the field, but this book did not come to my attention until ten or twelve years later. Anderson’s 1983 book became very popular as cognitive psychology began to dominate the field. Ausubel regarded the latter book and similar books as neo-behaviorist, and I saw them as failing to shed the positivistic views of behavioral psychology. The complex interrelationships of the ideas in Ausubel’s Assimilation Theory of Learning did not compete well with some of the other books on cognitive psychology mentioned above and the still widely popular behavioral psychology books published in the 1970s and 1980s.

Based on research done by my research teams, and my teaching experiences presenting these ideas to others, I argued that rote learning and meaningful learning should not be viewed as discrete forms of learning,
but rather as two ends of a continuum, as noted earlier in this chapter. I observed that when learners first began learning about a new domain of knowledge, their understanding of key concepts in that domain was relatively limited and they had little or no understanding of how concepts in that domain were related to each other. As learners gained expertise in a domain of knowledge, they began to see and understand many more connections between concepts in that domain, thus building a much greater understanding of all these interrelated concepts. The integration of new concepts and propositions related to this domain becomes more richly integrated. As this integration of new concepts related to this domain became more interconnected, each concept and proposition had deeper meaning for these learners. Marton and Säljö (1976a, 1976b) have used the label deep learning as contrasted to surface learning to describe the differences we have referred to as meaningful in contrast to rote learning. There are similarities in their work to the ideas we were developing.

I argued further that what I and my students observed in our research was that those individuals who came to them with new ideas, that is new related concepts and propositions, were essentially doing very high levels of meaningful learning. This suggested that we could represent this as showing that creative learning was best viewed as part of a learning continuum but at very high levels of meaningful learning. After we developed the concept mapping tool, to be discussed later in this chapter, it was very easy to see explicit examples of students or researchers progressing in the quality and extent of their meaningful learning for a given domain of knowledge.

Although Ausubel initially did not support the view that rote learning and meaningful learning are best seen as two ends of a continuum, he did accept this idea in his later writing (Ausubel, 2000). I also argued in later years that creativity can be viewed as a very high level of meaningful learning. Therefore, if we wish to encourage individuals to think creatively, we must help them become powerful meaningful learners. These ideas are illustrated in Figure 1.4.

While verbal learning takes place in the cortex of the brain, this region is richly connected with other areas of the brain. Some lower regions of the brain include areas that primarily store visual information, coordinate muscle activity and the feelings experienced when learning or doing anything, as well as regions involved in autonomous activities such as breathing and digestion. To become a skilled athlete or an accomplished musician requires building connections between the frontal cortex and many other regions of the brain. This is one reason it
takes years to become a skilled musician or an accomplished artist or athlete. It is truly remarkable how well the human body integrates all of our thinking, feeling and acting in ways that allow humans to do such remarkable things.

Another important feature of meaningful learning is that it usually involves some form of action on the part of the learner and these actions are accompanied by feelings, either positive or negative, that occur during the actions. Thus, in meaningful learning we not only have new concepts and propositions integrated with relevant existing concepts and propositions, we also have feelings and actions integrated into the developing concept and propositional framework. This integration of thinking, feeling and acting during meaningful learning confers enhanced retention and future usability of these concepts and propositions.

So, the short answer to the question: What makes the learning of young children so effective is: most of their learning occurs in settings where they are integrating their thinking, feeling, and acting, while dealing with real events or objects. They are engaged with the objects and events labeled by the words they are learning and experiencing the connections of these words in ways that make sense to them. The result is that young children are highly effective meaningful learners. What we seek to do in this book is
to illustrate how we can help learners of any age become more effective meaningful learners, just as they were in preschool years. We shall also explore how new learning tools and ideas can enhance learning effectiveness at any age and in any domain of knowledge.

**How Can We Encourage and Facilitate Meaningful Learning?**

In the course of my research programs, first at Purdue University from 1959 to 1967 and then at Cornell University from 1967 to 1998, my teams conducted a number of research projects that dealt with children’s and adult’s learning. Almost all of these studies were done in real-world classrooms or other real-world settings for learning. Throughout this book we will show how some of these research projects led to new ways to help people learn.

One of my research projects involved young children learning basic science concepts with the aid of Audio-tutorial (A-T) instruction. A-T tutorial instruction was first developed at Purdue University with Professor Postlethwait with his Introductory Botany course. I adapted A-T instruction to teach basic science concepts to grade 1 and grade 2 children while on sabbatical leave at Harvard University in 1965–1966. Figure 1.5 shows a seven-year-old child learning about the conversion of electrical energy to other forms of energy. Most of the lessons in our A-T program were based on an elementary science series that I had written, published in 1966. I will say more about this project in later chapters.

We designed a group of A-T science lessons in the 1960s in order to teach basic science concepts to children in primary grades. Very few elementary school teachers have the science knowledge, or the materials needed, to teach about the nature of matter and energy, necessary requirements for living things to live, etc. The conventional wisdom, based in part on Jean Piaget’s work with children, was that children cannot begin to understand these abstract concepts of science until age thirteen or older. My experiences with my three children, and some limited research with primary school children, indicated that this was not true, and one objective of our study was to prove this. Most important was our goal to demonstrate an effective way to bring high-quality science instruction into elementary schools (Hibbard and Novak, 1975).

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The Invention of the Concept Map as a Knowledge Representation Tool

When we interviewed and talked with the children after instruction, it was obvious that the children were beginning to acquire an understanding of the concepts we were teaching. The problem was that we needed a better assessment strategy to demonstrate convincingly that the children were developing a genuine understanding of the concepts and propositions we were teaching. My research team turned to the theoretical foundations in Ausubel’s learning theory and constructivist ideas about how humans construct new knowledge. We came up with these basic ideas to guide our search for better evaluation tools:

Figure 1.5 A grade 2 child experimenting with converting electric energy from a battery into heat, light, and motion in apparatus developed in an A-T program.
1. All knowledge is composed of concepts linked to form meaningful statements or propositions.

2. In meaningful learning, knowledge is stored hierarchically, with the more general and inclusive concepts at the top and the more specific concepts at lower levels of a knowledge structure.

3. As children learn more about any domain of knowledge, they should build more elaborate, more accurate knowledge structures for that domain.

The solution to our assessment problem did not occur in one sudden insight. My research team struggled with this problem for a few years in the early 1970s. We tried studying individual statements or propositions made in the interviews with the children. We made lists of these propositions given by children and recorded in our interview transcripts.

We finally settled on building a hierarchy of concepts and propositions starting with the most general, most inclusive concepts in a given interview and working on down to the most specific, least inclusive concepts. We also added linking words connecting the concepts to form propositions, recording these just as they were given by the children in our interviews.

Organizing the concepts in the children’s statements in our interviews in this way gave us what we called a concept map. The latter approach proved to be the most useful, most explicit way to illustrate what a child had learned on a given topic. This approach was also the most congruent with our theoretical foundations. Figures 1.6 and 1.7 show concept maps drawn from interviews with Cindy, one of the students in our research study. Originally, the maps were drawn using pens or pencils, but I no longer have these maps in my files. After we developed computer software to make it easy to draw concept maps, all of our concept maps were done using this software. I discuss the development of this software in the next chapter.

One of our interviews with Cindy was done near the end of grade 2, after two years of A-T science instruction. This concept map shows that Cindy had begun to understand some basic concepts about the structure of matter, although some of her ideas are faulty, or she could not recall the correct label for the concepts. She uses the label “little bits” and “very tiny specks” rather than atoms or molecules. This is a common observation we see with students of all ages. She also has the faulty idea that the little bits are “squeezeable.” One of the A-T lessons used small balloons to illustrate that the air the subject blew into the balloon took up space, but remained
squeezable, unlike a balloon filled with water. It is quite common to observe in interviews with individuals of any age that they confer the properties of the whole thing they are observing to the particles that make up the whole thing. Cindy has obviously acquired some understanding of the idea that the things we see are made up of tiny particles. This is a good beginning for later learning about atoms and molecules that are the building blocks of all matter.

Owing to limited funding, my research team could not continue the A-T science instruction in grades 3 to 6, as we had originally planned to do. I described my struggles to obtain funding for this project in my biography, cited footnote 1. My team did manage to do follow-up interviews with samples of the original students in the study in grades 7, 10, and 12. We observed some gains in understanding of basic science concepts, as a result of enrollment in conventional junior and senior high science courses. However, there were striking differences in performance

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Figure 1.6 A concept map prepared by one of the author’s graduate students from the transcript of an interview with Cindy in grade 2, following two years of A-T instruction in science. She is beginning to understand the concepts of atoms and molecules but has more to learn, including the scientific name for “small bits.”
between the children who had the A-T lessons in grades 1 and 2 and a similar sample of students who did not have these lessons.

My research team made a concerted effort to interview all the original students who participated in the study who were still in Ithaca schools in grade 12. The concept map in Figure 1.7 was drawn from the transcript of an interview with Cindy toward the end of grade 12. Compare the ideas in this map with those shown above in her map in grade 2 and you can see that Cindy did indeed learn much more about the nature of matter as she progressed through her school years.

My research team found that the children who received the early A-T lessons in grades 1 and 2 very significantly outperformed their schoolmates who did not receive these early science lessons. These results supported Ausubel’s learning theory that says if children begin to form valid anchoring concepts in early years, this will advantage them in all future learning of related concepts in later years. We see evidence of this in Cindy’s grade 12 concept map.

By the time the students in our study reached grade 12, there were only 38 students from the original instructed sample still enrolled in Ithaca schools. There were seventeen students still available from the
uninstructed control sample group who had no A-T lessons. All these had been interviewed in grades 2, 7, 10, and 12 by my research teams. The analysis of the concept maps made from these interviews showed that children who received A-T science lessons in grades 1 and 2 (instructed students) held significantly more valid concepts and propositions than the uninstructed group, and this difference increased in later grades when all students received regular school science instruction. These results are shown in the upper part of Figure 1.8. The lower part of this figure shows that the A-T instructed children held fewer invalid notions and the number of these declined with additional science instruction in later grades. The results were highly significant, and they were consistent with what had been expected, based on Ausubel’s learning theory.3

The findings of the above research were significant for three reasons. First, they confirmed that, contrary to Piaget’s cognitive development stage theory, with proper instruction, six- and seven-year-old children can begin to understand important abstract concepts of science, and these understanding have a very positive influence on future science learning. Second, the results support Ausubel’s Assimilation Theory of Learning that predicts that when given high-quality, meaningful instruction in science in early grades, children will begin to form subsumers or anchoring concepts that will facilitate later science learning and diminish the formation of invalid ideas or misconceptions. Third, the study showed that concept maps can be a very useful evaluation tool for cognitive learning (see Novak, 2004).

I wish I could show you similar results from similar research. However, I have found no other study that followed the cognitive development of the same children in a specific subject matter area through twelve years of schooling. Having struggled with the funding and logistical problems we experienced, it is easy to understand why this is the case. Later researchers have shown that A-T instruction can be effective. Kulik, Kulik, and Cohen (1979) published a meta-analysis of research on the use of A-T methods, showing the general superior effectiveness of this teaching strategy.

When the Cognitive Psychology Revolution occurred in the late 1980s and beyond, researchers such as Donaldson (1978), Chi (1983), and many others began to do research that supported the kind of research results our team had found, albeit with studies of much shorter durations. The Cornell University program to help people learn had a twenty-year head start as a result of our early embrace of a cognitive learning theory and with practice in applying the ideas to improve student’s learning.

Figure 1.8  Grade levels. This figure shows that students who had A-T science lessons in grades 1 and 2 (instructed) held substantially more valid science notions in high school (top of the figure), and far fewer invalid notions (misconceptions) in high school grades (lower part of the figure). (See Novak, 2004.)
Important as the twelve-year study was for debunking some myths about children’s learning, it was the invention of the concept map tool to represent knowledge in any domain of knowledge that was the principal achievement of this project. This will be illustrated throughout the remainder of this book.

**Learning from Our Students How to Help People Learn to Learn**

As my graduate students prepared concept maps to show how children’s learning progressed as they studied A-T science lessons, they became very proficient in constructing concept maps. Many of them began to use concept maps to summarize and clarify their own studies in graduate science courses and other courses. I also found that making a concept map of a difficult research paper or section of a textbook was very helpful in clarifying my own ideas and providing me a better understanding of the ideas being presented. It occurred to me in 1978 that our research was suggesting that there were some very helpful things we could teach to Cornell University students that would help them become more powerful learners.

The course I developed drew heavily on what I learned in our research program. I had observed that planning and conducting interviews with students helped my graduate students better understand Ausubel’s Assimilation Theory of Learning. They observed that those students who were seeking to understand what they studied had much better organized structure to their knowledge, they could apply their knowledge to new but related problems, and they felt more confident about their knowledge. Building concept maps for the students interviewed helped them to see the hierarchical nature of cognitive structures and gave deeper meaning to Ausubel’s idea that most learning involves subsuming and integrating new concepts into more general superordinate concepts. In short, they saw that students who were trying to engage in meaningful learning had more and better organized knowledge and were much more successful in applying their knowledge in new situations.

So, I required all students in my new Learning to Learn course to begin with learning the basic ideas of Ausubel’s learning theory and to make a succession of concept maps that illustrated their growing understanding of his theory. I also required them to plan an interview on any subject of interest to them and to interview ten subjects of their own choosing on the subject they had chosen.
Volunteers presented to the class what they were observing as their interviewing and concept mapping progressed, and this helped both the presenter and other students improve their interviews and the quality of their concept maps of interviews. A few students showed video clips from tapes of their interviews, and these were very helpful to everyone. The esprit de corps in the class was excellent, and I looked forward to every class meeting. Each student prepared a final written report on their project that included concept maps for each interview done and whatever other observations they wished to make. An example of one student’s project will be presented later in this chapter.

Most of my students who enrolled in my course were juniors or seniors. Initially I was surprised that most of them said they had not written a major paper since Freshman English, and almost all had never presented orally the results of a personal research project. As the semester progressed, all of the students became active participants in the discussions. Given the high standards for Cornell University admission, many of my students indicated that they were not aware there was any other way to learn other than to just memorize as much as possible. This strategy had worked for them in high school and most large Freshman and Sophomore courses. But Cornell University is a great university and most upper division course professors require a higher level of thinking and reasoning. The students who learned primarily by memorizing saw their grades fall from As and Bs to Cs and Ds. That is when they became interested in getting help with their learning strategies.

Lev Vygotsky had pointed out years ago that students can learn better by interacting with their peers. I had all of my students prepare a one-page biography and I shared these with the whole class. This facilitated the process of choosing a “learning partner,” since most of the students had previously not known any other class member. Students were asked to share and critique each other’s written materials, and a few assignments were explicitly to be done with their learning partner. Many of the complimentary things said about my course by my students included comments on working with a learning partner. In fact, I learned later that at least a few learning partners wound up getting married.

So, if you can do so, may I suggest that you find a learning partner or two to read this book and perform the suggested activities as a team. Even if this team breaks up after a chapter or two, you will have some lasting benefits.

In the twenty years that I taught this course, I never had a student fail to succeed to become a relatively good meaningful learner. I did have about a
percent dropout rate, but this was usually because they found the course required more time and/or effort than they were prepared to commit to. Not all courses in the Department of Education required a fairly high degree of commitment and time to perform successfully.

Here are a few things they learned in my Learning to Learn classes that caused this transformation from passive rote learners to active, creative, meaningful learners. First, they were taught key ideas in Ausubel’s Assimilation Theory of Learning. They learned that only the learner can choose their learning strategy, and this can vary from simple memorization of information to strong efforts to integrate new concepts and propositions with related ideas they already knew. They also learned that depending on the quality of their existing ideas, the degree of meaningful learning can vary from almost rote learning to very high levels of meaningful learning. Only the learner can choose to learn by rote or by her/his best efforts to accomplish meaningful learning. Therefore, learning is not a simple dichotomy of rote versus meaningful learning; it is a continuum. This continuum was illustrated in Figure 1.4.

The second important idea they were helped to understand is that knowledge in any field is essentially a large body of well-organized concepts and propositions. New knowledge is created either by an individual or by a team. When a new pattern in events or objects is identified or created, this pattern is given a name. In our case, our research team chose to call a hierarchical structure of concepts and propositions a concept map. We had invented the concept of a concept map.

Not all of my students found it easy to make their first few concept maps. It soon became evident that those students who had been learning throughout their school years, and even in college, primarily by memorizing information really struggled to make their first acceptable concept map. Some came to my office to discuss dropping the class because they thought they just could not think in the way that was needed to make good concept maps. I assured them that if they learned to talk by age three, they could become very successful at concept mapping knowledge they wanted to understand within a few weeks – and they all succeeded by week 5 or 6 of the course. Some spoke with me about how depressed they were to realize that they had gone through all their past schooling and really understood almost nothing about the subjects they had studied! Remember, these were Cornell University students and most of them were in the top 10 percent of their high school class!
In our early work with concept maps from 1972 to 1983, all were drawn using a pen or pencil. We found that even building a good concept map with as few as ten or twelve concepts required two or three revisions. These revisions can be done rather quickly, but when one tries to make a concept map of some more complex topic with twenty to forty concepts, revisions can be frustratingly time consuming. Moreover, our experience was that for almost any more complex topic, at least three or four revisions were needed to obtain a satisfying concept map. Making three or four larger concept maps could become very tedious!

One solution we tried for this problem was to write concepts and linking words on strips of paper and then arranging these on a desk or table. Figure 1.9 shows an example of this. It was a good way to get children started in building concept maps.

In some training sessions we used sticky notes placed on wrapping or butcher paper, so it was easy to move around concepts, but once linking lines with linking words were added, revisions were difficult. It was not until the late 1980s that desktop computers became widely available, and also software specifically designed to do things such as making concept maps.

Our later development of software for laptop computers in the mid-1980s facilitated concept map making, and this was a great boost to our work. The development of excellent concept mapping software by Alberto Cañas and his team will be presented in the next chapter.

![Figure 1.9 A concept map about animal characteristics made using strips of paper, one color for concepts and another for linking words.](https://doi.org/10.1017/9781108625982.002)
Making Your Own Concept Maps

If you have never built your own concept maps, we suggest that you do so now. You may find it helpful to begin by reviewing Figure 1.10 that shows important characteristics of good concept maps. We also recommend that you make a copy of the definitions and ten “rules” for making good concept maps given below. Use these to guide your preparation of concept maps, and also as a checklist after you have made a concept map.

Criteria and Rationale for Making Good Concept Maps

Definitions

CONCEPT: A perceived regularity or pattern in events or objects, or representations of events or objects, designated by a word or symbol.
PROPOSITION: Two or more concepts linked with words to form a statement about how some aspect of the universe appears or acts. Propositions are the units of meaning in meaningful learning and form the structure of a domain of knowledge when well organized and integrated.

Rules for Making Good Maps

1. A context for the concept map should be defined, commonly with a stated explicit “focus question.”

Concept maps are very helpful for organizing the knowledge needed to find solutions to problems or questions. These may derive from a topic of study or some form of inquiry. The focus question helps to delineate the knowledge that is most relevant to the problem or question. Stating an explicit question can be very helpful in identifying the best concepts to include at the top level of a concept map. In turn, identifying the best concepts to include at the top of a map often leads to a better, revised focus question. When working in a group setting, the process of identifying a good focus question and the six to ten top-level concepts may take half as much time as constructing the complete initial concept map. A good focus question helps to define clearly the context we are working in and aids in the process of concept mapping the knowledge pertinent to that context. The focus question may appear as the top node of a concept map, or as a header for the map.
Figure 1.10 A concept map showing the key features of concept maps. More requests were received for publication of this figure than any of the author’s other figures.
2. Concept labels in maps should be only one or a few words labeling a specific concept.

Concept labels represent the perceived regularities or patterns in events or objects, or transformations of records of events or objects, designated by a label. Usually, the label is one word or a few words, e.g., history, medieval history, disease, or heart attack. Usually when more than one word is used to label a concept, one must consider if some of the words in the label are also labels for other concepts and should be indicated as separate concepts in your map. Only rarely is a concept indicated by several words. When sentences or longer phrases appear as a node label in a concept map, a submap might be more appropriately included, showing the structure of knowledge represented by the sentence or phrase.

3. Linking lines should be labeled with one or a few words, and not contain concepts labels important to the map’s conceptual content. They help to specify the proposition or principle formed by the concepts and linking words.

Linking words and the concepts linked by these words should form a meaningful statement about some event or object, or class of events or objects. More specific linking words give more explicit meaning to the relationship between two concepts, and these are often preferred to more generic linking words such as: is, a, are, includes, related to, etc. More specific links may include words such as: requires, composed of, derived from, etc. The degree of understanding of a given domain of knowledge is indicated in the precision and/or specificity of the proposition shown in the concepts and linking words given in the map.

4. Maps should have hierarchical organization, with the most general, most inclusive concept at the top, and progressively more specific, less inclusive concepts at lower levels.

There is evidence that our brains store knowledge hierarchically and thus organizing knowledge in this fashion helps to acquire and use knowledge more efficiently. Building a hierarchical structure also follows Ausubel’s Assimilation Learning Theory, wherein new knowledge is most easily acquired when it is subsumed under an existing concept in our mind. Evidence from studies of experts versus novices also indicates that acquiring expertise is usually associated with better-organized, more hierarchical map structures. Building such concept maps encourages higher
levels of meaningful learning, leading to longer retention of knowledge and
greater ability to apply this knowledge in novel settings.

5. In general no more than three or four sub-concepts should be linked
below a given concept.

A fundamental consideration operates here: Usually when we find five
or more sub-concepts linked under a concept, there are maybe two or
more concepts of intermediate generality that can be added to a map, thus
increasing the detail and precision of the ideas presented.

6. Specific examples of objects or events may be added to maps where
appropriate, but these should clearly be distinguishable from concepts.
This may be done by eliminating the concept box or oval being used.

Given the epistemology or theory of knowledge underlying concept
maps, it is important to recognize the difference between specific events
or objects and concept labels for regularities recognized in specific events
or objects. By noting specific examples (not in boxes or other node
forms) helps to clarify the kinds of events or objects that are identified
by the concept label in the node. On the other hand, numerous examples
that are not needed to clarify concept meanings results in a “cluttered”
map and thus obscure the structure of knowledge we are trying to
elucidate.

7. Crosslinks should specify significant interrelationship between two
concepts in different submaps of knowledge shown in the whole map.
These are best added when the map is nearing completion.

Creative insights usually result from recognition of new relationships
between concepts and/or propositions in one subdomain of a given body
of knowledge with those in another subdomain. These kinds of rela-
tionships can be indicated by crosslinks in a concept map of sufficient com-
plexity and inclusiveness and can lead to creative insights. Partly for this
reason, if we are looking for new creative insights, it is important to plan to
build concept maps that are hierarchically well organized and large and
complex enough to optimize the chances for identifying significant cross-
links, and yet not so large as to be overwhelming. Otherwise, we might
better use submaps.

8. Concept labels should not appear more than once in a given map.

The meaning of a concept is represented by all of the propositions that
contain the concept in a given knowledge domain. Thus, to define the
meaning explicitly, it is best to use a given concept label only once in a given concept map. A map that contains the same concept two or more times can usually be restructured so that the concept only appears once. Sometimes this may require reconstruction of other sections of the map and usually this leads to general improvement of the map.

9. Resources may be added to concept maps either on concepts or on linking words when using CmapTools software. This software is described in the next chapter.

Resources can be added to concept maps to provide formal definitions of concepts and specific examples, to elaborate further on concept meanings, and attach submaps or other illustrative material. There is always the consideration of whether concept map attachments would be better shown directly as part of the map, or as an attached resource. This is a judgment call and may vary depending on the primary purpose for using the map. Any material that can be digitized may be added as a resource when using CmapTools software.

When resources are attached to linking words, one must always consider whether one or more words in the linking phrase might be better included as additional concepts added to the map structure instead, forming additional concept nodes in a revised map.

10. Additional global maps may be constructed to show crosslinks between concepts on the superordinate and subordinate concept maps. Such global maps may contain fifty or more concepts.

Often in the past, new creative insights have arisen when creative people find new important relationships between concepts in two different subdomains of knowledge. Searching for new crosslinks between concepts in different subdomains on a global concept map for possible crosslinks may increase creative insights.

Begin building your concept map, applying the above rules.

1. Find a page of a book you want to study or an interesting newspaper or journal article or website pages.
2. Select a portion of the document to be mapped.
3. Prepare a “focus question” for the selected content. A focus question indicates what key question is answered by the segment selected, or what key idea is discussed. Your concept map should help to answer the focus question.
4. Identify the key concepts in this piece. While most words are labels for concepts, some are much more pertinent to answering your focus question.

5. Make a “Parking Lot” listing the key concepts selected. If you have already downloaded CmapTools and begun to use this software, the steps that follow will be easier for you.

6. Try to reorder your parking lot items so that the most general, most inclusive concepts are at the top and the least general, most specific concepts are at the bottom.

7. Begin building your concept map, beginning with the top concepts in your Parking Lot.

8. Place all the concepts in your Parking Lot into your map with appropriate linking words. Try to build a good hierarchical structure as you build your map.

9. Add pertinent concepts you may have missed initially.

10. Revise your concept map to make it more precise and more specific. This may require finding more explicit linking words.

11. Check your map against the ten rules for good maps given above.

Revise it again if need be.

An Example: Here is an approach I have used successfully to teach concept mapping to first grade children:

I brought a Geranium plant to the classroom and proceeded to ask the children the names of parts of the plant. I pointed out that each of these words is a concept. Many other flowers may look different, but they may have the same kinds of parts. Here is the list I wrote for the names of these parts on the board as they were suggested:

**Concept List (Parking Lot) Elicited from the Students**

- leaf
- flower
- stem
- plant
- petal
- nectar
- bees
- color
- green
- orange
- roots
Next, I indicated that we needed to reorder this list of concepts from those that were biggest or most inclusive down to those that are smaller or most specific. So next we created this “Modified Parking Lot”:

plant
stem
leaf
root
green
petal
orange
nectar
bees

I then began to build this concept map on the blackboard starting with plant and asking the children where we could connect, one at a time, the other concepts. They built this concept map:

A week later, I brought in sheets of paper with a list of concepts on the top side and asked the children to use those words to construct a concept map just as the class had done a week earlier. I had five different word lists and children chose one they wanted to use. Every list was chosen by at least one student. The concept map created by Denny is shown in Figure 1.12.

Denny’s teacher was impressed with the good thinking evidenced in Denny’s map – and with all the maps created by the children.

![Concept Map](image)

Figure 1.11 A concept map about plants created with a grade 1 class.
So now that you have seen what grade 1 children can do in building concept maps, try making a few of your own. Choose any topics of interest to you and try making three or four concept maps. Go back and look at these a few days later and consider what changes you might make to improve each map. Check your map against the ten rules for good maps given earlier. By the end of this work, you should be on the way to becoming a good concept map maker.

**Testing Our Tools and Ideas in Other Settings**

In August of 1980, I accepted an invitation to be a Fulbright Senior Scholar to lecture in Australia. In recent years I had had several visiting professors from Australia and had enjoyed discussing and debating educational issues with them. All of them were also delightful to socialize with. I was based at Monash University in Melbourne, but I also was committed to lecturing at other universities in Australia as part of my Fulbright Fellowship. In the course of my five months in Australia, I lectured at universities in all Australian states except the Northern Territory. A country almost as big as the USA, Australia had only some 20 million people, so most of the country is sparsely populated “outback” or jungle.

At Monash University, Peter Fensham sponsored a seminar on educational research. I made several presentations at this seminar and received some very critical, but also very encouraging feedback on my *Theory of Education*, published in 1977. There was also extensive discussion on how concept mapping might improve education. One of Fensham’s former Ph.D. students, David Symington, worked with elementary school teachers and he wanted to see how concept mapping might facilitate learning in first through third grade classes. Some of the teachers Dave had worked with previously were interested in seeing how concept mapping might help
their students become better learners. Dave and I introduced students in grades 1 to 3 to concept mapping and also explained the difference between rote learning and learning for understanding. Both Dave and the teachers were impressed with how quickly the children caught on to concept mapping and how receptive they were to learning ideas about how to become better learners. These were some of the most encouraging experiences I had had working with grade 1–3 students, and they added to my confidence that the learning tools and ideas I and my students had developed in upstate New York could work anywhere in the world.

A concept map prepared by one of the grade 1 students David and I worked with is shown in Figure 1.13.

When I returned to the USA, I moved into our condo on Carolina Beach, North Carolina. I had accepted a position as Distinguished Visiting Professor at the University of North Carolina in Wilmington. Professor Joel Mintzes was my sponsor. Although I had agreed to do some lectures and workshops for the University, my primary activity was to write a draft of a new book that was published by Cambridge University Press in 1984 with the title, Learning How to Learn. I drew heavily on my experiences teaching two courses at Cornell University: a graduate course, Theory and Methods of Education, and an undergraduate course, Learning to Learn, plus my recent work in Australia and North Carolina. I also wanted to follow up on my experiences teaching concept mapping to elementary school students in Australia. Fortunately, I found some of the teachers in Carolina Beach Elementary School interested in working with me.

The reading specialist at Carolina Beach school was fascinated with concept maps and she thought they may very well help a student she
had been working with for a couple of years. Ricky was in sixth grade, but he did poorly on reading exams and was in danger of failing promotion into junior high school. I met with Ricky on a Thursday and began by showing him how we can make concept maps for familiar things, similar to the concept map on animals shown in Figure 1.13. Ricky appeared to be interested in working with me, so I asked him if he would make a concept map on something he was interested in. Ricky said he would. I asked what he planned to map, and he said, “motors.” When I returned the following Thursday, Ricky showed me the map he made on “Sports.” I asked, “What happened to your map on motors?” Ricky said when he started to make this map, he decided he did not know much about motors. But he sure knew a lot about sports!

Ricky showed his map to his teacher, and she was intrigued by it. She said they would be studying feudalism next week and asked if he would read this section of their history book and make a concept map for it. The map Ricky made is shown in Figure 1.15. The teacher was so pleased with it she asked Ricky to present it to the whole class. He did this – and also made concept maps for other things his class was studying. The positive remarks by his teachers and classmates were a great ego boost to Ricky and his performance in all areas of study improved markedly. He was promoted to junior high school in June. This is just one case of hundreds we have experienced where helping learners become better meaningful learners changed the course of their lives.
Learning How to Conduct and Interpret Clinical Interviews

As noted earlier, using clinical interviews with children was the only reliable and valid way we could find to assess children’s learning of science concepts. Over the years my research teams became very skilled in conducting and interpreting interviews. Once again, my students were telling me something that I had not incorporated into my earlier work as an educator. Teaching students how to design, conduct, and interpret clinical interviews was a great way to help students become better learners. From the mid-1970s to today, I see learning how to design and use clinical interviews as a major foundation for learning how to be a better learner. Interviewing subjects and concept mapping these interviews provides a window into the cognitive and affective structure of the subjects, insights into the concept/propositional knowledge of the interviewees, and their feelings about this knowledge. Designing, conducting, and evaluating interviews became a major portion in my Learning to Learn course and my Theory and Methods of Education course.

To introduce my students to interviewing, I first showed video clips of interviews done by me and my graduate students working on our twelve-year longitudinal study of children’s science learning, and other research projects. Later I also had some good videos of interviews done by students in my classes as part of the required class work.
Prior to planning an interview, I had required my students to learn basic ideas of Ausubel’s Assimilation Learning Theory. I also tried to help them understand something about the nature of knowledge, namely that the building blocks of knowledge in any field are concepts and propositions. The essentials of this information were presented earlier in this chapter and were part of the first few weeks of my courses. I also introduced them to one of the few educational principles that research has solidly confirmed, the principle of wait time. Mary Budd Rowe (1974) and her students found that, on average, teachers wait only 0.7 seconds for a student to respond to a question before revising the question or asking another student to respond. She called this interval between teacher’s questions and student’s response or moving to another student or restatement of the question wait time. Rowe found that only questions requiring essentially rote recall of information can get valid response with this short wait time. If wait time is increased to at least 3–4 seconds, questions may require more thought and student answers can be more thoughtful. The point I wish to make here is that when doing a good interview, we should ask questions that require some thought and reflection on the part of the interviewee. While some good questions might be responded to in 3–4 seconds, questions that require 15–30 seconds for a thoughtful response result in more thoughtful answers and a better interview.

When you do your first interviews, have a watch or clock in view that clearly shows the seconds elapsed. You may be amazed at how a wait time of 30 seconds really feels like forever. As you gain experience interviewing, you will find you are using better questions, probing more deeply into your interviewee’s cognitive and affective memories. You can become comfortable using wait times of 20 to 40 seconds or more.

The challenge for the interviewer is to design questions in such a way that they will elicit the interviewee’s concepts and propositional ideas about whatever topic she/he chooses to study. The first step is to prepare a concept map of the domain of knowledge about which you choose to question your subjects. This map will suggest not only the questions you need to ask but also the sequence to use in asking the questions. In general, it is always best to begin with the most general, most inclusive concepts. All interviewees should be able to respond to these questions, whereas many or even most may not be able to respond to questions dealing with relatively minor, specific concepts that might be included in the lower sections of your planning concept map.

It is helpful to select one or more props to use in an interview. The prop may be as simple as a photo or as complex as an apparatus used in studies
in this field. Asking pre-planned questions about the props helps to standardize the interview administered to different subjects making comparisons between subjects more valid. Figure 1.16 shows some of the props used in an interview in our twelve-year study. One of my graduate students is interviewing a grade 12 student about materials in a jar dealing with the nature of matter that were studied in grade 2.

Of course, there are always surprises when one begins to interview people about any subject. So, one must be prepared to modify the concept map you began with and then the questions or question sequence. The goal is to get the best possible insight into each subject’s concepts and the propositions they think with on this subject. It is also important to try to elicit their feelings about the ideas they present. Later in this book I will discuss other strategies to get insight into the role of feelings in learning and using knowledge.

I required each of my students to select a topic they felt they knew well and to design a clinical interview to be conducted with ten subjects. They were free to select any subject matter and any age group they wanted to work with. Planning, conducting, and analyzing interviews with ten subjects can be very time-consuming, so I urged my students to choose
carefully the topic of their study. Planning, conducting, and preparing a report on their study were to be 50 percent of their course grade. My students invested some 30 to 60 hours planning, conducting, and preparing their written report on their project. Student feedback on this work was very positive.

Figure 1.17 is a concept map made by one of my students to guide her in her interviews. I chose this example because it involves both thoughts and feelings. It is also a subject that all of my readers can relate to.

Guided by her concept map, she proceeded to interview ten friends who were willing to cooperate. As she proceeded with her interviews, she found that her subjects placed more emphasis on experiences other than math anxiety, unlike what she had initially expected. In later interviews she probed these alternative thoughts and feelings more than in early interviews. The result is partly evident in the concept map she made for one of her later student interviewees shown in Figure 1.18.

This student found that due to good planning, she was successful in eliciting the thoughts and feelings her ten subjects held about anxiety with the math they had studied. She also found that those subjects who felt the least anxiety about doing math were students who saw ways to use the math they were learning and felt they had mastered the ideas taught. Taken all together, she felt she had gained some good insights about math education. One of her conclusions was that supplementary tools such as workbooks and the use of concept mapping could be helpful in learning math and reducing math anxiety.

Over the years, we have come to appreciate that learning to construct, administer and concept map clinical interviews is not just a tool to be used to help us understand the nature of knowledge and how people store and use knowledge. Acquiring the skill to plan, execute, and evaluate clinical interviews has value in almost every kind of learning challenge you will encounter in your life. As we continue with this chapter and the other chapters of this book, we shall illustrate in case after case how this process was employed to capture and organize knowledge of others in ways that facilitated the use of that knowledge.

Not only were my students learning how to design, conduct, and evaluate interviews, they were also gaining insight on the nature of cognitive learning in human beings. They were observing how the subjects combined concepts to form propositions and how these propositions were organized into hierarchical structures. They were acquiring what has come to be known as metacognitive knowledge (Kuhn, 2000), or knowledge about cognitive processes in human beings. They see these knowledge structures
Figure 1.17 A concept map prepared to guide an interview about math anxiety.
Helping People Create New Knowledge

Important as our research team’s work over the past sixty years has been for helping people learn in school, work, or informal settings, we believe our greatest achievements have been in developing the theory, ideas, tools, and strategies to help people create new knowledge. As noted earlier in this chapter, we see creative thinking as essentially what occurs with very high levels of meaningful learning. Therefore, the same tools, ideas, and methodologies we have presented to facilitate meaningful learning can be employed to facilitate creative thinking. We present below one example of this done by one of my graduate students at Cornell University.

As a result of successful collaboration on projects that I had done with colleagues in plant biology at Cornell University, I was able to persuade...
one professor to encourage his students to use concept mapping to assist in planning, conducting, and reporting their Ph.D. research. Christi Palmer had studied with me, and she decided to see how concept mapping might help her plan and conduct her Ph.D. thesis research in plant pathology.

There was an interest in the Plant Pathology Group at Cornell to see if they could find some way to retard or prevent formation of grey mold that was killing a number of crop and ornamental plants. Christi began as any good researcher would; she studied all the pertinent literature she could find dealing with grey mold infections and treatments. Christi began building a concept map to show all the key ideas and questions she could identify from the literature. She built a concept map showing what concepts and propositions she found validated in the literature, and where there were significant questions remaining. She identified six possible linkages between concepts regarding preventing grey mold that were not answered in the literature to date.

Identifying potentially promising questions to study is usually the hardest part in any area of research. Once good questions are clearly specified, it is usually relatively easy to conduct the research needed to answer these questions. Unlike the field of education and some other fields, most fields of science have well developed theories, principles, and methodologies for solving problems and answering questions.

Christi did the necessary experiments and reported what she found in her Ph.D. thesis. In her final oral exam, her graduate committee complimented her on the quality of her thinking and clarity of her report on the results of her studies. The concept map Christi developed to guide her research is shown in Figure 1.19.

In subsequent chapters, we will build further on the foundations developed above to help you build your understanding of how we learn and how we create new knowledge. In the following chapters, we will take you through our continuing journey to help people learn up to the most recent work we and others are doing. This will include new educational strategies that show promise.

The evolution of personal computers and the development of the World Wide Web had not yet occurred when I wrote *Learning How to Learn* in 1981. The Digital Revolution was yet to come. The impact of this revolution on teaching and learning transformed our world, and this process continues today. The explosive development of cell phone technology is in many ways even more revolutionary, allowing anyone to hold virtually all of the knowledge in the world in the palm of their hand. What we hope to do with this book is help you see new ways to benefit from
these extraordinary developments. We cannot even imagine what the next Apple or Facebook company will do to open up better ways to help people learn. We can be certain that more revolutionary changes will come in technology, and these will have profound effects on how people learn and how they interact with one another.

In the next chapter, I shall describe some of the things that we have done at IHMC that are having a very positive impact on efforts to help people learn.

Figure 1.19 Christi Palmer’s concept map on bicarbonate salts is based on pertinent literature and her six Ph.D. thesis research questions derived from concept mapping key ideas in the literature (Palmer, 1996).