Making a Difference

In Spite of Difficult Academic Politics, A Cornell University Professor's Lifelong Journey to Improve Education and Knowledge Creation Succeeds

My Professional Biography

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Acknowledgments

Throughout my career, I have enjoyed the support of my students, who provided constructive feedback on my teaching and counseling. They have also been the best critics of the ideas I have put forward, and helped me to build and refine both the theoretical foundations for our work and the tools and practices we have developed. This was especially true for the development of the concept map tool for representing knowledge, now being used all over the world in school and work settings for all ages and in all fields of knowledge.

I am deeply indebted to the Florida Institute for Human and Machine Cognition, led by Ken Ford, and especially the work of Alberto Cañas and his team for creating the powerful software CmapTools, that facilitates the creation and use of concept maps. He has also helped people all over the world to use this software. Alan Ordway has quickly resolved my computer problems as they arise.

There have been many long, intensive days and weeks during the six decades of my work. The love and caring of my three children and especially my wife, Joan, have sustained and motivated me, and they continue to be a source of energy for my work. Joan continues to be my most valued critic and counselor.

I am fortunate to have been employed by great universities with great scholars who were an inspiration to me. Joan and I also visited other great universities worldwide and enjoyed sharing our time with other outstanding colleagues. Cornell University was an ideal setting for me to carry on my work for 28 years. Many fine visiting professors joined me at Cornell, and our collaborations continue to this day.

It has also been my good fortune to have had some 350 graduate students and visiting professors over my career, plus numerous coauthors of publications and collaborators on projects. I am indebted to all of these for important ways they have helped me both professionally and personally.

It remains to be seen whether the Theory of Education we created will someday lead to significant improvements in education, including learning in school, home, and workplace. I remain committed to the idea that just as good and evolving theories in the sciences have led to incredible advances, our best hope for radical improvement in education depends on building good theory. Time will tell whether this claim is valid.

Most of the photos and other figures are my own or from my projects. A few are from public sources.

Finally, I wish to thank my friend, James Kelleher, a 30-year veteran English teacher, for editing the entire manuscript. Drawing upon his long experience, he devoted his time not only to suggesting many corrections, but also to encouraging the completion of this project.

Synopsis of the Book

This book presents the story of my lifelong effort to improve teaching and learning, not only in schools but also in all settings where learning should occur. Trained as a scientist, I have also worked to develop a comprehensive theory of education. This book presents my personal story, from my early days in a poor but loving family, to marriage and raising children, to dealing with academic politics. It presents some of the professional battles I have had to deal with, and in later sections it also presents some of my successes and honors received. While the focus in this book is on my professional career, I include comment on my family, since they were so much a part of why I persisted in my professional efforts to improve education and learning.

The book begins with the story of the family in which I grew up. I was born in 1930 in the depths of the Great Depression, when it was a struggle for my parents to provide the necessities for daily living, which they managed to do. As the economy improved, so did conditions in our home. Through all of this, my parents never failed to support my brother, my sister and me, providing not only basic necessities, but also experiences with music and learning that gave us all the confidence that we could go to college and we could enjoy good lives. My dad was especially supportive of me and assured me many times that I could do anything I chose to do. He also taught me the important lesson that there are many false prophets, and when someone tells you something that doesn't make sense, it is probably wrong. Repeatedly, this counsel guided me in my work.

My family, with parents seated and me with my older brother and sister, 1943

My career was essentially three careers, the first as a biologist and biology educator, the second as a teacher educator preparing teachers for school teaching in math and sciences, and a third career helping people to learn how to learn in both school and many other organizational settings. Throughout this work, my wife Joan was a constant supporter, as well as a very successful mother and partner. Our three children were a constant source of joy to us. They also helped me to see the extraordinary capabilities that children can evidence when they have the support and guidance every child deserves. They helped me to see that some popular ideas in education could not possibly be valid. All three went on to successful careers and happy marriages. More stories about their lives are presented in this book.

Daughter Barbara Age 6, son William, 5 and Son Joe, 7.

I was fortunate to have great support and guidance from key faculty and administrators in my three positions, first at Kansas State Teacher 's College in Emporia, then at Purdue University in West Lafayette, Indiana, and finally at Cornell University in Ithaca, New York, where I worked for 28 years before retirement in 1995. I have been blessed with having more than 350 graduate students and visiting professors work with me, and from whom I learned so much. Following retirement from Cornell University, I enjoyed the opportunity to take the tools and ideas we developed in our education programs to the corporate world, starting with Procter and Gamble from, 1993-2003. In 1987 I began work with colleagues at the University of West Florida in Pensacola, and then increasingly with Florida Institute for Human and Machine Cognition (IHMC). This collaboration continues today.

While at Purdue University, I worked with Professor Samuel Postlethwait to develop a method of instruction we called Audio-Tutorial Instruction. With

this system, students are guided through activities with various items pertinent to a lesson by the use of audio-tape. I adapted this approach for instructing elementary school students to build their understanding of basic science concepts, such as the nature of matter and energy, plant and animal growth and other basic science concepts.

Second grade child working on A-T lesson dealing with transformation of electrical energy into heat, light, and motion.

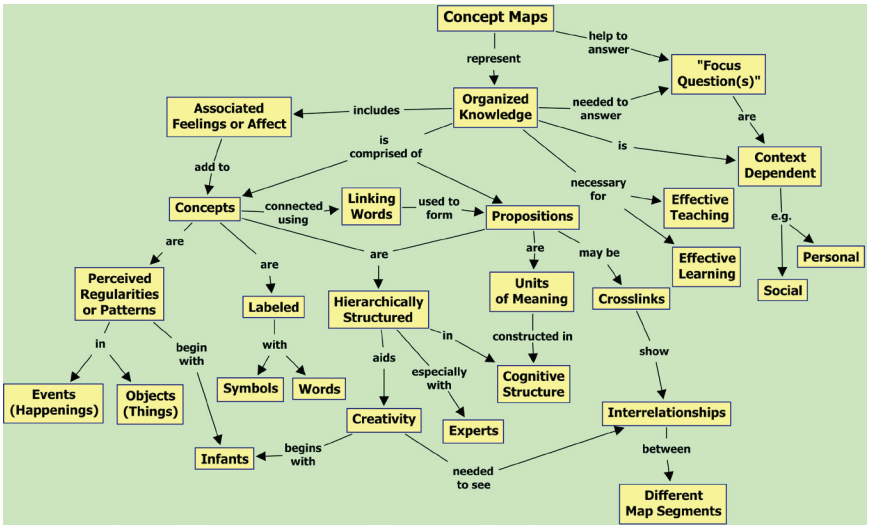
While it was evident to us that the children were gaining an understanding of basic science concepts, we needed a better form of assessment to convince our critics that substantive science learning was occurring. We found that the usual kinds of assessments of children's learning were not effective for our needs, and this led our research team to develop in the early 1970's a new knowledge representation tool we called **concept maps**. These maps could show precisely the new concepts and propositions the children had acquired, and as noted below, these are the indicators that meaningful learning had occurred.

The idea for what became concept maps grew out of two different lines of thinking. The first was the evolving idea that all knowledge is made of concepts, and we defined concepts as perceived patterns or regularities in events or objects, or records of events or objects, designated by a symbol or word. New concepts are invented by creative people, and they may become modified over time. The other important characteristic of knowledge is that we connect concepts with "linking words" to form statements about objects or events. This view of the nature of knowledge complemented David Ausubel's psychology of human learning which viewed learning as primarily the process of gaining new meanings of concepts and propositions, and not conditioned behaviors! We designed our Audio-Tutorial lessons to present children with opportunities to observe patterns in science events or objects and to help them acquire the correct language labels for these things. I held the latter

view of the nature of knowledge and the nature of human learning. This view led to the invention of the concept map tool as a method for representing knowledge. Over coming decades, we found that concept maps and the ideas that underlie them could be applied to any subject matter at almost any age.

As our work progressed, we found that concept maps could be used not only for assessment of learning but also for the facilitation of learning. In fact, we found that concept maps could be used for a wide variety of purposes, and we initiated a wide range of studies demonstrating these uses and the value of this tool.

In our early work, the concept maps we used were all drawn with pencils and pens. After 1985, when desktop computers became more common, I worked with colleagues at the Florida Institute for Human and Machine Cognition (IHMC) to develop software that could be used to easily construct and modify concept maps. Later these computer based tools also provided for the attachment of any digital resource to a concept as an icon. Subsequently this resource could be accessed by simply clicking on the icon for the resource. Thus it became possible to create what we called a knowledge model or portfolio. These are described in later chapters of this book. The CmapTools software developed by IHMC was used to make the figure below. We found that building such concept maps and knowledge portfolios could facilitate student learning and creativity in any subject matter area.



A concept map showing the key features of concept maps prepared using CmapTools. This figure is the most requested figure from all of my publications. That paper is in Appendix 7.

Concept maps also became a tool for capturing and archiving expert knowledge in any field, and enhancing creativity in any field. It was largely this application that led to my third career in helping experts in any field better organize and use knowledge in new, creative ways. In addition to facilitating learning in school and university settings, we found that any corporation or other organization could benefit from the use of the concept mapping tools. NASA, the Department of Navy, the Electric Power Research Institute, the National Security Agency and other organizations found value in the use of concept maps, and provided the funding needed for IHMC to refine and enhance what are now called CmapTools. The software can be downloaded by anyone, free of charges, at: http://cmap.ihmc.us Concept maps are now being used in many settings all over the word.

Important as the invention of concept maps was for our programs, they evolved as my research team made progress to understanding how people learn and how to facilitate learning. The book, Learning How to Learn was published in 1984, and subsequently translated into eight other languages. The work of David Ausubel and his assimilation theory of learning, published in 1963, helped our research team advance in our work. In 1978, I coauthored a revision of Ausubel's1968 book, Educational Psychology, A cognitive view, with most of my work centered on key chapters that dealt with the nature of human learning. Also critically important were our efforts to better understand the nature of knowledge and knowledge creation. In all of our later work, we came to see that the fundamental building blocks of knowledge are concepts and propositions, the latter comprised of two or more concepts connected by linking words. These comprise the structure of knowledge in any field, and concept maps are a tool for explicating that structure.

Propositions are also another name for the meanings that humans build as they learn. In my work, I have also emphasized the important role that feelings play in human learning. What the master teacher does is not just to help her students acquire the meanings for important concepts and propositions, but also to acquire strong positive feelings coupled with this knowledge. Ausubel's work emphasized the distinction between rote learning and meaningful learning. In rote learning, little or no effort is made to integrate new concepts and propositions with pertinent existing concepts the learner already knows. In meaningful learning, the learner seeks the integration of new knowledge with relevant knowledge they possess. When this is done well, strong positive feelings accompany such learning. In my work, I give high emphasis to both the acquisition of new meanings and also to the concomitant acquisition of strong positive feelings. Every reader of this book can recall the strong posi-

tive feelings she/he experienced when the meaning of an important idea was grasped.

As the work of my students and myself progressed over the years, we found increasingly that rather than representing a small minority view for improving teaching and learning, many of our ideas were becoming accepted by the mainstream in what was sometimes referred to the "Cognitive Revolution" that took place in the late 1980's and 1990's. There was also increasing international recognition of the value of our work, and late in my career I received Honorary Doctorates at important universities in Argentina, Spain and Italy. Most recently our work has engaged some excellent scholars in China. A Chinese translation of my latest book was published in 2016.

Although I no longer do international travel, I began a new collaboration with colleagues at Beijing Normal University. Several of my former students, Alberto Cañas, who led the development of CmapTools at IHMC, and other colleagues have joined to explore ways to introduce our work to the Chinese.

We are also working to explore ways that concept maps might be used in conjunction with functional neural brain imaging (fMRI) studies to learn more about the basic mechanisms of brain function. It may be that these new endeavors will do much more to improve human learning than was accomplished with concept mapping and other tools and ideas we have developed. My story goes on, but only God knows how long this will continue.

As I enter the twilight of my career, I am blessed with the continuing love and support of my wife, Joan. I am also enjoying the accomplishments of my children and grandchildren, and since 2014, the smiles and antics of our great granddaughter, Noelle. Life has been good to me, and I hope I have made some contribution to the lives of other people.

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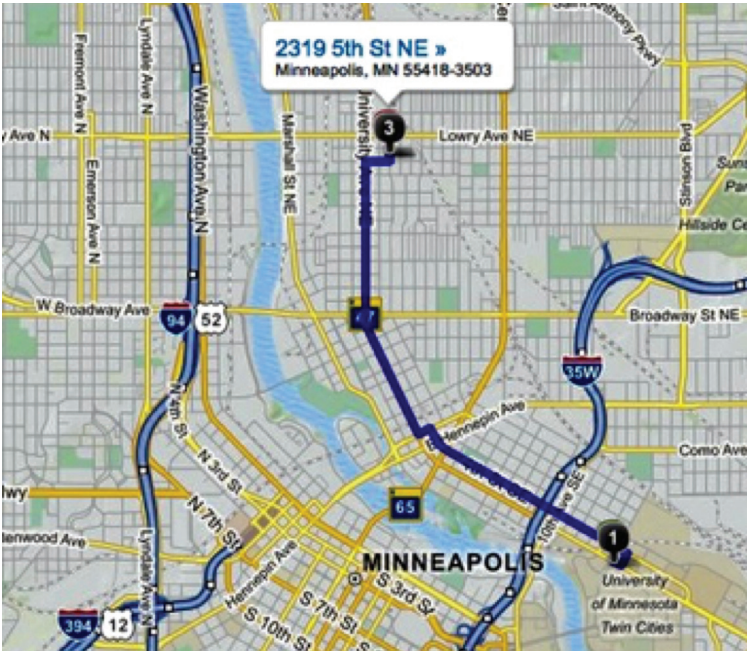
Chapter 1

My Early Years

My Modest Home

I was born on a cold December 2 morning in 1930. A midwife assisted my mother, and I was born in the bedroom of my parents home, a house originally built by my mother's parents. My sister Eleanor was also born in the same bedroom on January 6, 1928. My older brother Dick was born in 1925 in an apartment my parents rented when they were first married. Weighing over nine pounds at birth, Mom said I was happy, healthy, baby boy.

My mother grew up in Northeast Minneapolis. Her dad built the small house in 1901. There was also a barn that housed chickens and a Jersey cow. The family ate most of the eggs produced, but they sold some of the milk to neighbors who did not have a cow. As a young girl, my mother took the cow to local fields to graze during warm weather. There she joined girls who were also watching their family cow.



MapQuest map of my home area (dark circle). University Avenue runs 2 blocks west of my home and past the University of Minnesota. The orange road to the right is Central Avenue where I worked. Expressways did not exist until the 1960's.

Our home was located in a blue-collar neighborhood, at 2319 5th Street in NE Minneapolis, Minnesota. The above map shows the area. The home was 1 ½ blocks South of Lowry Avenue, a main East - West road. The house was about two blocks West of the Great Northern Railroad tracks, a major North - South railroad. Our home was on what was once the floodplain of the Mississippi River, and the land rose rapidly a few blocks East of Central Avenue. The homes at the higher elevation were generally better than those in my neighborhood, and I grew up literally and figuratively on the "lower side of the tracks".

My Dad had emigrated in 1923 from what was then Austro-Hungary and is now Slovakia. He grew up in the village of Dubova, about 40 miles NE from the capital city, Bratislava, and 100 miles south of the border with Poland. Life in Dubova was not easy where most of the people survived by farming small farms and raising chickens and occasionally a cows, pigs and a horse. Dubova's school went only to grade four, and this was all the formal education Dad had. During the revolutionary war, Dad's family was poor and he arrived in the USA in 1923 with little more than the clothes on his back. Two of Dad's sisters and three of his brothers had immigrated to the USA prior to my Dad's arrival.

Dad tells the story that he had to wear his suit coat to cover a hole in his pants, even though these were hot summer days at the time. He had no other dress clothes. Dad lived with his brother Nick near 15th street and 5th avenue, in Northeast Minneapolis. Another brother, Dan, lived near 23rd and 5th street, and Dad frequently visited there. The Podany family lived next door to Dan, and soon Dad saw and was attracted to their daughter, Anna. The Podany's were also from Slovakia, so they shared the same language and culture. Anna and her older brother, John, were both born in the USA. It was not long before Dad and Anna began dating, usually just walks around the neighborhood, since money was tight. My parents were married February 9, 1924, and took up residence in an apartment on Lowry Avenue, a few blocks from the Dan Novak's and Podany's family homes (see map on page 9).

Mom's Dad died in 1915 from tuberculosis when my mother was nine. Her Mother, Julia, was a good cook, and the family survived by housing several boarders, most of whom also came from Slovakia. It never occurred to me to ask my mother where everyone slept in the small one bedroom home. As my grandmother got older, she could no longer manage doing all the work associated with having borders, and she was financially in trouble. Uncle John signed an agreement with my parents giving them ownership of the Podany home in exchange for lifetime care for my grandmother. Surprisingly from

my perspective, the arrangement worked well and my grandmother lived with us almost until she died in 1945 at the age of 72.

My grandmother was a very warm, loving person and I felt very close to her, as did also my brother and sister. She often defended what we did, even when we were a bit out of line and our parents were angry with one of us, most often my older brother, Dick. A coal stove in a corner of the dining room heated the house. I remember how cold it was on mornings when the temperature was below zero, and how delighted I was when my parents installed central forced air heating in 1937. Also in 1937, a manual hot water gas heater was attached to the hot water system, and we turned this on for weekend baths or on other occasions. It was not until 1945 that an automatic gas water heater was installed.

My Dad, A Big Influence On Me

Dad learned the upholstery trade and in 1929, he opened up an upholstery business a mile away from home on a main street called Central Avenue. Next door to Dad's shop was Central Cleaners, owned by Peter Chorakis. Dad and Peter became good friends. The cleaners later moved several blocks north, and that is where I would begin work when I was 13. Although he had found several good customers, for most people, redoing their furniture was the last choice of a place to spend money during the depths of the Great Depression that began in 1929. By 1931, my Dad found it necessary to close his upholstery business and to conduct his work from the basement of our home, a basement recently added beneath the house. While this helped with the expenses, customers for his services were hard to come by and the family struggled to make ends meet.

My Dad had also learned to play the accordion, and playing at weddings or "hard times" parties supplemented the family income. Dad was usually paid in "tips" offered by people at the party. I recall going into my parent's bedroom the morning after a Dad played a job and seeing what looked to me like a huge pile of coins on the dresser. In fact, the coins probably totaled no more than $5-10, but for a kid who thought 10-20 pennies was a goodly sum, my Dad's earnings seemed enormous. In 1935, Dad's earnings kept the family getting by from day to day. As a toddler, I spent a good deal of time with my Dad, hanging out in the basement while he worked. When I was older, Dad was always there to help me fix things, such as re-greasing my wagon's wheel bearings.

Dad and his accordion, Christmas, 1972 . Though Dad had only a 4th grade education in Dubova, Slovakia, he was very wise. He often said, "if something doesn't make sense, it is probably wrong.

My Dad was very active in local, state and national politics for many years. A strong supporter of Franklin Roosevelt's New Deal policies, and local Democratic candidates, I recall that as a child, I delivered literature with my Dad to homes in our neighborhood, supporting Hubert Humphrey first for Ninth Ward Commissioner, and then for mayor of Minneapolis and then as senator for Minnesota. Although I had only limited understanding of the issues, I felt that what we were doing was important and part of being a good citizen. I recall also that Dad's good friend, Peter Warhol lost his job as Secretary of the Minneapolis Upholsters Union when he came under false attacks from Senator Joseph McCarthy's terrible communist witch-hunts. The lesson for me was that politics can be important, and it is worth fighting for what you believe is right

According to my parents, I asked a lot of questions about how things worked even as a toddler, Since Dad worked in his basement shop when I was young; I spent a lot of time with him. Even as a young child I remember asking Dad questions that had no simple answers. Though Dad sometimes could not answer my questions, he usually tried his best. I also remember Dad's counsel that he often said, "If something doesn't make sense, it probably is wrong." I

don't know how often he said this, but it was a message that stayed with for my whole life!

During my youth, I did not spend much time with my brother Dick. He was more than five years older than I, and he had a number of same age friends in our neighborhood to play with and to pursue other activities. Though my sister was two years older than I, we often played together when we were young. We enjoyed doing many of the same things both in the house and outdoors. We often "played house" together making a house using a card table and some old sheets. We also played games together both in the house and outdoors. We often went to the movies together, or played card and board games together. On Sundays, Ellie and I usually sat on Dad's lap as he read the comics to us. He was warm and patient with us, even when we asked him to re-read one or more of the comics.

Sister Ellie and I were very close friends in our youth, shown here at ages 10 and 8.

Later Ellie and I washed dishes together and we often paused our work to dance to a popular tune on the radio. For many years, we danced to songs on Your Hit Parade, which was broadcast on Saturday evenings. We continued to be close friends as adults.

Ellie was always a little short on money, even though she did baby sitting and other work as a teenager. Dad always stepped in to help Ellie when she needed help. Ellie married an alcoholic, and their marriage slowly deteriorated. With four children, and a single mom after her divorce, it was hard to find decent rental homes, so Dad stepped in and bought a house for Ellie with the understanding that she would make monthly mortgage payments. Dad did a lot of repair work and upgrading on the house, so it did permit Ellie to have

decent housing until her children grew up and went on their own. The lesson I learned is that when you make a commitment to someone you care about, you don't back out when you hit some bumps in the road.

Dad was always doing projects around the house, and I usually stood close by, helping when I could. As I got older, Dad often asked me to do little projects, such as repairing a light switch or painting a room. These little jobs helped me develop confidence in my ability to do almost anything around a house. At age 14, Dad's car needed a motor overhaul, and Dad asked me to do this, even though previously I had never done more than change spark plugs. Dad said he knew I could do the job by keeping track of the parts as I took the engine apart and then putting things back in the same order, including new rings and rod bearings. You can imagine my delight when the car started up and ran just fine when I had finished! Dad often said, if someone else can do it, you could do it!

When Dad's 1940 Dodge needed a motor overhaul, he asked me to do it. I was apprehensive since I had never before done more than change spark plugs. He said I know you can do it, so I took the motor apart, had the machine shop come and hone the cylinders and grind the valves, and then put the motor back together. When the motor ran perfectly again, this was a tremendous confidence builder for me

My Youth Were Formative Years

Our church sponsored a Boy Scout troop and most of my cousins were in the troop. I joined the Boy Scouts at age 12 and participated in various scout activities, including summer camp. I always liked cooking, so I was often the camp cook for our troop's outings -- and earned a merit badge in cooking. Our troop was sponsored by our church and we met on Church property. I was not eager to earn merit badges and some of the other formalities of the Scouts, but I enjoyed getting together with the boys, camping and other outings. I did earn merit badges in cooking, cycling, and a few others, and I did get promoted to First Class before the troop disbanded.

Soon after I joined, our troop, members agreed to serve as altar boys during masses on Sundays. At this point, I did not have much interest in church services, but I participated anyway. World War II was in progress and our troop also participated in collecting scrap metal and other patriotic activities. One of the highlights was a week at the annual Minneapolis Acquatennial Fair where we assisted in some activities and paraded on our bicycles in the Fair. We stayed for the week in army tents on the Parade Grounds, sleeping on army cots and being fed in a mess hall staffed by army cooks. I got a bit of taste for what Army life was like, and I decided this was definitely not for me! We never succeeded in recruiting a scoutmaster for our troop and it disbanded when I was 15 or 16.

Me in my scout uniform at age 14.

School enrollments were shrinking in the 1940's due to the drop in births during the Great Depression. In 1942, my elementary school was closed and most of us who had begun school in January were skipped ahead a semester, placing me in a junior high school that had been combined with the local Edison high school. The high school students were not happy to see us in their school, and junior high was not a good experience for me. However, I did meet new friends there and many remained close friends through college and beyond.

On the whole, I thought our teachers were pretty poor, especially our junior high science teacher. Her name was Edna Gans, and she had been placed to

teach science due to the science teacher shortage caused by the war. Her science knowledge was so poor I recall correcting her on a number of occasions, since I was very interested in science and I used to quiz my brother who had been taking high school science classes. Coincidentally, I later worked with Edna Gans' brother, Leo, when he was Vice President of Bobb's Merrill Publishing in Indianapolis, Indiana. The company published a Grade 1-6 elementary science series for which I was the principal author. There is much more to this story presented later in this book.

On the whole, my family life was relatively pleasant, even in the years when the family had very little money. Many Sundays the family went to the Palace theater downtown and saw a movie or two and an interesting Vadaville show -- all this for a 10 cent ticket! We almost always took a summer vacation, albeit primarily to visit relatives in other states. Many of these trips included a stop in Chicago, usually staying with Uncle and Aunt Peter Novak. We did make one vacation trip to Northern Minnesota, staying in a cabin belonging to my Dad's coworker. We all thought this was great fun, although my Dad still preferred visiting relatives.

In most of my classes in junior high and high school, teachers stressed little other than memorizing information for tests. My high school English teacher, Miss Fish, and my physics teacher, Sam Drage, were exceptions. I really enjoyed their classes because they asked questions that made you think about the real meaning of what we were studying. I was not a serious student in junior or in senior high school, partly because I was working at Central Cleaners after school and on Saturdays and partly because I had other interests such as tinkering with things, gardening, and social activities. I never received less than a C grade, but I did not often earn an A grade. My parents never urged me to get better grades, and in general, they were satisfied with my school performance.

The six years I spent at Edison High School, named after Thomas Edison, were largely uneventful. I was too small to take part in most schools sports teams and wrestling or track did not interest me. Since I worked after school every day, there was also no time for most sports and other school activities. I did play a part in a musical performance, Shamrock Serenade, in my Junior year, singing and dancing in the show.

Throughout junior high school, I went ice-skating at one or the local parks almost every evening in the winter. Most kids in Minneapolis went skating every day during the winter, so it was a good place to meet friends and make new friends. I often met some of the girls in my classes at the ice rink, but I

did not start dating girls until my sophomore year, usually going to a picnic or other outing. I was Vice President of the boys Hi-Y club in my junior and senior years, and one of my duties was to arrange parties and outings such as wiener roasts and sleigh rides.

The photo below shows me and some of my friends on a sleigh ride. I dated Joan Bircher on this occasion, a gal I found very attractive (as did many other boys), and she was also a good dancer. Joan "went stead" with a couple of my classmates through most of high school, so I did not date her again until my sophomore year in college. On this occasion, I was surprised to find that my early attraction to Joan Bircher had faded, and I did not call her again. Another girl I frequently dated in high school was Mary Jane Hanson. We enjoyed each other's company, but there never was that special spark between us. The second photo below shows Mary Jane and I before our high school senior prom.

Joan Bircher and I on a sleigh ride with Chuck Roberts (on left), & Harold Nelson. We were good friends through high school and even today. Chuck died in December 2014.

On a recent visit, I found Edison much the same as when I was there, but with better lighting. The school had changed roles and now served as the location for a number of programs for special needs students. From the outside, Edison looks the same today as when I attended. Inside the major change was that rooms and halls were no longer all beige color but a variety of colors. Edison had almost no green areas other than narrow boulevards. I was surprised

to see the extensive green areas around newer high schools in more affluent communities when I began to travel to other schools for football games.

Forming a Lifelong Commitment

My parents attended a Russian Greek Catholic Orthodox Church several blocks from our home. When I was young, church services lasted for 3 hours and most children found it impossible to sit or stand for the whole service. The first experience I had when attending church was one of great awe. Our church had many beautiful murals and many gold gilded ornaments and statues. The large dome above the central section of the church had angels flying in the clouds. I thought it was magical the way all of the events of the mass proceeded, including the priest moving through the congregation dispensing incense. The photo below shows my parents at their 50th wedding anniversary in St Mary's Church. Note the guilt splendor of the interior. The idea that God could do anything and that we must behave with reverence when in the church impressed me deeply.

St. Mary's Russian Greek Catholic Church, front view, 2011.

My parents renewing vows for their 50th anniversary at St. Mary's Church. Note how ornate the church is!

As I learned some of the stories of the Bible, I was fascinated by the message that we must strive to do our best to help other people. I believe it was probably some of these early experiences in the church and with the stories about the church that made me believe I should strive in my life to do something to help other people. Sometime in my early teens I believe I lost what had been the beautiful experience of religious belief. I thought maybe I would regain that beautiful, mystical experience of religion later in life, but so far that has not happened. Nevertheless, I do believe that my early experiences with the church and perhaps religion contributed to my lifelong commitment to see if somehow I could do something that would make a positive contribution to society. I read about the great inventors such as Thomas Edison, for whom my high school was named, and thought perhaps someday I might invent something that would improve the lives of people. My career has been essentially a lifelong effort to help people by improving education.

In spite of the magic that the church and religious teachings held for me as a child, by the time I was a teenager I begin to doubt many of the teachings of the church. In college I read a number of books on the history of religions, and these readings further eroded any religious beliefs. These readings illustrated how religions borrow beliefs and rituals from one another and this led to real questioning of the validity of any of these beliefs. I became aware of the very long history of religions, and recent archeological studies suggest that even Neanderthal man had religious beliefs 50,000 years ago. Nevertheless, I respect the religious beliefs of others and support their right to promote their religion. My wife Joan went to Catholic schools for 12 years and she has some deeply held views on religion, while also recognizing some of the many

transgressions of the Church over two millennia, and more recently with the sexual abuse scandals that have plagued the Church. The recent film, Spotlight, dramatizes some nefarious Church activities.

The Eastern European people I grew up with were always singing and dancing at almost any kind of occasion. Since my Dad played the accordion for some of these events, I was exposed to a variety of songs and dances. I was very interested in pop music and regularly listed to The Hit Parade and other programs that featured contemporary music. As noted earlier, my sister, Eleanor, was two years older than me, and she taught me many dance steps including polka, shottish, waltz and lindy. We often danced in the kitchen when washing dishes together and listening to the radio.

In our teen years, the war had taken most of the young men, so I was often the only dance partner Ellie had. In 1948, we both enrolled at the University of Minnesota, so we went together to the welcoming dance for new Freshman students. Since we had done so much dancing together, we must have stood out in this crowd, and we were surprised to see a large photo of us dancing in the Sunday society section of the Minneapolis Star-Journal newspaper with the caption, Freshman boy meets Freshman girl!

Even though none of the adults in my life during my childhood had attended college, from a very early age I knew that I wanted to go to the University after I graduated from high school. I knew I would have to finance my own education. Partly for this reason, and also to have some money to buy small gifts for my parents and siblings, I sought ways to earn some money. My first "job" was to walk to the neighborhood bakery to pick up a fresh loaf of Jewish rye bread, which my mother used for sandwiches and meals the next day. A one pound loaf of rye bread cost $.09 at Blackey's bakery, and the penny change from the dime I carried to the bakery was mine to keep. Over the weeks, this plus other small cash gifts were enough to save up for a small Christmas gift for my parents and my brother and sister. Occasionally I treated myself to some candy or a one-cent roll of caps for my pistol.

At age 12, I got a paper route for a shopping newspaper. My route included 320 houses, and I had to make a trailer to hitch to my bicycle to haul the papers. I received $.80 each week for distributing the Shopping News and $.70 for distributing special advertising papers. After distributing papers in rain and snow for 8 months, I decided I needed to find another job.

The Second World War was in progress and there was a labor shortage. My cousin, Peter Novak, was working at Central Cleaners and he invited me to

apply for a job there shining shoes. At age 13, and small for my age, I was not sure I could do the job, but Peter assured me I could. I earned $.25 an hour plus tips that might equal my pay on a good day. I began to save what seemed to me like a lot of money, even after buying some of my clothes and paying for most of my recreation costs. I worked from 3:30 to 6 PM on school days and 9 to 6 or 7 PM on Saturdays, earning some $8-15 per week, far more than delivering the Shopping News.

My brother joined the Navy after graduation and first trained as a radioman on a torpedo bomber. These planes flew at low altitude and dropped torpedoes on enemy ships. This required flying straight toward target ships and then veering off after dropping a torpedo. These approaches were very dangerous, and fatality rates for torpedo bombers were about 50%. Fortunately, the war ended before Dick finished training. He was very disappointed to miss action, but the rest of the family was very relieved. He served for about a year and a half on a seaplane tender ship as a radioman. He often said that his days in the Navy were the best times of his life. For some reason, I never had photos of Dick in his Navy uniform.

I continued to work at Central Cleaners during the war years, and also after the veterans began returning including two of them who joined the staff. After a year shining shoes, I was taught how to press cloths and wait on customers. I moved primarily to this work, earning $.50 an hour and gradually gaining raises until I was earning more than $1 per hour later in high school and in college. In high school I was one of the smaller boys in my class, and also suffered from a serious case of acne.

Working after school everyday and on Saturdays did not allow much time for school activities. In my senior year I joined the Inventor's Club supervised by my physics teacher. I learned a bit about electronics, assembling radios and amplifiers. I also participated in a school vaudeville act, "Shamrock Serenade", singing and dancing as one of the chorus. I was also elected Vice President of our Hi Y club, arranging social events and other things. However, for the most part, high school for me was a rather boring affair and I was eager to move on to the University.

A Hoffman steam pressing machine similar to those I worked on.

Seeking to Make a Difference

From my early years and continuing in high school, I had a growing desire to do something in my life that would help to make this a better world. I don't know if this desire stemmed from my home life, my limited experience in the Church, my Boy Scout training and experience, or possibly some combination of these things. I knew I would need a college education to do much of anything of value to society. This urge to do something to benefit the people of the world persisted over the years. I never anticipated that my major contribution would come in the form of finding ways to improve education and knowledge creation.

My high school graduation photo, 1948.
The photographer had done a good job air brushing away my rather severe acne.

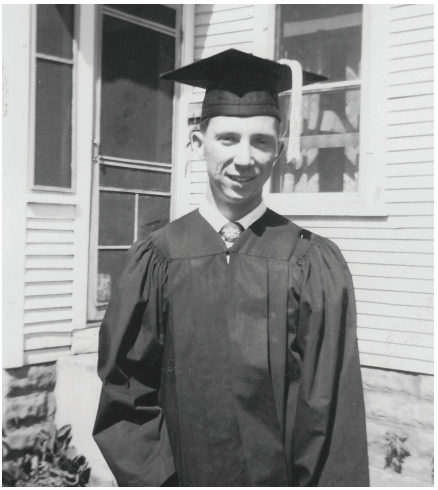
During my first two years at the University of Minnesota I worked an average of 35 to 40 hours per week while pursuing full-time studies at the University. I always liked singing, so I thought I would audition for the University Choral group. The audition went well as the auditioner pushed me through 2 ½ octaves of scales. The person working with me indicated they really needed more good tenors. However, when I learned of the planned rehearsal times, it was clear I could not do these and continue my work schedule at Central Cleaners. I had to abandon the idea of joining the Choir.

Needless to say, there was not a lot of time to study, and this was reflected in my grades. I did manage to pay all my school expenses and personal expenses including my clothes. I always liked dancing and went to Wednesday evening dances held in the Student Union. After a semester, I volunteered to select music to be played at the Wednesday evening dances. These dances were my primary avenue for meeting new girls, and the few dates I had were with girls I met at these dances.

My brother had GI Veteran's benefits that not only paid for books and tuition, but also a monthly stipend that was at first more than I was earning pressing clothes. My parents provided me and my siblings with board and room during our undergraduate years. I should note that this was not common in other homes in our neighborhood. Some of my cousins that went to college also had to pay some board and room for living at home. My parents also paid tuition at times when my sister could not. Ellie had worked for two years after graduation and my brother took two years off after his sophomore

year. When he returned to the University, he changed majors from forestry to history.

I and my brother and sister completed BS degrees at the University of Minnesota, Dick and I in 1952 and my sister in 1953. We all benefitted from having the great University of Minnesota just a few miles down University Avenue that ran two blocks from our home (See map on page 12). Most of the time during my freshman and sophomore years, I hitched rides on University Avenue to the university. Most of the time I traveled much faster than taking the public streetcar, five blocks from home that requiring a transfer in downtown Minneapolis. It also cost about fifteen cents each way, about what I paid when I occasionally bought lunch at school.



My BS Graduation. 1952

Chapter 2

Joan
The Wind Beneath My Wings

Joan's Early Days

Born January 14, 1932, Joan Lucille Owen grew up in Northeast Minneapolis, about 1 1/4 miles from my home. Her Dad worked for Northwestern Bell Company that later became Bell Telephone. Her mother was a secretary for several years until Joan was born. The family had a cook/housekeeper, Mrs. Kranz. Her work allowed Joan's mother the freedom to pursue her interests in shopping downtown and playing bridge. Joan resented Mrs. Kranz because she missed having her mother around. Joan's sister Carole was born May 7, 1936. As a young child, Joan's mother liked to dress her up and many of her early photos show her standing in a new dress or wearing one of Mother's old hats, or wearing a dance costume. She enjoyed playing games outdoors and inside, and also riding her tricycle, weather permitting. More than once she suffered a scraped knee when falling off her trike or playing on the sidewalk.

Joan's first communion was a big occasion for the family, and we have several photos from this day. Her mother encouraged her to develop her skills, and Joan took several kinds of lessons.

Joan age 6, in a new dress.

The family went to St. Charles Catholic church, about 1/2 mile from her home. Joan went to the elementary school operated by St. Charles, and then to a St. Margaret's Academy, a Catholic high school for girls in downtown Minneapolis. The school was housed in an old mansion and Joan loved the marvelous stairways, fireplaces, and other beautiful features of the school. Most of her playmates and friends in her growing up years were also classmates. She was especially close to Peggy Hirt, the daughter of a dentist who lived nearby. This friendship continued through college and beyond.

Joan took lessons in ice-skating for many years and also piano lessons. She never gained a high level of success in any of these areas, but she was invited to do several radio performance on the piano in high school. She also sat on a weekly radio panel with other students discussing issues of concern to high school students. Joan liked the uniforms they wore, since everyone looked the same and there was no rivalry in dressing for school. Everyone also wore comfortable Peter Piker's Happy Hikers shoes, except seniors who were required to wear high-healed shoes so they could march elegantly during graduation.

As a child, it never occurred to Joan that it was odd her sister never had the private lessons nor did she attend a private high school. The favoritism her mother showed toward her led Joan to sometimes play tricks on her younger sister, knowing she could get away with these. In spite of this childhood, Joan was very close to her sister as they grew older and they remain close friends today. Unfortunately, with her sister and her family living in California most of her adult life, they have had relatively little time together.

Joan at High School Graduation from St. Margaret's, June, 1949.

We Meet at the University of Minnesota, and Later Marry.

Joan was very popular with the boys in high school, often "going steady" with one or two guys. I was not nearly so popular with girls in high school, partly because I had a bad case of acne. During my Freshman year, thanks to doctors at the Student Health Service, I began x-ray treatments followed by ultra-violet radiation. Within six months, most of the acne had cleared, giving me increased confidence in dating girls. This acne treatment is no longer done, since it led to a high incidence of skin cancer. Fortunately, I have been spared this nightmare so far.

At the beginning of the winter quarter of my Sophomore year, I spotted a very attractive girl heading for the line to check out laboratory equipment for our chemistry class. I quickly moved behind her and was considering how to open a conversation when Joan turned and asked me if I had a chemistry lab partner. When I said no, Joan asked if I would like to be her lab partner. I was delighted to accept her invitation. Joan had a male chemistry partner in the fall quarter and he did most of the lab work, so she hoped to repeat this arrangement.

I had little interest in the "cook-book" laboratory activities and found that we could file laboratory reports by using made-up data and constructing obvious answers to the relatively inane questions. I recall one laboratory dealt with solvents and the task was to determined what kinds of substances each solvent would dissolve. With my experience working in a dry cleaning shop for eight years, all the answers were obvious to me without doing the "experiments". We chose instead to spend most of the scheduled laboratory time to chat and have snacks in the Student Union. These conversations ranged over a variety of subjects and both of us found the conversations enjoyable. Some days one of Joan's "steady" boyfriends joined us at the Union, so it was obvious to me that Joan's social life was very busy. Not wanting to be turned down if I asked for a date, and maybe impairing our good relationship, I did not ask her for a date until weeks later.

In late March, I did ask Joan if she would like a ride to the final exam for Chemistry, since I was going to have my Dad's car to use. I planned to pick up motorcycle parts at a machine shop for a bike I was rebuilding and repainting. Joan quickly accepted and we both enjoyed this time together. As she was about to leave the car when we returned to her home, I put my hand on hers. Years later Joan told me how warm my hand was and how warmly she responded to the touch. I asked if she would like to go for a motorcycle

ride when I finished work on the bike, and she enthusiastically responded that she would.

Strangely, our paths did not cross during the Spring quarter. Working 30 to 40 hours per Week at Central Cleaners, plus carrying a full load in science and math at the University, it was June before the bike was finished and ready to ride. When I called and asked her if we could meet for a motorcycle ride on Sunday after classes had ended, she said she could not because she had a chemistry final on Monday and had to spend Sunday cramming for the test -- something I never did. Before I could register my disappointment Joan said, how about going out the following Sunday, and so we had our first date.

I wanted our first date to be special. Fortunately Sunday's weather was perfect for a bike ride. I had planned to take Joan to a lovely state park, Taylor's Falls, about 50 miles north of Minneapolis. After we had ridden about 10 miles, Joan asked if I could stop the bike so she could jump up and down a little. She did not know where to put her feet and her legs had been dangling along side the bike and fell asleep. We stopped and then I showed her where to rest her feet. The remainder of the ride went smoothly and we returned home about 5 PM. I asked if she would like to go dancing in the evening -- my favorite thing to do. She accepted the invitation, and since I had arranged to use my Dad's car that evening, we had nice transportation to the Marigold Ballroom in downtown Minneapolis.

The evening was delightful and we talked about all kinds of things. In fact, we even talked about how many children we would like to have if we got married, something neither of us had done before on a date. For both of us, the whole day had been something special. We began dating at least once a week, and after a few weeks, Joan dropped her other "steady" boyfriends and we began spending more of our free time together. It was obvious to both us that this relationship was what we both wanted.

We continued to spend increasing amounts of time together, limited only by the demands of school and work schedules. In the winter of 1953, after I had completed six months in a graduate program at the University of Minnesota, Joan began to discuss friends of hers that had made marriage plans. Her closest friend, Peggy Hirt, had announced her engagement to a future medical student, Jack Smith. One Sunday afternoon Joan mentioned that Peggy and Jack had planned to marry in August, after they both completed undergraduate school. Jack had been accepted to the Medical College at Minnesota and would begin the program in the fall of 1953. Joan asked, why couldn't we get

married next summer? I could continue my graduate studies and she would begin work as a medical technologist in an area hospital.

We both were committed to our relationship, so after thinking about how we could manage financially to marry in the summer of 1953, I bought an engagement ring for Joan and presented it to her in February, 1953. Joan's mother was not thrilled with the plan, partly because she was looking forward to having more time to do things with Joan after she graduated, and partly because she did not see teaching as promising as for example medicine. Nevertheless, plans moved forward for a July 18 wedding.

Our wedding party included my brother and sister, Joan's sister, and several of our close friends.

Joan was stunning at the wedding, and so excited about everything. I was more interested in greeting everyone, and then setting off on our honeymoon. In those days it was customary not to sleep together before marriage, so we both were excited about this. There were a number of out of town guests on my side of the family, so my parents invited all of them to their house for an evening celebration, but Joan and I were already on the road. We drove a 1940 Dodge I had purchased from my Dad for $50. I had rebuilt the engine of this car in 1944, but it needed another overhaul and new brakes. I also painted the car, so it looked and ran almost like new.

Joan and I on our wedding day. July 18, 1953

We had dinner then danced at one of our favorite restaurants in Wisconsin, just 50 miles from home. We spent the night at a motel in Wisconsin. Our first time together in a bed, we did not sleep much that night. Joan will never forget that the motel room I had rented had no door on the bathroom, so she was very embarrassed using it. The next day we took an auto ferry from Wisconsin to Michigan. The weather was again perfect, and we had time to relax on the ferry, especially since our departure was delayed for several hours due to the late arrival of an engine to move freight cars off and onto the large ferry.

We arrived in Michigan in the afternoon and drove to Flint, where I had relatives living on a farm. My Aunt prepared a whole farm chicken for each of us plus all the trimmings. The homegrown birds were more like small turkeys, and I had to explain that we could eat at most a small part of one. Joan weighed 98 pounds when we were married, so she never had a big appetite. My Aunt remarked that her boys always ate at least one chicken each when they return from threshing wheat all day. My cousins were husky 6+ feet tall men.

My Aunt and Uncle had not yet installed indoor plumbing, so this was a challenging first experience using an outhouse for Joan. After a hearty breakfast we left for Niagara Falls, a famous honeymoon destination on the Canadian border. We rented a "Honeymoon cottage" and spent the remainder of the day and most of the next day seeing the sights. Then we drove to a motel on Lake Erie near Erie, Pennsylvania. We saw one of the most beautiful sunsets over the lake that we had ever experienced.

The next day we drove to Barberton, Ohio where my cousins lived. My cousin, Lorain, grew up next door to me, so we were long time friends. Her husband Frank owned a filling station. He changed the oil in my car, greased and washed it, and filled the tank for our journey west. Loraine and Frank took us to a nightclub that evening where they had a hypnotist performing, something we had never seen before or since!

The next day we drove to Chicago to visit with my cousins, Steve and Dorothy Prokop. Our family often visited my Dad's brother in Chicago on summer vacations and Dorothy once spent three weeks at our home in Minneapolis. We had other relatives in Chicago and visited with a few of them, but time was limited. The whole honeymoon had cost us less than $100, and it was years before Joan realized that part of the reason for visiting all the relatives was to save money.

We returned to Minneapolis and stayed at my folk's house, since they had gone on vacation and the apartment we were moving into needed major cleaning and repainting. The prior renters had dogs and the place was so messy I literally had to use a shovel to clean the floors in some rooms.

My brother and I had helped to purchase the four-plex a few years earlier. Since my parents had almost no savings, Dick and I wanted to help our parents buy a building that could assure significant income when my Dad retired. In the long term, this proved to be a wise decision, for once paid off, the four-plex provided my parents with income that not only helped with monthly bills, but also allowed them to accumulate significant savings.

Since my Dad owned the building, we were free to make whatever improvement we wanted. We added an automatic hot water heater in the bathroom. After our son Joe was born, we installed a small used Bendix side loading clothes washer we purchase for $13. We paid $30 per month rent, and this was not increased during the four years we lived there. Our neighbors were high school graduates, but they led a different life style than we did even while I was in graduate school.

This four-plex was our first home and we occupied the upper left apartment. Each unit had four rooms in a row with a bath along side the Kitchen.

The front room was our bedroom, the second room was our living room, and then there was a TV and oil space heater room, and finally a kitchen and bathroom in the back. This is a 2011 photo with more plantings than when we lived there.

Joan took a position in the laboratory at Fairview Hospital, across the river from the University of Minnesota (and now part of University Hospitals). It was convenient for me to drop her off at work before beginning my day at the Botany Department, and then picking her up in the evening to return to our apartment. Most evenings I returned to the Botany building to work for another 2-3 hours. We both had busy schedules, but we always took time to do things together, especially on weekends.

After almost three years of marriage, we had our first child, Joseph Mark. Fourteen months later, daughter Barbara was born 10 days after we had moved to Emporia Kansas where I took my first position in the Biology Department of Kansas State Teachers College. In May,1959, son William was born. With three children under three years old, and this was before Pampers, Joan was very busy being a mother! Nevertheless, she also was always there to support me in my work and to provide love and encouragement.

Joan, My Best Critic and Best Supporter

I had taken on a challenging PhD thesis project that required developing a special laboratory and study guide, designing methods for individual research project work, developing a test for assessing problem solving ability, collect-

ing and processing all of the pertinent data for over 300 students — then writing a thesis. The last 6 months of my PhD program required a 70-80 hour workweek, and many small frustrations and disappointments (such as the only computer available being down for a day or more). Joan never complained about my absence and always was positive about my progress.

I had planned to graduate in August, but when my advisor asked for major changes in my thesis and then left for vacation for the month of August, I was ready to scrap the whole project. Joan said this was foolish and urged me to carry on, confident that I would finish the thesis and pass the final thesis exam.

The faculty at Emporia State Teachers College where I had accepted a position was also supportive, saying my problems were typical of those many of young people. They supported my efforts to complete the thesis with a lightened teaching load. I did my final thesis defense over the Thanksgiving's day holiday with a very positive response from my advisor and all of my committee members. Thank goodness that with Joan's love and support, I persevered and was on my way to a career as a biologist and educational researcher and innovator.

When we moved to Emporia Kansas, we were fortunate to quickly make friends with several couples who also had young children. Joan had not learned how to drive, so it was fortunate that her friends could take her places when I was at work or out of town for meetings. Ellen Siegel, who grew up in New York City, was a bit bored in Emporia, so she frequently came over with her two young children and often took Joan and the children to parks or shopping. Emporia had a population of about 15,000, so there was not much to do other than spend time with friends at their homes. Consequently, we made some very good friends during our two-year stay in Emporia.

Joan was very happy to be a mother and enjoyed her time with the children even when they were very small. We had a student helper, Terry Meres, who did housecleaning and maintained the 7 rooms we had on the second floor of our home that we rented to male students. She also baby-sat for us from time to time. We rented 2 double rooms for $12.50 per month per student and 5 single rooms that rented for $15 per month. The rentals pretty much paid for Terry's time and also the monthly mortgage. Joan did most of the managing for the rentals. Almost all of our renters were from Kansas farms, and what they lacked in polish, they more than made up for in kindness and helpfulness. One evening when we had tornado warnings, the boys carried the children's two cribs to the basement and other items Joan needed, and

then moved them all upstairs again when the tornado watch had passed. I was working at my office and missed all the excitement. Most of the rooms were available for visiting family and friends during summers and school vacations, so this was a nice perk that came with the house. Our plan was to take over the whole house when the children got older, but we left Emporia before this happened.

Dad and daughter Barbara in front of our Kansas home.

Our Kansas home was a very nice older home with beamed ceilings and a lovely brick fireplace. I redid the kitchen, including installing new cabinets and fixtures, converted the electricity from 110 volt service to 220 volts, redid some of the plumbing and relocated the rear door to allow our tenants to go upstairs without passing through our kitchen. We installed a window air conditioner in the living room and one in our bedroom. These were sufficient to keep the downstairs comfortable in summer when temperatures are usually in the 90's. The backyard was fully fenced, so it was safe to have our children play out there. The photo below shows our family in front of the fireplace at Christmas time, 1958.

Our family in front of the fireplace in Kansas, Christmas, 1958.

In May, 1959, we were expecting our third child, our second to be born in Kansas. I received an invitation to apply for a joint position in the Education and Biology departments at Purdue University. Joan's mother had arrived to be on hand to help with the new baby. We decided this would be a good time for me to fly to Lafayette, Indiana, since Joan and the new baby could stay in the hospital until I returned and Joan's mother could look after our son Joe and daughter Barb. There is quite a story to how this appointment came about, but that will come later in this book. In any case, I accepted the position at Purdue University and we moved to Indiana in August, 1959, stopping in Minneapolis in route to visit family and friends

At first we rented a University owned house, a factory built home made by National Homes located in Lafayette, Indiana. The construction was very poor and we had numerous small problems, including single pain windows that dripped with condensation in cool weather creating puddles on the floors where our children played -- a real nuisance for Joan. Fortunately we found a nice older home and moved there in the spring of 1960. Joan soon got to know many of the neighbors, most of whom also had small children. We often had friends over for dinner or cookouts in our large backyard. Lafayette had a very nice park where we often visited on weekends to picnic, or ride on some of the nice rides or a miniature train.

Me with two of our children on a miniature train in Columbia Park.

We made many good friends in West Lafayette. Joan also joined a "little theater" group and performed in several plays presented in community buildings. She and the children often went shopping at a large mall in Lafayette, especially in the winter months. Our home had a large lot with many trees, including a mulberry tree that the children loved to climb and to build tree houses in it. Often we would have four or five neighborhood children plus our three climbing in the mulberry tree. There was also a 6X8 foot playhouse on the back of the lot that I cleaned and painted for the children. Somewhat to my surprise, the children rarely played in this house, preferring doing things on our large lot with much room for the children to play.

Our home in West Lafayette Indiana, Spring, 1958.

Since I was working long hours, and traveled several days a month on school related business, Joan had the lion's share of parenting, and she did this very well! One of the tasks she took on in West Lafayette was serving as Cub Scout host mother. This was easier in summer when the boys could do things outdoors, but it was challenging in rainy or cold weather. All of our children when they reached adulthood frequently commented on their happy childhood, and Joan deserves the most credit for this.

Joan and son Joe in his Cub uniform, 1966.

Joan spent many hours with our children doing everything from shopping and driving them to events, to arranging parties and supervising when other children were visiting. There was very little time for "doing her own thing". When the children got older and spent all day in school, she began to have some time to herself. She began doing painting, mostly teaching herself how to do oil, acrylic and watercolor paintings. Below is one of her first oil paintings. After the children left home, she had much more time for painting, especially when we were away from home on sabbatical leaves. Some of her later paintings will be shown in other chapters. More about Joan follows in later chapters.

One of Joan's early oil paintings done when we lived in Ithaca, NY.

Chapter 3

The Joy of Raising Children

Planning Our Family

From our very first date in June of 1950, Joan and I agreed that we wanted to have children. After we married in July of 1953, we were also aware that with my limited income as a graduate teaching assistant in the Botany Department at the University of Minnesota, and almost no savings, it would be unwise to have children immediately.

Joan took a position as a medical technologist at Fairview Hospital, just across the river from the University of Minnesota. Joan's net earnings were $45 per week, and I was earning close to that amount. As my brother and some of our close friends began to have children, Joan became more and more eager to have children. She really wanted to be a mother! As a graduate student, I was not assured of a continuation of my teaching assistantship, since unlike my Botany colleagues, my major was in Science Education, and some professors objected to using limited assistantship support for someone not majoring in the Department.

Fortunately, I had strong support from senior Professors Albert Frankel and Ernst Abbe, so after my fourth reappointment in June, 1955, I felt more confident that the Botany Department would support me until I finished the PhD degree, projected for the summer of 1957. In September, 1955, we actively sought to have a child, and son Joseph Mark was born June 25, 1956. To my surprise, the Botany Department asked me to accept a half-time position as Instructor to oversee work in the laboratory sections of the introductory botany course, and this paid $2,000 for the academic year, 1956-57. With the end of my graduate studies in sight, and this enhanced salary, we felt pretty confident we could manage financially, and we did.

Joan had a hard time with son Joe's delivery, due to the incompetence of her doctor, who failed to see her the month before the delivery. Dr. Mack had been the Owens' family doctor since before she was born, and she trusted him. Dr. Mack never asked Joan if she had any swelling, or any other questions about her health, other than are you feeling OK? Joan developed a rather severe case of eclampsia, which made the delivery difficult and dangerous. We brought in an obstetrician who helped reduce Joan's swelling, using very painful magnesium sulfate injections. Joan was in labor for 48 hours, but fi-

nally Joe was born in good health June 25, 1957. He also suffered from some swelling and a large bruise on the top of his head from pushing on Joan's pelvis during the protracted delivery. The pediatrician assured us the bruise would heal and our baby would be fine, and this proved to be the case.

This was our first experience with medical incompetence, but it was far from the last. In most cases the problems were similar -- our doctor had simply not kept up with the latest medical knowledge and used ineffective or even dangerous procedures and/or medications. These experiences caused me to have considerable interest in seeking to improve medical education later in my career, albeit I found the resistance to new education ideas in medical schools to be monumental!

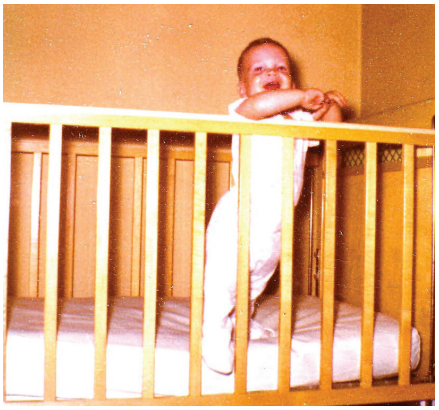
From our first date in 1950, I joked with Joan that we would have very special children. With her family background of French, Irish, and English, and my family background of Russian and Eastern European stock, we would be merging two very diverse gene pools. Our children should be great genetic hybrids. As time went by and our children grew older, they have developed in remarkable ways, and we are very proud of each of them.

Our son Joseph Mark

Born June 25, 1956, Joe was such a happy baby. We had his crib in our bedroom, so when he woke up he seldom cried for more than a minute or two. When he could stand, he would look down on us from his crib jumping up and down with a big smile on his face. Of course, we could not delay feeding too long, but he was very patient for a little tot. When he was old enough to walk by himself, he was very content to roam around our fenced back yard, looking at trees, flowers, and birds. Somehow he took a liking to our toilet plunger, and would walk around the house or yard using the plunger like a cane.

Joe was fascinated by the vacuum cleaner. I made him a toy vacuum, using a block of wood covered with imitation leather and a handle with a rope attached and an electric plug on the end. Joe would spend hours pushing around his vacuum and making noise like a vacuum motor. He was curious about how things worked. We bought him several toys that made noise when they were pushed around. After a day or two, he would frequently take the toy apart to see how it made the noise. Joan and I would sometimes assist him with looking into the toy, and sometimes he was satisfied and went back to pushing it around. We bought him a plastic horse mounted on springs, and he would spend hours rocking the horse back and forth as far as it would go.

When he was older, he frequently stayed right next to me when I was repairing something, often asking questions. By age five, he had a pretty good idea of how electricity moved from the fuse box, through wires in the walls, to receptacles and out to appliances. He took apart electric motors to see how they worked, and later he did the same with gasoline motors.



Our happy son Joe at 8 months in our apartment in Minneapolis

From an early age, Joe was very kind and solicitous with his sister Barb, and later also with his brother Bill. At age 18 months, he was pushing her around in a buggy (see below). Occasionally Barb or Bill might have an altercation with a playmate, and Joe usually resolved this by simply standing by Barb or Bill, and their playmates would calm down or walk away. When Joe was older and mowed our lawns, he would often give Barb and/or Bill a ride in a garden trailer.

Joe at 18 months, pushing his sister in her buggy

Joe giving Barb and Bill a ride in the garden trailer

Joe had some problems in school, beginning in kindergarten where his teacher said Joe was behind the class in doing cutouts with scissors. The problem with the cutouts was that Joe was left-handed and should have been given left handed scissors, as we learned later. In fourth grade his math teacher advised us that he was not finishing his work, and we needed to accept the fact that he was "slow." To check on the school's assessment, we had him tested by competent psychologists. His IQ was estimated at 140. The problem was that compared to things Joe was doing at home, school was boring for him, and he made little effort to conform. Joan often found his "homework sheets" crumbled in his pockets when she washed his clothes. We often wondered how many children had their self-image damaged by poor school assessments.

When Joe was 12, he found an old sewing machine motor somewhere. He used this to power a pulley system he rigged up to open and close his window drapes by simply pressing switches on a cabinet near his bed. His electrical gadget creativity also enabled him to rig up various things on an electric train set he had. Joe enjoyed music, and he was constantly designing bigger audio systems that satisfied him. He became interested in computers and built a small computer when home computing was still in the future. I marveled at his ability to write programs for his computer -- something I never learned to do.

Perhaps even more than our other two children, Joe was always very good with younger children. He would often help them with something they were

trying to do, but also encouraged them to do most of the work with only his supportive guidance.

Joe did better in high school, where some classes such as math and physics were of interest to him. He and a high school friend, Bill Weyman, formed a "We repair anything" business, advertising on local store bulletin boards. They not only repaired cars and lawnmowers, but almost anything, including installing a new bathroom at the ground level of the home of one of our friends. For several years after Joe and Bill had gone to college, we got phone calls asking for help from their business. Bill Weyman took a position at Xerox Corporation after graduation, trouble shooting glitches with equipment, a position he continued until his recent retirement. He succeeded in patenting a number of his innovations, to the benefit of Xerox Corporation.

Joe spent one year at the University of Minnesota. He was admitted as a major in architecture at the State University of New York at Buffalo and graduated with good grades. After two years working as a construction manager for an oil company based in Houston, Joe decided there was little future in this kind of work, and he returned to Cornell University to earn an MBA degree at the Johnson School of Business and Management. He was employed by Firestone, first in Akron, Ohio, and later at the company offices in Irvine, California. He met Elizabeth De Marco, who was also working for Firestone, and they were married on September 16, 1985. The day was also memorable because our condo in North Carolina was destroyed by a hurricane the same day.

Liz completed an MBA degree at the University of California - Irvine, and Joe took additional courses in computer science and information systems. They did not find the life styles of southern California to their liking and after a few years, they moved to Liz's hometown of Cleveland, Ohio. Liz had accepted a position as a senior manager for University Hospitals, and Joe found a job as Chief Financial Officer with American Consumer Products. After a few more positions as CFO at Cleveland area companies and senior positions in data management at other companies, Joe decided to form his own hedge fund company, solely to manage their investments. Liz had progressed to Vice President for Financial Management at University Hospitals. They chose not to have children.

Joe receives MBA Degree at Cornell University in1978.

Joe and Liz Marry, September, 1985.

Freed of the drudgery of corporation employment, Joe now can engage in things that have interested him since he was a child. He volunteers with an auto museum in Cleveland, helping to recondition cars and improvise special parts or other items needed. With several other colleagues, he formed a company, Launch House, that offers space and counsel to start-up companies seeking to market innovations. As with all capital ventures, some of their start-ups have failed, but some are thriving and show promise for continued growth. He has found a number of ways to engage his creativity. Joan and I watch and listen with interest as he describes new ventures. We wonder what

may have happened to his future had we let the school's disparaging comment on Joe in early grades dampen his enthusiasm for learning and experimenting.

Liz retired from her position in May, 2016, so they now have the freedom to do whatever interests them! They recently purchase a townhouse in Sarasota, Florida, so they will spend part of the winter near our Florida condo.

Our Daughter Barbara Joan

Unlike the protracted delivery of son Joe, Barbara was born within minutes after we arrived at the hospital, September 9, 1957, 10 days after we had arrived in Emporia, Kansas. Barb was a happy baby and Joan enjoyed breast feeding her, and later playing games with her. She always was an early riser, and if morning feeding was delayed more than a few minutes, she complained loudly. Once she was fed, her smile and happy antics resumed. I got a kick out of how she would gulp down baby food, complaining if one paused too long between spoonfuls. When she was full, the last spoon of baby food would ooze out of her mouth with a big smile, and we knew feeding was over. She was always fascinated by whatever brother Joe was doing, and as soon as she could move about, she followed him everywhere, trying to play with the same toy or other item. She never crawled as most babies do, but rather "ran" with her seat up and legs and arms moving as swiftly as chimpanzees move.

Barb (at 10 months) crawled on her hands and feet, not her knees, moving faster this way.

When Barb was about three, she heard the word infinity somewhere and she asked me what was finity? (She could not say the word infinity). I gave her a few examples, such as the number of stars in the sky being a very large number, but still not an infinite number. After a few examples, Barb's attention appeared to wane and I thought, well there goes nothing. However, a few days

later she was discussing with a neighbor girl how much candy she collected on Halloween with Pam, about the same age as Barb. Pam said she collected dozens and dozens of candies, and Barb replied that she got hundreds of candies. Pam remarked that she got hundreds and hundreds of candies! Barb replied that she got finity of candies. Pam responded by saying she got more than that. Barb strongly asserted, "You can't have more because nothing is more than 'finity!" On a number of later occasions, Barb again used infinity correctly in some argument she was making, and now she could pronounce the word correctly. No wonder Barb majored in math and physics in college, earning all A's.

Barb always enjoyed birthday parties, and was very excited as the events progressed. She was so excited about the party she usually spent little time eating. She also enjoyed playing games with her friends.

Always eager to participate in sporting events at school, Barb often rode her bike to the high school or a park near her school. On one occasion while speeding done the main road a car honked it's horn at Barb and she turned to check on the car. The result was she crashed into a utility pole and her handle bar went into her gut, rupturing her spleen and banging her head. We were very concerned about her, especially when our priest came to anoint her. Fortunately, Barb was one of the rare persons who had a second spleen, and she was soon back to her normal high energy active life! We felt so fortunate as parents that Barb survived what could have been a fatal accident with no permanent damage.

Of our three children, Barb was the most interested in playing instruments. She played the clarinet at age 10, but later switched to the sax when she learned this was the preferred band instrument. The figure below shows her in her band uniform with the Ithaca High School band. She later picked up piano and guitar, though she never pursued mastering one instrument.

Barb in Ithaca High School band uniform

In school, Barb's competitiveness extended to her studies. She was often the top performer in her classes, and curious about many things. She took 2 or more extra classes each term in high school, usually earning A's in everything. She became bored with high school and was admitted to Cornell University after her junior year, beginning college before her 16th birthday. She began with a major in mathematics and astrophysics, with Carl Sagan as her advisor. She excelled in math and physics, but also pursued other studies as she progressed through Cornell.

Barb moved into what used to be the women's dormitory at Cornell. Unfortunately we did not realize that this dormitory had become popular with junior and senior women, many of whom had their boyfriends living with them. Barb was not ready for this, so she moved back home. The following year she took a room in a coop house on campus, and here she met Bill Hunt, who would later become her husband. Bill was majoring in environmental studies and also participated in the Air Force ROTC program. Both received their BS degrees in June, 1977.

After graduation from Cornell University, Barb began a Master's program in child nutrition at Penn State University. Bill went off to Oklahoma for basic

training to become an Air Force pilot. Bill visited Barb at Penn State, and Barb made at least one trip to Enid, OK. Needless to say, neither Bill nor Barb was happy with this arrangement, but it was Barb who pushed Bill to get married on one of her trips to Oklahoma. Apparently Bill wanted to wait, and Barb came home saying she never wanted to see him again! The following week, Bill flew to State College, and they subsequently announced that they planned to marry at Christmas time. They had a perfect winter wedding at Sage Chapel on the Cornell Campus, and a perfect winter reception at a picturesque restaurant near Ithaca.

Barb and Bill's wedding party at Sage Hall Chapel, December 28,1977

A few days after the wedding, Bill went to Enid, Oklahoma to complete basic training with the Air Force, and Barb went to Penn State University to continue her MS studies in infant nutrition. We were a bit concerned about their beginning married life this way, but all turned out well. After basic training, Bill was stationed at Johnson Air Force Base in North Carolina, and Barb got a job as the Director of a Women, Infants, and Children (WIC) program in Goldsboro, NC.

The mean age of Barb's clients was about 16, with many women having babies in their early teens. Some of her clients were not fully aware of how pregnancy occurs, and many saw no difference in the nutritional value of Twinkies and carrots or celery.

When Bill was transferred to Griffiss Air force Base in Rome, New York, Barb left the WIC program, and they bought a house in Durhamville, NY. Barb

decided to pursue a PhD program in Infant Nutrition at Cornell University and began in the spring semester of 1983.Their daughter Rachel was born in September,1982, so Barb's schedule was hectic to say the least. Since she wanted to nurse Rachel, Joan would pick her up at the baby sitter's home and drive to the campus where Barb would nurse her between classes. Somehow they managed to do this throughout the school year, with Barb and Rachel spending most weekends in Durhamville, or Bill joining them in Ithaca.

Life for Barb and Bill was complicated, with Bill flying refueling missions out of Griffiss AFB, and Barb pursuing the PhD degree in Ithaca. After one year, Barb decided that she really did not want to continue the PhD program. She knew the demands made on professors in a first-rate university, and she did not want to be part of the mediocrity she saw in lesser colleges. She took a position at Syracuse Medical School, assisting with programs in curriculum improvement at the Medical College. The commute to and from Syracuse was a bit tiring, especially in winter, but Barb stayed with this work until Bill completed his term of service with the Air Force and took a position flying with American Airlines, a position he continues today.

Bill was based in Boston, but they wanted to live in a rural setting so they bought a home in Carver, Massachusetts, 30 miles to the south of Boston. Barb took a teaching position at Taunton High School, MA, teaching math and physics. Son Joseph was born in October, 1988, so Barb became a full-time mother while also pursuing her interests in sports.

Barb Excels in Sports

Of our three children, Barb was always the most enthusiastic about sports. She played every sport available, and when in college, she helped to start up Cornell University's first women's soccer team. In most sports, she was either the top performer in her age group or near the top. From our perspective, Barb had extraordinary drive to excel in sports. In 1992, she won a position on the US International Triathlon team. She came in 15th in a field of 45 at the world competition in Manchester, England, and she was the only woman in the group that was mother of two children. She was disappointed with her performance, but we thought it was extraordinary!

Every sport Barb engages in, she seeks to do very well. Her vigorous efforts in downhill skiing made her one of the best on the slopes, but it also led to two crashes that damaged first her right shoulder and later her left shoulder. She continues to be very active in sports, but age does take its toll and now in her

50's, she no longer competes in skiing and running, but she continues active participation in cycling and swimming.

Barb competing on the US International Triathlon in Manchester, England. She was the only competitor with two children, and she came in 15th in a field or 45.

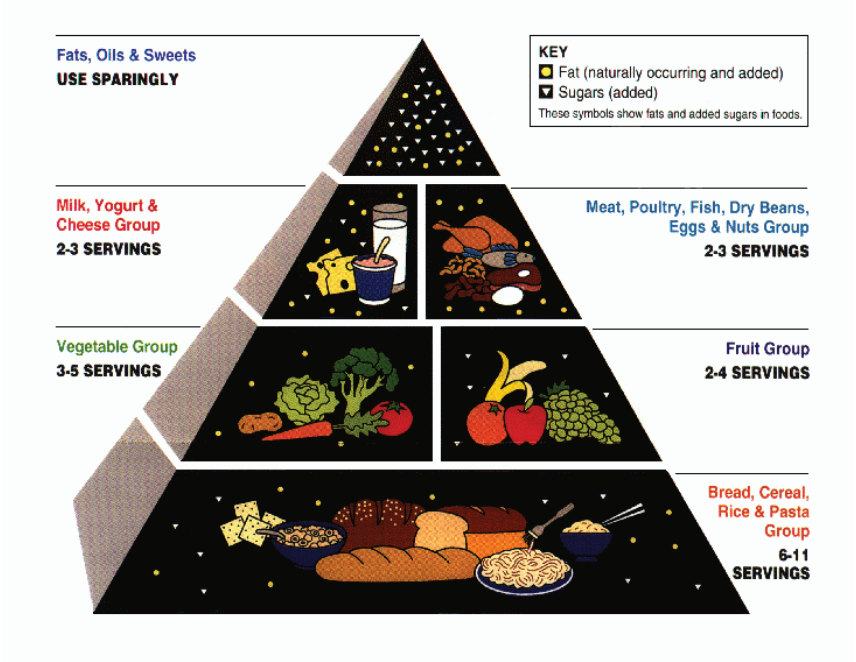
Although Bill loves flying for American, his principal recreation is flying light aircraft. Bill purchased his first plane when they lived next to a small airport in Durhamville, NY, and then he bought an experimental open-cockpit plane from a builder in Minnesota. With most of their recreation involved with airplanes and pilots, Barb decided she would get a pilot's license so she could be a direct participant in their plane-centered recreational life. Now flying is one of her principal joys in life. They moved from their Carver, MA home to a home on the lake in Lakeville, MA in 1990. They purchased boats, jet skies and other water toys, enjoying life on the lakefront.

Barb ready to fly their RV plane

Barb Starts a Wellness Business in Dartmouth, MA

Always eager to do more, Barb started a wellness business in Dartmouth, MA, near where Rachel and Joseph were attending school at Friends Academy. This continued for several years, but with an economic downturn, business slowed and Barb closed her business.

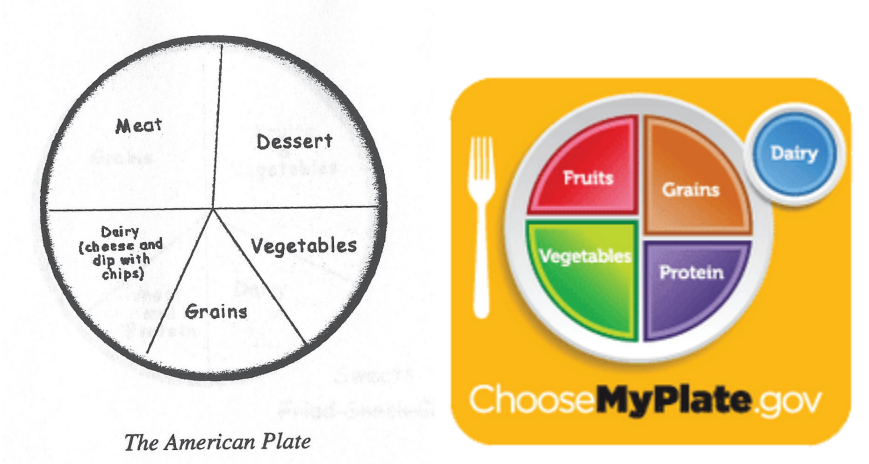
For many years the nutrition programs of the US Department of Agriculture used a model for nutrition that was in the shape of a pyramid with recommended foods occupying progressively larger spaces moving from the top to the base of the pyramid, as shown below.



The US Department of Agriculture used the above model for recommended daily diets.

In her teaching and counseling people on personal and family nutrition, Barb had not found the pyramid model very helpful, so she devised her own model of healthy and unhealthy **food plates**. One of her example food plates is shown below. Barb approached several publishers of cookbooks with her book, but none expressed an interest in publishing the book, though some found the book very innovative.

To her surprise, in 2011, the US Department of Agriculture issued a new set of dietary recommendations and these recommendations used **food plates** almost identical in concept to those in Barb's guidebook, except that they added color. Although it was highly likely that someone on the USDA Advisory Committee has read Barb's book, there was no reference to her work done 20 years earlier! Below is an examples of food plates from Barb's book, and an example from the 2011 USDA Dietary Guide an economic downturn, her business slowed and she closed her office.



Barb's American plate as shown in her 1985 book on the left, and one of the USDA plates as shown in a 2011 book.

Joan and I thought Barb should hire an attorney to sue for recognition of her work, but Barb did not want to pursue this. Perhaps in the end, such an effort may have achieved nothing.

With their children now grown and working in the Boston area, Barb and Bill have the freedom to focus more on their own lives. They decided to sell their lakefront home in Lakeville, MA and purchased a summer home on a lake in Sebec, Maine. They also purchased a winter home in an airpark community in Lake City, Florida. After spending two winters in Lake City, Barb and Bill decided to move 200 miles further south where winters are warmer, and they now have a large home on Lake Placid. Bill has changed from flying Boeing 767's to flying Airbus A 320's, and he is now based in New York City, an easier commute from their homes in Sebec, ME or Lake Placid, FL. It is good to have them living closer by our winter home in Tarpon Springs.

Our Son William John

I was completing my second academic year at Emporia State Teachers College when Bill was born on May 25, 1959. A day later I received an invitation to interview for a position at Purdue University. We decided that it would work best if I went to West Lafayette, Indiana for an interview while Joan and Bill were in the hospital. Joan's mother was staying with us, and it was easier for her to look after son Joe and daughter Barb than also helping Joan with our newborn. In those days, hospitals were willing to allow mothers and babies to stay on if they wished, so Joan spent two extra days in the hospital with William John.

Biology Department Head at Purdue University, John Karling, knew me from my participation in a conference at Douglas Lake, Michigan that he co-chaired in 1955. I attended while still a graduate student at Minnesota, since none of the professors in the Botany Department wanted to accept the invitation, and they thought I would benefit from attending. I will discuss the value of networking in a later chapter, but suffice it to say now that I was pleased to be offered the position at Purdue University. This was a great professional opportunity for me, and a good move for the family. The position vacancy at Purdue was the result of the accidental death of Richard Armacost, who was co-chair with Karling for the Douglas Lake Michigan conference.

From birth, Bill was a joy to Joan and me. Because he was the third child, we were much more relaxed about child care, and Joan really enjoyed nursing and mothering Bill. With son Joe and daughter Barb always very active, Bill had a two ring circus to watch from his playpen, and later to engage in whatever they were doing. Both Joe and Barb were always very good with Bill, bringing him toys when he was an infant and engaging him in whatever was going on. By age two, Bill's interest in building things was evident, and he loved making houses from wood blocks, cartons, Lego logs, and anything he could craft into a building. He also enjoyed playing with cars, frequently combining his building interest with the cars in creative ways. By age five, he became interested in drawing, an interest that grew as he became older. By junior high school age, he was drawing houses and other things, using very fine ink pens.

Son Bill at age 2. Bill always got excited at his birthday parties.

Bill really enjoyed building with sand, both at the beach and in the sandbox we had in our backyard in Lafayette, Indiana. While all of our children enjoyed building with sand, Bill was the most meticulous and most persistent.

Bill, Joe, and Barb building with beach sand, 1969

Joan spent more time alone with Bill, since he was the youngest and was therefore at home when Joe and Barb were in nursery school or elementary school. He enjoyed going shopping with Joan -- especially when he got a new small car to add to his collection.

When he was six, we were living in Arlington, MA while I was on sabbatical leave at Harvard. Joan bought a white communion outfit for Bill and he participated in the First Communion ceremony at the local Church. When he was dressed to go, he looked at himself in the mirror and asked, "Is everyone going to be dressed like this all in white?" When he was assured they were, he was content to go to the church.

Bill, age 6, dressed in his first Communion outfit

In the summer of 1966, we had rented an apartment near the beach in Ocean City, New Jersey. When we returned from Church on Sunday, the children rushed down the block to the beach where we were told by the apartment manager they could swim. Joan and I were just finishing changing our clothes when son Joe came rushing in and said Bill had drowned and he was not sure about Barb. Joan and I were stunned and we could hardly move when we

headed to the beach. When we got there I began to rush into the surf, but two lifeguards stopped me. They assured me that other lifeguards were bringing Barbara and Bill in and they were OK. Barb had managed to climb onto a rock jetty. We were so relieved to see Bill vomit as they brought him to the shore. In a couple of hours, he was just fine. One of the 12 lifeguards had sustained a broken rib in the rescue, but they were successful! Fortunately, Joan's efforts to take all three children to the HiY for swimming lesson paid off! To this day we are thankful to the lifeguards that saved Bill and Barb's lives. We cannot imagine what life would have been without them!

From an early age, Bill was fascinated with buildings, and he had a remarkable facility for observing and recalling building details. After we visited the House of the Seven Gables in Salem, Massachusetts, when Bill was six, we recall his remarking on how the hidden staircase was positioned next to the stone chimney that traveled through the second floor. His ability to recall three-dimensional details of the building was remarkable to us. As a teenager, Bill traveled with Joan and me to England, visiting several castles and churches. When we looked at photos we had taken months after the trip, Bill would comment on building details that we had never observed or had totally forgotten. In York, Joan and Bill visited a shop where copies of brass rubbings could be made. Bill chose to copy a large three-color brass plate. The proprietor suggested, since he had never done a brass rubbing, he should begin with a smaller one-color plate. Bill said, "If I don't try it, I will never know if I can do it." His copy came out beautifully, and now it is hanging in Bill's home. It came as no surprise when he chose to study architecture in college.

When Bill began college at the State University of New York at Buffalo, he was unfortunate to have a roommate who was selling drugs. He was getting very little sleep, since deals would go on much of the night. The roommate was making so much money that he could fly from Buffalo, New York to San Francisco every weekend to visit his girlfriend. Bill tried to get his room changed, but the counselors denied drug dealing was going on and said Bill needed to learn to live with other people. We spoke with a friend of ours, who was a senior lawyer for Cornell University, about Bill's case, and he said talking to counselors was a waste of time, as we had found out. Our friend called a fellow attorney for the NY State University System, and Bill was given a new room in 24 hours.

Bill chose to transfer to the University of Cincinnati because they had a strong work-study program in architecture. Once again Bill was unlucky with his roommate. This time he was paired with a severe drug user who frequently passed out from drug use. Bill feared he would find the roommate dead some

night, or killed by a drug dealer to whom he owed money. Once again we called on our lawyer friend to get Bill's housing problem solved. Bill's roommate was moved somewhere, and apparently dropped out of college soon after.

We knew that Bill sometimes complained to Joan that he just wasn't like everyone else. Joan tried to reassure him that he was just fine and that we loved him totally. It was at Christmas time in 1977 that Bill told us he was homosexual. This came as a shock to us, since we had no idea he was anything other than straight. He had been dating a lovely girl from a Chinese family, and she sometime joined us for church services.

We were concerned for Bill's safety, since there were frequent stories in the papers about homosexuals being attacked, and some killings were reported. At this time, AIDS was also spreading in the gay community and it was usually fatal. In fact Bill lost a number of friends to AIDS while he was in college and in years following.

Bill worked for several design companies, mostly doing store design. For several years, he worked as a store designer for LensCrafters. He lost his job when the company decided to outsource its design work. Bill found a good position with the Limited Corporation in Columbus, Ohio and moved there in 2000. Bill has worked on store design for Victoria Secret, Bath and Body, Henri Bendel, and other Limited Corporation stores.

In Columbus Bill found a good mate who was a manager for a newspaper advertiser organization. Bill and Marc Henry soon paired up and bought a lovely home in Bexley, OH, a small city within the city of Columbus. Mark has become a loved member of our family, and Marc's family warmly accepts Bill.

Bill and Marc at our 60th wedding anniversary, 2013

Bill has advanced to the position of Senor Design Manager at The Limited, now called L-Brands. He now plays the lead role in the design of a number of stores from Columbus, to New York, to Dubai in the United Arab Emir-

ates. Bill played a major role in the redesign of the Henri Bendel store on 5th Avenue in New York. This is L-Brands' flagship store, but it had been losing money for decades. After the redesign, the store has become profitable as well as beautiful. As Senior Design manager, Bill is now working on the redesign of hundreds of Bath and Body and White Barn stores.

We have had Bill help us with some redecorating and refurnishing. It amazes us how he can look at a room and in 10 minutes come up with recommendations for new furnishings and or paint, and the result is always beautiful and functional! Both our son Joe and our daughter Barb have called on Bill to help with interior design – with great appreciation of the end results!

Bill and Marc decided they needed more free time to relax and do other things than yard work and building maintenance. They purchased a very nice townhouse in New Albany, Ohio, and have settled into a comfortable new home. We visited their new home in October, 2014. We were impressed with the home -- and all the artwork and other additions that make it homey and attractive.

After over 15 years living as a couple, and the US Supreme Court decision to ban gay, lesbian and transgender marriage discrimination, Bill and Mark decided to marry. They chose to have their marriage in gay friendly Provincetown, MA on May 22, 2015, the 15th anniversary of their first meeting. They held a lovely wedding celebration for family and close friends in Columbus, Ohio, near their new home in June, 2015.

Bill, Mark and the minister who married them in 2015

Our Granddaughter, Rachel Hunt

While Barb and her husband Bill Hunt had a pretty challenging first few years of marriage with Bill stationed in various locations with the Air Force, they did manage to keep it all together. Bill was still with the Air Force when

Rachel was born on September 10, 1982 in Goldsboro, North Carolina. Rachel was a beautiful, happy baby, and we were all delighted with her.

As noted earlier, during Rachel's early years she and her mother lived in Ithaca, NY while Barb attended Cornell University. Rachel had four cribs for a while, one at our home, one in campus housing, one at the baby sitter's home, and one in Durhamville, New York near the Air Force base where her Dad was stationed. Despite all this moving about, Barb managed to continue nursing Rachel and she was much loved by all of us. She was a happy, very alert baby and a joy to spend time with. Joan and I were delighted to have so much time with Rachel in these early years. We often journeyed the 90 miles to Durhamville on weekends to spend time with Rachel and her parents. We were amused that when we asked Rachel where she would like to have lunch, she would quickly respond, "the O Club." She liked the ambiance of the Officers' Club on the Griffiss Air Force Base.

When Bill completed his tour with the Air Force, he obtained a position flying with American Airlines and was based in Boston, Massachusetts. They bought a house in Carver, MA, about 30 miles south of Boston. Rachel attended preschool and then elementary school in Carver. After the family moved to a lakefront home in Lakeville, MA, Rachel attended Friends Academy, a private school in Dartmouth, MA. Throughout her schooling, Rachel earned top marks and also excelled in all sorts activities. However, her real talents were in the arts, and she made many fine drawings in elementary and high school. She was proud of her drawings and kept them safe. One occasion when we were visiting in Minneapolis with Rachel, she posted some of her drawings on the refrigerator at Great Aunt Mildred's house. Mildred thought they were hers to keep, but the day before we left, Rachel gathered up all her pictures for their return home.

Rachel began high school at Bishop Stang school, a private Catholic school. However, she was not happy there and found it hard to make friends, since most of her classmates had enrolled there in elementary school years and she was not included in the local student cliques that had been formed. She transferred to Lakeville High School, close to her home where she already had friends. Rachel did well at Lakeville, especially in art classes, and one of her teachers was especially helpful and encouraging.

After a school trip to New your City that included a visit to Ellis Island, Rachel painted a picture of an emigrant saying goodbye to his mother before departing for the USA. We treasure this picture, since it reminds us of the time Joe's Dad left Slovakia for the US in 1923.

Rachel's painting at age 16 of an emigrant leaving Slovakia for the USA

Always quick to try new things, Rachel had become quite proficient on the piano and later taught herself to play the guitar. But her real love was in art. After completing high school in 2002, she enrolled in the Massachusetts College of Art and Design on a full scholarship. Rachel also worked part-time at a stationery store in Boston, designing special cards and stationery on occasion for customers.

Rachel had met Mathew Adams in high school, and Mathew moved in with Rachel in her Boston apartment. Mathew was something of a goof off, and we were not happy with the arrangement. Nevertheless, Rachel did well at Mass Art and her exhibits were always well attended, with many compliments and kudos. We had a chance to see some of these on our trips to the Boston area, since we had chosen to spend summers in Taunton, MA in 1998, after I retired from Cornell University.

Rachel and her parents at graduation from Massachusetts College of Art and Design in 2006

Rachel received a scholarship to attend Cranbrook Academy to pursue a Master of Fine Arts degree. The Academy is world renowned in the arts, and admission is very competitive. The Academy provides on campus housing, but Rachel chose to rent an apartment instead. We were concerned that Mathew would be joining her, but Rachel insisted that he stay in the Boston area and complete an Associate of Arts degree at the for profit college he was attending. In her case, distance did not make the heart grow fonder, and Rachel broke off the relationship during her first semester at Cranbrook.

Rachel met Chris Durocher at the Academy. He was pursuing a MFA degree in photography and graphic design. From our first meeting with Chris, we were delighted that Rachel had chosen such a handsome, competent, hard-working man. Chris soon moved into Rachel's apartment, and the relationship flourished as they proceeded through their master's degree programs, with both graduating in May, 2008.

Unfortunately, the economic downturn that began in 2008 was dragging on, and Chris and Rachel were not successful in finding positions in their fields. Rachel was offered a scholarship at Arrowmont School of Arts and Crafts in Gatlinburg, Tennessee. Rachel accepted the scholarship, and she and Chris moved to Tennessee for the academic year. The stipend was modest, so they had a tough year financially, but Rachel did well with her work at Arrowmont.

With Rachel's program going well, Chris and Rachel decided they would marry in March, 2009. They had hoped to have a wedding reception at a Boston theater lobby, but the cost proved to be prohibitive. Together with Rachel and Chris's parents, they planned instead for a simple ceremony at a justice of peace and a wedding dinner at a local restaurant near Chris's home in Windsor, Ontario. All of the family and many friends attended the very nice dinner reception.

Rachel and Chris's wedding dinner, March 7,2009

With no jobs and no home, Chris and Rachel moved in with Rachel's parents until October, 2009 when our condominium in Taunton, Massachusetts became available as we returned to our winter home in Florida. In addition to their rent-free housing, we paid all utility bills and provided Rachel and Chris a monthly subsidy to help with other living costs. Rachel did succeed in finding part-time work as a hostess in a local restaurant, but the earnings didn't meet their monthly living expenses. We were all delighted when Rachel was chosen from a field of 300 candidates to fill a temporary teaching position at Lexington, MA Public Schools in September, 2010. Chris also found part-time employment at Bristol Community College, teaching photography.

With both Rachel and Chris employed, and some help from Rachel's parents, Chris and Rachel succeeded in buying a lovely older home in North Billerica, MA. The property had a huge lot extending from the front road some 400 feet back to the Concord River. The lot was totally overgrown and needed clearing and landscape work, which Chris and Rachel completed. The house also needed repairs, painting and other work, most of which Chris and Rachel also completed. The property is now worth substantially more than they paid for it. We are all proud of the good work they have done.

In 2011, Rachel was given a continuing appointment at Lexington High School when she replaced the previous art teacher who had held the position. She teaches all kinds of art subjects, including a current class in metal art. Chris worked part time at Bristol Community College for two years. In 2012, Chris was selected to a tenure track position teaching photography at Mount Ida College, near their home, but the position ended in May, 2013 when

the College, facing financial problems, cancelled all non-tenured positions. Chris is now employed with Malden Public Schools in a tenure track position teaching various courses in photography and graphic design. We expect he will achieve tenure with this school by 2017.

Rachel was granted "Professional Status," approximately equal to tenure, in July, 2013. With Rachel's employment relatively permanent, Rachel and Chris chose to begin a family. Their beautiful daughter, Noelle Riley, was born May 24, 2014. She is a happy, delightful child and a real joy to all members of the family. We regret that we cannot spend more time with our great granddaughter.

Rachel and Chris in front of their first home, N. Billerica, MA, 2011

Noelle Riley Durocher at 5 1/2 months

Our Grandson, Joseph Warren Hunt

It was a warm October 29 day when Joseph was born in Carver, Massachusetts in 1988. The saying, "happy as a baby boy" truly applied to Joseph. It was rare to hear him cry, and that was only when he was very hungry or very in need of a diaper change. As with Rachel, Barbara nursed him until he was almost three. Needless to say, he was very content when being nursed by his mother. On occasions when we baby sat for him so that his parents could have some time off, he would often throw to the floor the bottle we had given him, complaining, "I want Mommy's milk!"

Joe was a precocious boy, talking in sentences by age one and asking very intelligent questions by age two and three. Joe's dad was flying Boston to London for American Airlines at the time, and I remember Joe asking me to show him were Boston and London were on a large globe the family kept in a hallway. When I showed him the route from Boston to London, Joe commented, "It doesn't look very far --- but then it's a small globe." It is not uncommon for older children and adults to fail in proportional reasoning no more challenging than this globe task.

On another occasion when Joe was 6, we were at a county fair. There was a large gallon flask full of gumballs, with the question posed: "How many gumballs are there in this jar?" Joe did not see a good way to estimate this, so he asked me for an answer to the question. It looked to me like there were about 4 gumballs per cubic inch, and a gallon jar is about 230 cubic inches, so I asked Joe how many gumballs that would be? He knew the answer would be 4X230, but he could not do the computation in his head. We did not stay to the end of the fair to learn the correct answer to the gumball question. Clearly Joe had inherited his mother's math skills, and this was evident throughout his schooling.

Joe was always interested in building things from Lego blocks, etc.

Even in his preschool days, Joe was interested in the small hand held computer games that came on the market. Later he would play video games for hours at a time. His most common birthday or Christmas presents were computer or video games. Joe also liked to play board games such as Monopoly, checkers and chess. By age 6, he almost always won the game when playing with Grandpa or Grandma. This was often the case even when he was simultaneously playing one of his hand held computer games. As is true for many Millennials, multitasking appeared to be Joe's preferred style of thinking.

Joseph age 7 beating me at chess

Joe was always thinking up schemes to make some extra money. For a number of years in junior high school and high school, Joe would buy doughnuts at a Dunkin Donuts shop near his house, and then sell them to hungry classmates at school for twice the price. He sometimes found games or other items at bargain prices and then resold these for a considerable gain. When he became a licensed driver, he would sell rides to his friends to school or other outings. Since he charged the gas purchased to his Dad's credit card, these rides were quite profitable.

Schooled first at Friends Academy and then in junior and senior years at Bishop Stang High School, Joe benefited from the small classes and personal attention given in these schools. We recall when Joe began high school at Bishop Stang, parents and grandparents were asked to write a letter stating why they thought their child was a great kid. These letters were later passed along to Joe. We thought this was a great idea to build self-confidence early

in their high school studies. This was but one of the many positive emotional aspects of Bishop Stang. The fact that everyone wore the same uniforms also contributed to a favorable emotional and business-like environment.

Some public schools require student uniforms, and this is a practice we think should be universal, as it is in many countries with high student achievement. Joe was an avid player of games that required special materials, such as the various pieces of Warhammer. Although Bishop Stang was a Catholic sponsored school, Joe never had problems with this, and in fact we think he benefited from some of the religious studies. Joe was active in the Unitarian church near his home and participated in many Church sponsored activities. Until recently, he took time off to go to a camp on Star Island in New Hampshire, connecting with friends from his high school days.

When it came time to apply to colleges, Joe explored a number of options. With his skill in math and sciences, he narrowed his search to schools with strong programs in engineering. His parents thought he would benefit from a school with rigorous study and personal habits and encouraged Joe to apply to the Massachusetts Maritime Academy (MMA), about 30 miles from his home. Joe received a full scholarship at MMA, and enrolled in September, 2007.

Joe never took to the military style rigors of the Academy, but he did well in classes and on shipboard activities that were also required. He did tutoring in English and math, earning some money for his many hobbies. Some of his expenses were paid for from New York State 529b funds we had set aside for his college education. Perhaps because he did not enjoy life at the Academy, Joe took extra classes many semesters and together with Advanced Placement credits, he graduated in 2010, a year early, finishing the BS program in Maritime Engineering in just three years.

Joseph receives BS degree in Marine Science, Massachusetts Maritime Academy

The first job Joe had was on board the Mary Ann Hudson, an older bulk cargo ship that usually hauled grains or coal between the USA and ports in Africa. Joe spent most of his time in the engine room keeping track of engine and ship performance. Although the engine room was usually hot, Joe did not mind this. He did get to see a number of foreign ports.

When Joe was laid off due to the need for extensive ship maintenance, he found a job with the engineering department in the City of Marion, MA. He found the pace of the work much slower than work on the ship, and pay was significantly less. When the Mary Ann Hudson was ready to sail again, Joe accepted the invitation to return to the vessel. However, after two three-month tours of duty, he resigned his position. How much of this was due to his desire to find land based work, and how much was due to a relationship with a young lady, this we do not know.

We were concerned that quitting this job might not look good on his record. However, after several months enjoying no commitments, he found a position with a power transmission company based near Worcester, MA. He enjoyed being relatively close to old school friends, a nearby ski resort, and some of the family. He thought his job situation was secure, so he wisely purchased a large two-story home, with plans to rent the lower unit to a family and to share the upstairs unit with a friend and roommate. He also enjoyed the camaraderie in being a volunteer fireman and took the coursework necessary to become fully certified.

Unfortunately, the position with the power transmission company ended in 2014, and it took a while to find another position. Fortunately, in 2015 he was hired by a company that provides engineering services to other companies, and so far this work is going well. He did not have to relocate his residence. Always a friendly, happy person, Joe is likely to continue this pattern in the future.

Joseph with his new motorcycle and Subaru car.

Chapter 4

Planning and Conducting My PhD Research and Creating a Theoretical Foundation for Future Work

In the field of education, it is common for the majority of graduate students not to continue the line of inquiry done in their thesis work, and indeed most do not publish their thesis work nor even continue as active researchers. For me, my thesis work formed a cornerstone for much of the work I would do in my research and curriculum development activities for the next twenty or so years. Therefore, I pause my story to discuss this work.

A search for theoretical foundations and study design

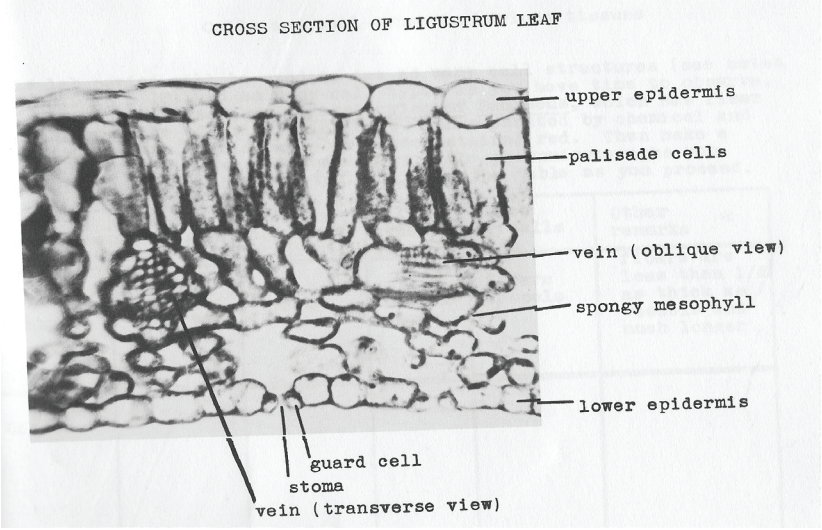
For many years I had observed that individuals varied greatly in their ability to use information to solve problems. In the teaching work I had done, I often observed students who could get high scores on tests for information presented, and yet they failed totally when asked to apply that information to solve problems. I thought that if students could be taught in a way that would make them better problem solvers, this would be a significant accomplishment. I wanted to address this issue in my PhD work. I also thought that education might be improved if research was done more like research in the sciences, that is, it should be based on solid theory and principles.

The only theory of leaning taught in the College of Education at Minnesota in the 1950's was behavioral psychology. Since I thought this theory was useless for the kind of research I wanted to do, I sought an alternative. I turned instead to Norbert Wiener's ideas as presented in his 1948 book, *Cybernetics,* and also his 1954 book, *Human Use of Human Beings.* Cybernetics is a trans-disciplinary approach for exploring regulatory systems, their structures, constraints, and possibilities. The details are not relevant to my story, so I will skip these.

To do the study, I had to design an instructional program to move an experimental laboratory section through two quarters of Introductory Botany at an accelerated pace to allow for a six week period for each student to design and conduct an independent research project dealing with plants. The other 10 laboratory sections (my control group) took the standard botany program.

A key task that I faced was to design a test for problem solving ability that would be valid for this study. I also had to develop a special laboratory study

guide that would accelerate the students progress through the standard botany course in order to provide time for the research project each student in my experimental group would be required to do. These two tasks took more than six months of intensive work. Among other things, the study guide I prepared used about 50 labeled photomicrographs showing plant structure such as in the photo below. Most study guides require students to add their own labels to such photographs or to line drawings.



One of the labeled photomicrographs prepared for the experimental botany class.

In my last year of work in the Botany Department during 1956-57, I was promoted to the position of Instructor and was placed in charge of overseeing all laboratory sessions and preparing and scoring exams. This was somewhat remarkable, since I was continuing my major PhD concentration in Science Education, and it was good evidence that the Department endorsed my competence as a botanist. The arrangement also made it easier to conduct my research study with the Introductory Botany course. I did earn more pay as an Instructor, and this was helpful, since we had had our first son in June. My wife was no longer working as a medical technologist.

The details of my PhD thesis research have been published, so I will not bore the reader with these. Suffice it to say that the study showed there were ways to accelerate student learning, including aids such as labeled photomicrographs and other plants structures. This was important because it led to the development at Purdue University of what we called Audio-tutorial instruction, and I adapted this form of instruction to teach basic science concepts to first and second grade students. Seeking better ways to assess the learning

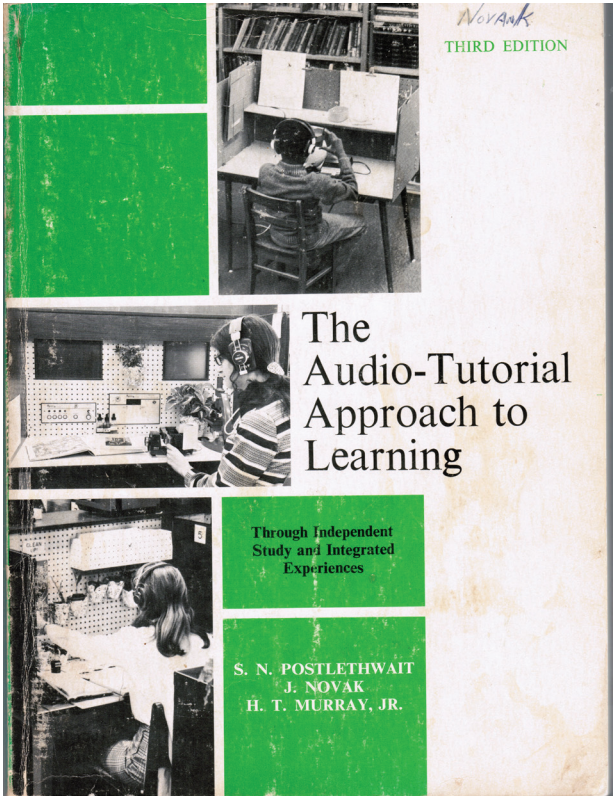
of first and second grade students using our Audio-tutorial lessons led to the development of what we call concept maps. The invention of the concept mapping tool changed the remainder of my career, so I will be saying much more about this tool in the remainder of my story.

The origin of Audio-Tutorial Instruction

A few years after I finished my PhD work, I was employed in the Biology Department at Purdue University, my colleague Sam Postlethwait, had been recording his lectures and making them available for student study in the Audio-Visual Center. I suggested that he might use some of my labeled photomicrographs and other materials I had developed to enhance the taped lecture presentations. Sam did this and then went further, providing some actual plant materials to supplement his lectures.

In the span of about a year, Sam evolved his teaching to the point where traditional laboratory and discussion sessions were converted into audio-guided, tutorial instruction in modified laboratory rooms. He reduced his lectures from three per week to one per week and most of the learning was now taking place in carrel units in a "Learning Center" in the Biology Building. Teaching assistants served as aids to student's doing audio-tutorial lessons, and they also led weekly discussion sessions. Thus was born the Audio-tutorial approach to learning (Postlethwait, Novak & Murray. 1964; 1973).

This approach was widely adopted in many college and university courses and some secondary schools all over the world. The book cover shown below shows an audio-tutorial lesson in an elementary school classroom (top) and two photos in Postlethwait's Audio-tutorial learning center. After I moved to Cornell University in 1967, my graduate students helped to create an audio-tutorial course in the Physics Department, the Biology Department, and in the Chemistry Department at Cornell University. These courses continue today, with modifications and updates, of course.



The Audio- Tutorial Approach to learning was developed in the 1960's in Professor Postlethwait's botany course. My research group later adapted audio-tutorial instruction for use with first and second grade children (top photo).

The Discovery of Ausubel's Assimilation Theory of Learning

In subsequent research done by me and my graduate students at Kansas State Teachers College and Purdue University, it became increasingly evident that while Wiener's Cybernetic theory may be valuable in designing autonomous devices, it was of little value or perhaps wrong for the design and interpretation of better educational programs.

I recall one of my graduate students, Darrel Murray, coming to my office one evening and complaining that we had to find a better theory for our research!

It was just a few days after this discussion with Darrel that the work of David Ausubel came to my attention, namely his 1963, *Psychology of Meaningful Verbal Learning*. I was immediately struck by how well the ideas in his Assimilation Theory of learning provided an explanation for the kind of data

we had been gathering, and also how well it might work to guide our future experimentation.

The weekly seminars with my research group immediately turned to reading and discussing Ausubel's theory. It also struck me as interesting that a former PhD student, Richard Schultz, now working in Cedar Rapids, Iowa Public Schools, had also discovered Ausubel's book a few months after we began using his book and Richard recommend that we look at it, since he knew we were looking for this kind of learning theory. Thus began our work with Ausubel's ideas, and his theory continues to play an important role in our work today. In later sections of this book I will discuss some of the contributions our research made to enhance Ausubel's theory of human learning.

Chapter 5

Moving Toward a Career as a Biology Educator

Finding a Career Path

When I first began college studies in 1948, I had no definite career goal. I started out as a math major, partly because I had done well in math in high school and partly because, unlike sciences, one earned one credit for each hour in class. This gave me more time to work at Central Cleaners pressing clothes. However, I also took some science courses simply because I enjoyed them, and some were required. For the most part, I did relatively little studying my first three years in college, since I spent 35-40 hours per week working at Central Cleaners. Nevertheless, I always earned a C or better in my classes, and B's and A's in courses that most interested me.

By my sophomore year, I decided that I would work to earn a teaching certificate in math. While math in high school had always been easy for me, I found college courses more challenging. And then when I was taking a course in integral calculus, I discovered that while I could do the problems assigned, I really did not have a ***conceptual understanding*** of the math I was studying. In fact, I realized that this had been the case in high school and in my college algebra, geometry, and trigonometry studies. It was clear to me that if I really wanted to do mathematics well, I would need to go back and re-study all the subjects I had taken to gain a conceptual understanding of these subjects. The easier route was to change my major to science, where I always felt I understood the concepts as well as the procedures. I increased the time I was spending on science courses, but still managed to spend 30 plus hours per week working at Central Cleaners.

Beginning in my senior year my wages pressing clothes had advanced to $1.25 per hour. I could see that I could finance my college and other expenses by working only 20-30 hours a week, providing more time for serious study. The Science Education program required a 20 credit hour major in one of the sciences. I chose botany, since zoology courses had so many pre-med students who were eager to memorize answers for test questions and had little interest in understanding the science they were studying. Most zoology courses catered to this kind of teaching and learning, which I found unsatisfying. Moreover, the Botany Department was much smaller. I felt closer to my professors and more a member of the Department.

Students enrolled in the teacher education program at Minnesota were required to pass a speech test. Apparently my early bilingual experiences had caused some distortion in my speech. I did a number of speech exercises for several months, even though some of my speech mentors could not detect any problems when tests were repeated. While I think some of the initial diagnosis may have been a result of the neighborhood in which I grew up, it was only later that I learned of the bias against students from some public schools, such as Edison High School.

I was aware that my vocabulary was not as extensive as that of my college peers, especially those who came from professional families and/or went to private high schools. In 8th grade we read a weekly magazine with "news" stories. I found most of the news to be dated as compared to the daily newspaper the family read, but there was a section on vocabulary, and I began writing down words and definitions I did not know. I was amazed at how many of these words turned up in the lectures of professors at the university, and I was thankful I had made the effort to broaden my vocabulary from the Weekly Reader magazines.

Another requirement of the teacher education program was one semester working with secondary school children in non-school settings. I chose to work with a Boy Scout troop in an impoverished neighborhood two miles from my home. About half of the boys in my troop had been in reform school, arrested for petty crimes, or suspended from school for a time. Nevertheless, I found them cooperative and appreciative of my efforts.

There was supposed to be a Scoutmaster for the troop, but one never showed up for meetings, so I was the de facto Scoutmaster. The local Eagles Club sponsored our troop, and provided a small amount of money for materials I needed, and paid the camp fees for a two-week summer stay in a wilderness camp. Once again, none of the adults who were supposed to assist at the camp showed up, so I had my hands full.

In spite of my scouts' poor school record and police encounters, they never stole even a pencil from me, nor did I have any serious disciplinary problems. I learned first hand how poverty impacts the lives of children and how poorly schools and the court system dealt with these problems. I had to withdraw from working with the troop in my senior year due to the press of other activities, and my continuing work at Central Cleaners. So far as I know, the troop failed to continue.

My scout troop on a two-week camping trip.

Becoming a Biology Teacher: My First Career

The Botany Department was much smaller than the Zoology department. Most of the professors really stressed the basic science ideas needed to understand the subject. In my senior year I took several botany courses and found my plant physiology professor, Albert Frankel, very receptive to new ideas. I requested some space in his laboratory to do an experiment where I was growing tomato plants in bell jars under normal air pressure and under 2 atmospheres pressure. Maintaining the plants under 2 atmospheres pressure was easy, but it took me a lot of trial and error to figure out how to water and feed plants under sustained pressure. Professor Frankel took interest in my project and often made helpful suggestions. While I noted some small variation in tomato plants grown under pressure, the term ended before I could get more definitive results.

When the term ended in June, 1952, I was faced with finding a job as a science teacher, or perhaps being drafted into the armed forces. (The Korean War was in progress.) While I was debating whether or not to accept a biology teaching job in a small town about 100 miles from home, I received a phone call from the Botany Department at Minnesota asking if I wanted to apply for a teaching assistantship in the Department. This invitation no doubt was a result of the work I did in Dr. Frankel's laboratory, as well as my frequent visit with Professor Abbe, whose major research was in plant morphology.

This was my first career experience with a good outcome attributable to my extra effort in pursuing an idea. I found teaching in botany labs very rewarding intellectually, and the annual stipend of $1200 was sufficient to pay all of my bills. I also worked part time as a research assistant to Dr. Frankel and participated in gathering data for his experiments in plant physiology. I had many of the same experiences I would have had as a PhD student in botany.

Professor Albert Frankel was a great mentor and supporter of my work in the Botany Department. He was honored nationally for his research on photosynthesis.

Since my undergraduate major was in science education, with a concentration in botany, I was not sure how well I would do teaching in botany labs. I was also assigned to teaching in biology labs, since I was one of the few botany graduate students who had taken several courses in zoology, and the introductory biology course was a joint effort of the Zoology and Botany Departments.

I continued to broaden my science background, taking courses in plant anatomy, plant taxonomy, cell biology, paleobotany, comparative anatomy, mushrooms, geomorphology, and philosophy of science. I spent most of my senior year as an intern teacher in science at the University of Minnesota Laboratory School. This experience was very helpful to me as a botany teaching assistant. I think I found teaching laboratory sections and leading discussion sessions easier for me than for many of my colleagues in the Botany Department.

The internship teaching experience also gave me doubts about a career in secondary school science teaching. Although I enjoyed teaching secondary school students, the general intellectual environment, even in this laboratory school at Minnesota struck me as something short of scholarly. In later work in teacher training, I found this to be even more the case in many public secondary schools. The net effect was that I definitely wanted to teach at the college level. Therefore, earning a PhD degree was essential.

Several of my botany professors argued that there was really no value in the study of education in colleges of education, and that I really should just do a PhD in botany. Professor Abbe, whom I respected highly, often teased me about studying education. In fact, I had my own doubts, since many of the courses I took in education were as useless as the Theories of Learning course, discussed below. Nevertheless, I was working with a respected scholar in statistics and science education, Palmer O. Johnson. While he applauded my in-depth studies in science, he also modeled for me that a career doing research in science education could be a scholarly endeavor, similar to that in the sciences. In fact, The American Educational Research Association chose to name their highest award for outstanding research the Palmer O. Johnson Award.

My office mates in the Botany Department often shared their research work with me, and I respected what they were doing. For example, John Rowley was studying the electron microscopic structure of pollen cell walls. He went on to become internationally known in this field, and perhaps some 50 to 100 scholars read the papers he produced subsequently. While I respected the search for new knowledge as a valid goal in itself, I wanted to do research that might have more of a positive impact on the lives of people. This was the vague goal I sought as a child. Deciding to continue a major and thesis work in Science Education was something I constantly reflected upon, but in the end, I think I made the right decision. This book is my testimony to the validity of that decision.

The philosophy of science course was taught by Herbert Feigl, internationally known for his writings on *logical positivism*. Minnesota was known as the world center for logical positivism. However, I found this view of science unsatisfactory and inconsistent with the way I saw science being taught in the Botany Department. Here the teachings of my dad came into play: "If something seems like nonsense, it probably is nonsense!" I saw James Conant's 1948 book, *On Understanding Science,* as much more congruent with my own thinking. Thirty years later, the most popular views on the nature of science and scientific discovery had moved to essentially the position I was trying to present in 1953.

Dad taught me to trust my judgment. "If something seems like nonsense, it probably is nonsense."

My graduate course in Theories of Learning presented only *behavioral* theories of learning. I recall debating the value of these theories with my professor, Gordon Mork, using some of the same arguments I used with Professor Feigl. Again, my father's teaching came into play: "if something just does not make sense, it is probably wrong." Mork agreed that there were shortcomings in the theories presented, but he argued that we were using the most popular book on theories of learning, and that he knew of no other popular theories.

Unfortunately, this was almost true in 1954, and it was some years later that I learned of the work of Bartlett, published in 1932, and his theory of *cognitive* learning. There was also Piaget's monumental work with children and his ideas on cognitive development in children, but neither of these works was taught in the College of Education or in the Psychology Department. Thirty years later the psychological world had shifted, and cognitive psychology became the dominant paradigm for human learning. Our research program was just thirty years ahead of most of the field!

One of the most significant events in my move toward a career as a biology educator occurred in the summer of 1955. The Botany Department received an invitation to send a delegate to a National Science Foundation (NSF) funded, two-week conference to study the need for new high school biology programs. None of the Botany professors wanted to take time to attend this

conference, and I was asked if I wanted to attend. When I learned that all expenses would be paid for by the Conference, I jumped at this opportunity to go to this national meeting at Douglas Lake, Michigan.

The Conference Directors were Professors John Karling and Richard Armacost of Purdue University. There were several sub-groups set up to study specific issues regarding new textbooks and new laboratory guides. John Breukelman, head of the Biology Department at Kansas State Teachers College, chaired my sub-group, and I had considerable interaction with him through the conference. Although I had attended for one day a Minnesota conference on biology teaching, I had never attended a national professional meeting. Douglas Lake was chosen as the venue for the meeting to assure that participants would not be distracted by sight seeing and other activities in a large city. In addition to formal meetings, there were many informal meetings with individuals at the conference, and I got to know some of the senior people quite well.

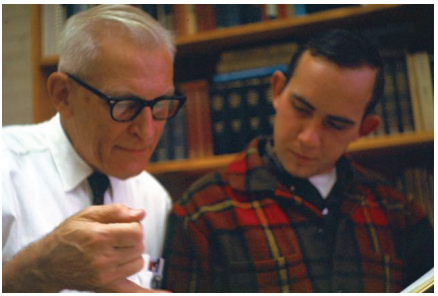
A major outcome of the Douglas Lake Conference was the formation of the Biological Sciences Curriculum Study (BSCS), an organization funded by the National Science Foundation (NSF) and directed initially by Arnold Grobman, who was also one of the key leaders at the Michigan conference. BSCS produced three different versions of high school biology textbooks and laboratory guides, all of which substantially modernized high school biology teaching. Later in my career I was heavily involved with BSCS, including membership on the Board of Directors for four years.

The Importance of Personal Contacts

The most recommended factor in job seeking is networking. The Douglas Lake conference proved to be the beginning of my professional career and a succession of career changing events. When I completed my PhD studies in 1957, I was recommended for a position at Kansas State Teachers College by a professor there, my former office mate, Gill Leisman. Although Gill had a low opinion of schools of education, he was supportive of the work I was doing. Professor Breukelman was retiring as head of the department, and he remembered me well from our Douglas Lake associations. I was offered the assistant professor position in spite of competition from more experienced candidates.

I had also interviewed for and was offered a position at Winona State College in Minnesota, which would have been a position close to our home. Moreover, the Winona State position offered a nine-month salary of $5,800,

while the Emporia position paid only $4,700. As I was coming out of graduate school with few assets, the $1,100 salary difference was relatively huge. But my major professor, Palmer Johnson, advised that if I took the Winona position, I probably would stay there and end my career there, whereas the Emporia position, he thought, could open many more opportunities for me. Fortunately, I accepted the position at Emporia. Not only did I receive the largest percent of salary increase of anyone in the college the following year (to $5,700, plus summer salary), but I was encouraged to participate in many professional state and national meetings, where I soon met most of the leaders in Science Education in Kansas and in the USA. Professor Johnson had given me good advice!



Prof. Breukelman was always helpful to students and colleagues.

The Biology Department at Emporia conducted summer programs for practicing high school biology teachers, including some outstanding teachers. The courses I taught in these summer programs gave me a better appreciation of the problems secondary school teachers had to deal with. The Department also made a practice of visiting the high schools of the teachers in our program, and I learned a lot about the working conditions of these high school teachers. These experiences proved to be invaluable when I moved to Purdue University to head the biology teacher training program.

When a position in biology education became open at Purdue University due to the death of Richard Armacost, Dean Anderson at the University of Kansas recommended me for the position instead of one of his former students that Purdue had inquired about. I had become well acquainted with Dean Anderson through participation in meetings I attended at the University of Kansas and nationally. He was also a former student of Palmer Johnson, so we shared this experience.

I recall that during interview sessions at Purdue, my seminar on the work I hoped to do at Purdue to improve theoretical foundation of education met with a rather cool reception from colleagues in education. When I met with

Professor Karling in the last of my interviews, we spoke about the Douglas Lake conference and the kind of work I wanted to do. When asked if I would like to come to Purdue for a joint appointment in education and biology, I expressed my strong interest, but also mentioned the cool reception of my ideas and research interests in the Education Department. Professor Karling leaned back in his chair, knocked the ashes off his cigar and said, "Joe, they don't count! If you want the position, it is yours." We moved to West Lafayette, Indiana in August, 1959, and I began my work training biology teachers and building a science education research program. Eight years later I would move to Cornell University as Professor and Chairman of Science Education, but that story will come later.

Moving to West Lafayette, Indiana was a great move for the family. Although West Lafayette was only the size of Emporia, Kansas, Lafayette across the river was almost three times larger. We enjoyed all the advantages of a small town, where I could easily come home for lunch, and yet there were far better shopping and recreation opportunities. Purdue University, about 10 times larger than Emporia State, had numerous concerts and other events. The Elliott Hall for Music could seat 6,000 people. It was possible to host large traveling productions and internationally known artists. Moreover, there were many more parks and lakes within easy driving distance. We were a 3-hour drive from Chicago, where I had numerous relatives. We usually went there at least once during the Christmas holidays. Joan joined a little theater group and played key roles in a number of local productions. Both Joan and I and our children made many good friends in West Lafayette.

Joan and her mother with our children on the Purdue campus,1960. Our 1950 Chrysler New Yorker is behind them.

Joan (at right) in a play in Lafayette, Indiana

Chapter 6

The Education of Teachers and the Politics of Education: My Second Career

My Early Work as a Teacher Educator

At Emporia State Teachers College, 1957-1959, I taught biology courses and a course for prospective teachers, Methods and Materials for Teaching Biology. It was my experience as a teaching intern that there was little preparation of teachers for acquiring and maintaining science equipment and other materials. I found that I could obtain many items I needed either from equipment vendors, local greenhouses, stores, and free offerings listed in science teacher journals. I had built up quite a collection of items when I did my intern teaching at Minnesota, and I used this experience to fashion assignments for my Methods class.

I divided the semester into a series of topics covering the field of biology, each section dealing with major biological ideas including cell structure and function, genetics, plant and animal evolution, and ecology. For many of my students, this was not only a chance to learn about methods and materials for teaching these topics, but also an opportunity to learn new and meaningful concepts. The Department offered a 12-week summer program for practicing teachers, supported by the National Science Foundation. I found that teachers in the latter program could benefit from the same program I offered to undergraduates.

As noted earlier, the Department also had the policy of visiting each teacher who participated in the summer program in their school setting during the academic year, since most of the teachers were from Kansas schools. This was a good opportunity to learn from teachers some practical problems they were dealing with on a daily basis, including problems with parents and/or school administration. What impressed me most was that in general, teachers were poorly prepared both in subject matter and in teaching strategies that could encourage student understanding of science concepts.

One of my colleagues, Merle Brooks, did a study of science teacher transcripts, as submitted to the state for certification. He found that most teachers were poorly prepared to teach science classes to which they were assigned, especially those assigned to teach chemistry or physics. Now, some 60 years later, the

problem of inadequate preparation in subject matter remains a problem for many teachers in elementary and secondary schools.

When I moved to Purdue University in 1959, my primary teaching work was the education of prospective biology teachers. In addition to courses in biology and other sciences, teachers took a required Methods of Teaching Biology course and a half semester of full time intern teaching. Initially, I organized the methods course along the lines of the course I had been teaching at Emporia State. I also found that most of the teacher candidates had a poor conceptual understanding of biology, even though they had taken some 20-30 semester hours of biology. They had memorized a lot of information, but acquired no deep understanding of powerful explanatory concepts. Consequently, as we worked through the various topics in biology, I spent as much time teaching basic biology concepts as teaching methods.

This emphasis on basic biology concepts was followed up when I observed these students in their student teaching assignments in local public schools. As enrollments in the biology teaching program rose from a dozen or so candidates to more than 30 per semester, I faced the problem of finding enough public school biology teachers knowledgeable in biology, and effective teachers to supervise our students. We also found it necessary to place our intern teachers all over the northern half of Indiana. This required a good deal of travel time, and often I put in a 16 hour day visiting student teachers in schools from Fort Wayne to Indianapolis, Indian.

Even with the large potential pool of mentor teachers, it was difficult to find teachers with a strong knowledge of biology. To deal with this problem, I organized an In-service Teacher Education Program, with funding from the National Science Foundation, and we offered this program on Saturdays at four of the Purdue Extension centers in Gary, Fort Wayne, Indianapolis, and Terre Haute. We offered the same new courses that were organized for undergraduate majors on the main campus, courses that were developed by the Curriculum Committee that I co-chaired with Fred Neidhart. The Saturday courses served as an excellent recruiting tool for competent supervisors of student teachers in our Purdue program.

We also conducted a summer program for high school teachers, supported by the National Science Foundation. This program offered a four-summer sequence leading to an MS degree in biology. The program was very popular, and we were able to recruit outstanding high school biology teachers. About 1/4 of these teachers opted to enroll in full-time PhD studies in biology. Since these teachers were older than most other graduate students in the Depart-

ment, and most were married with children, they needed a higher level of support than a graduate teaching assistantship provided.

Our solution was to offer Instructor appointments, rather than teaching or research assistant appointments that paid about 1/2 as much per year. Given the strong background in teaching adolescent students, teachers who moved from our NSF Summer Program to full-time PhD studies were excellent coordinators for the laboratory and discussion sessions in the five Departmental core courses. Most of these former high school teachers moved into university teaching and research positions, and some earned international reputations for their research. I also recruited one of these former teachers each year to assist me with supervising student teachers in our undergraduate program, which had now grown to some 30 students per semester.

My wife Joan played an important role in the summer programs for teachers. She organized various activities for the wives of participants, including picnics in the park and other activities, most of which included children of participants. Many of the participants became life-long friends, and we exchange holiday greetings with some even today.

Another teaching assignment I had at Purdue University was a one-credit Seminar on College Biology Teaching. When I first began teaching this seminar in 1959, the main thing we did was to discuss the major concepts of biology as they were presented in the Department's new core curriculum, and issues associated with assessing understanding. After Ausubel's *The Psychology of Meaningful Verbal Learning* was published in 1963, I introduced his theory in the seminar and showed how it aided the teaching and assessment of basic concepts. For the most part, the seminar was well received by students and faculty. This was the only course required of all Biology PhD students. Each time the issue of continuing this requirement was debated, there was overwhelming support to continue. Some of the students also observed that the course gave them a "competitive edge" when applying for academic positions, especially when these positions required mostly work with undergraduate teaching.

In addition to the above programs, I was placed in charge of the Biology Department's counseling program for some 600 undergraduate majors. Here again we found that recruits from our NSF summer program provided excellent people for the counseling work with biology majors, albeit the nature of their appointments meant that every year or two I had to recruit a new person to work with me in this program.

Managing all the above programs, even with some excellent instructor staff and clerical support, left little time to pursue my research and writing, even working typically 50 to 60 plus hours per week. Although I had clerical and travel support from the Biology Department, I had essentially no support for my research from the University.

During the summer of 1965, I was so stressed out with my workload that I sent Joan and the children to Minneapolis for a week to visit family, and free me to put in even longer work days. I thought I was approaching a nervous breakdown, and I knew that I could not continue with this kind of workload. The Education Department provided no financial support, other than 75% of my salary and local travel expenses to observe student teachers in Indiana schools.

The Politics of Academic Promotions

After a sabbatical leave at Harvard University during 1965-66, when I had almost full time to devote to my research and writing, I knew I did not want to continue at Purdue University. I had been offered an Associate Professor position at the University of Chicago in early 1965, but this was another joint appointment in a biology department and College of Education and I did not want to again divide my commitments this way. Moreover, it would have meant moving the family to a big city, and we found we preferred raising our family in relatively small college towns.

Over the years I had come to know some of the professors in education at Cornell University, especially Phil Johnson who was Chairman of Science Education. Phil was required to retire in 1967, and he asked me at one of our professional meetings if I would be interested in applying for a position as his replacement. As was the case when I applied for the position at Purdue University, I received strong support from the Biology Department and from the administration of the College of Agriculture and Life Sciences, in which the newly reorganized Education Department would now be housed. My interest in developing a theory of education was not welcomed by many of the Education faculty. I was offered the position of Professor of Science Education, which I had required as a condition of acceptance, since I did not want to go through the politics of academic promotions that I had experienced at Purdue University, as described below.

There were some interesting events that occurred at Purdue University that were factors in my decision to relocate. When I first arrived at Purdue in 1959, Henry Koffler, who had just been appointed Head of the Biology De-

partment in July, met with me in my office a few days after I had settled in. He welcomed me to the Department, but also said he did not intend to put any resources into biology education. While I was a bit taken back by this, I thought maybe his views would change as he saw what biology education could offer to the Department.

As my job evolved in the Biology Department, Koffler became in many ways my strongest supporter in the University, especially as regards my work to support improved teaching in the Department. However, while I was on sabbatical leave at Harvard in 1965-66, the Education Department had voted for my promotion to Full Professor, as had also the Biology Department promotion committee. Koffler was out of town when my promotion was approved, and sent to the next level of approvals. When he returned and learned of the recommendation for my promotion to Full Professor, Koffler interceded to block my promotion. Later on, Koffler called me to his office to explain that while he had a high regard for the work I was doing, he did not consider my research to have the high rigor and caliber he expected for a Full Professor in biology.

Of course he was right, but he admitted that he knew of no other professor doing better work in science education in the USA. I explained that I was in a catch 22: The demands of my job took so much time and effort, and financial support for my research was so limited. I was doing the best I could under the circumstances.

When I later told Koffler I had been offered a position as Full Professor of Science Education at Cornell University, Koffler said he would pay my full salary for two years, provide a graduate research assistant, provide $5,000 per year for my research and relieve me of all teaching responsibilities for two years so that I could pursue my research. I explained that what he offered was essentially what my job would be at Cornell University -- with no time limit on my support! Moreover, the position at Cornell was at the Full Professor level!

Koffler and I remained friends, and later we collaborated on some national curriculum projects. I supported his applications to Cornell University for the position of Provost, and his candidacy for Academic Vice President at the University of Minnesota. (He got that position.) Later he applied for the position of President at the University of Arizona; Koffler won the appointment. He remained at Arizona until his retirement in 1991, and remains there today.

Incidentally, when Koffler was at Minnesota (my Alma Mater), he was seeking a new Dean for the College of Education. He found the slate of candidates offered to him totally unsatisfactory, so he asked me to help him locate some top-flight candidates. I was familiar with Koffler's approach to candidate searches. He would call around to the best people he could identify in the field and ask them for nominations. Then he would return to the people nominating candidates and ask them to rank comparatively all the candidate on the list.

This process of screening might go through several iterations, until a top flight list of three or four candidates was found. I applied this procedure, using Koffler's telephone account, and after much searching, I identified three outstanding candidates now at first-rate universities. Unfortunately, none of these candidates chose to be considered for the Deanship. Koffler then ask me if I would be a candidate. I could not imagine myself in the role of managing a college with 242 faculty with widely diverse interests. I respectfully declined to be considered.

Henry Koffler, Head. Biology Department, Purdue University; 1959-73. President, University of Arizona, 1982-91

When I moved to Cornell University in 1967, Science Education was running a summer science teacher program for outstanding high school teachers with funding from The Shell Companies Foundation. Actually, this program and a similar program at Stanford University were the models that the National Science Foundation used to establish their Summer Institute programs beginning in 1955. I had little interest in once again running a summer program for high school science teachers, so I was happy that Phil Johnson wanted to do this as a part-time job after his retirement.

New Opportunities to Advance my Educational Research

By 1970, there was some feeling at the Shell Companies Foundation that with NSF programs now widely in practice, the Foundation might use their resources in other ways. I proposed instead a program in environmental education to train leaders for nature centers and similar organizations, as well as for schools, many of which were now offering special courses on environmental studies. For whatever reasons, the Foundation declined to implement this kind of summer institute, but they did agree to provide me with an annual grant of $5,000, later increased to $10,000, with no restrictions on the funds except that I would be in charge of the spending of these funds and would provide annual reports on our work.

The result was that what was originally a grant to Cornell for a summer science teacher education program now evolved into a program to support research to improve science education in general. It was possible to leverage the relatively small Shell annual grants into relatively huge opportunities to support our work. For example, I could offer a promising applicant for PhD study in science education a graduate assistantship, and then when the candidate was admitted, I could seek a teaching assistantship in one of the science departments, all of which were receptive to employing my students. Then I could use the same Shell funds to attract another outstanding applicant. Some years I could parley the Shell grant to attract two or three new students, and still have the Shell funds to support our research efforts.

In addition to support from Shell, the College of Agriculture had access to relatively large sources of research funds from the 1887 National Hatch Act that provides federal funds for agricultural research. As a member of the College, our work was eligible for Hatch support, and I succeeded in obtaining such support throughout my tenure at Cornell. These two sources of funds, the Shell Companies Foundation and the Hatch Act Funds provided most of the support for our research program and aided various aspects of our teacher education programs. I continued this pattern of work until I chose to retire in 1995.

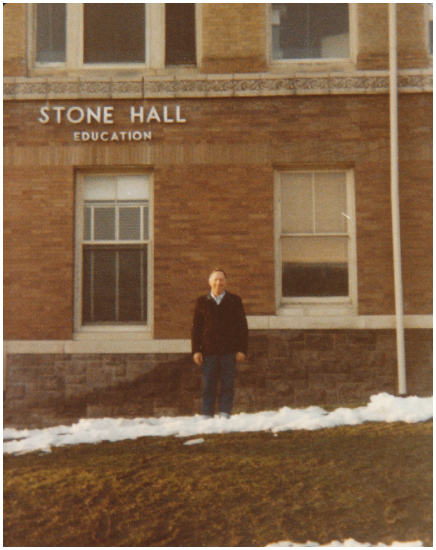
My efforts to obtain funding for my graduate students was not applauded by many of my colleagues. In fact, many of them resented that I was so successful in obtaining funding for graduate students, and also that I had 2-5 times as many graduate students working with me as compared with my colleagues. Covertly, no other professors in our Science and Mathematics Education and Educational Psychology programs permitted their graduate students to take a course with me. Another example of vicious academic politics!

I also had more visiting professors come to Cornell to study with me than the rest of the faculty combined.

Often when a new Head of our Department was installed, his first actions were to obstruct some of my activities. However, in two or three years when these people saw how my work benefited the Department, and how strong the support for my work was in the upper administration of the College of Agriculture and in Central Administration of the University, their attitudes changed, and in many cases they substantially increased my salary!

In 1967, the School of Education at Cornell University had been reorganized to a Department of Education in the College of Agriculture and Life Sciences. Over the years, there was a slow, steady decline of support for the Department, and the faculty shrunk from 33 professors to 15 by 2008. Then the Department was abolished, with only a small program remaining for agricultural education teachers. To me, this fate seemed inevitable, given the nature of the faculty interests.

I had tried to interest the Department in developing a strong program in Environmental Education, working jointly with the Department of Natural Resources, but the Education faculty rejected this idea. As so often happens in the world outside of Academe, politics often lead to the defeat of those who play the games. However, most people have no idea how vicious academic politics can be. Henry Kissinger, Secretary of State under Richard Nixon and Gerald Ford, was once asked if the politics of shuttle-boat diplomacy was hard to deal with. He responded that compared with academic politics he experienced at Harvard University, international diplomacy was a piece of cake.



Science Education was housed on the ground floor of Stone Hall prior to construction of the new Kennedy Hall at this site in 1989.

We did launch a promising new program for the MS degree in Science and Math Teaching in 1984. The idea was to recruit strong students graduating either from math and/or science departments at Cornell, or from other strong universities. We sought to provide them with a two-year program that would lead to certification for teaching and the MS degree needed for tenure in New York public schools. Students in this program took a 24 semester-hour major in one of the sciences or in math, 6 semester hours in required education courses and 6 hours in education electives, and a 12-week teaching internship in a New York public school. I was active in establishing the program, and in the early stages of the program.

After a few years, the Science and Math Education group decided to restrict the 6 hours of elective courses in education. My courses were unanimously rejected as elective options in 1988. Petty politics were in play again! I then decided that I would cease working with the teacher education program and direct my energies to other work, including faculty development seminars. Thus ended my 30 plus year career in formal teacher education. I remain active in state and national science teacher organizations to this date.

Chapter 7

Collaboration with David Ausubel to Revise His Book Educational Psychology: A Cognitive View

In 1965, I attended a conference on Concept Learning at the University of Wisconsin. Here I had a chance to have extended conversations with Ausubel about his theory, first published in 1962. These conversations helped me gain insights into his theory and its application to education. Thus began a continuing dialogue with Ausubel, and in 1975, he invited me to assist in the revision on his 1968 book: *Educational Psychology; A Cognitive View*.

As I revised key chapters dealing with Ausubel's assimilation theory of learning, I gained deeper insights into his thinking. I was also amazed at his prodigious knowledge of the literature. On several occasions, I called him to discuss his interpretation of certain research studies that did not seem evident to me. On each occasion, he explained the conclusions he reached from these studies. Considering there are over 1400 research references in his 1968 book, I marveled at his ability to discuss specific studies over the phone. Ausubel had a remarkable intellect; he was a genius in his own way! I marveled at how he could sift through the dustbins of behavioral psychology experimentation and tease out research findings that could be shown to contribute to his assimilation theory.

In the epigraph of his 1968 book, Ausubel wrote: "If I had to reduce all of educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly."

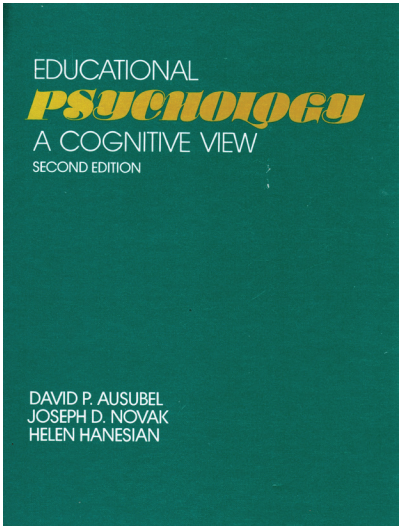
Now this may appear simple enough, or even simplistic. However, it is not easy to ascertain carefully what the learner already knows on a given topic, and it is even more difficult to determine how best to teach him or her effectively. In fact, I devoted most of my professional life to this challenge, aided by many gifted graduate students.

When Ausubel speaks about what a learner already knows, he is speaking about the concepts and propositions that have meaning for this learner. In our work we have slightly modified Ausubel's definition of these terms to better fit current epistemological thinking. We define a *concept* as: a perceived pattern or regularity in events or objects, or records of events or objects, designated by a label, such as a word or symbol. *Propositions* are two or more

concepts linked with words to make a meaningful statement about events or objects. *Propositions* can also be thought of as the *fundamental units of meaning*, for concepts standing alone convey little meaning.

Getting smart about a domain of knowledge requires building a powerful cognitive framework of concepts and propositions for that domain, together with supportive feelings and skills that were necessary to achieve this organized body of knowledge. To assess what the learner already knows requires using some strategy that will indicate what concepts and propositions a learner holds in her/his cognitive structure.

Behaviorists held that it is impossible to ascertain what information a person (or any animal) holds in their brain, and therefore they asserted that the only valid study of learning is to observe the *behaviors* of the individual under carefully prescribed conditions. Unfortunately, 75 years of this kind of research by thousands of psychologists has told us almost nothing worthwhile about human learning and how to facilitate human learning. Ausubel was not the first to propose a different *cognitive* psychology, but he was first to show explicitly how to translate this theory into improved educational strategies.



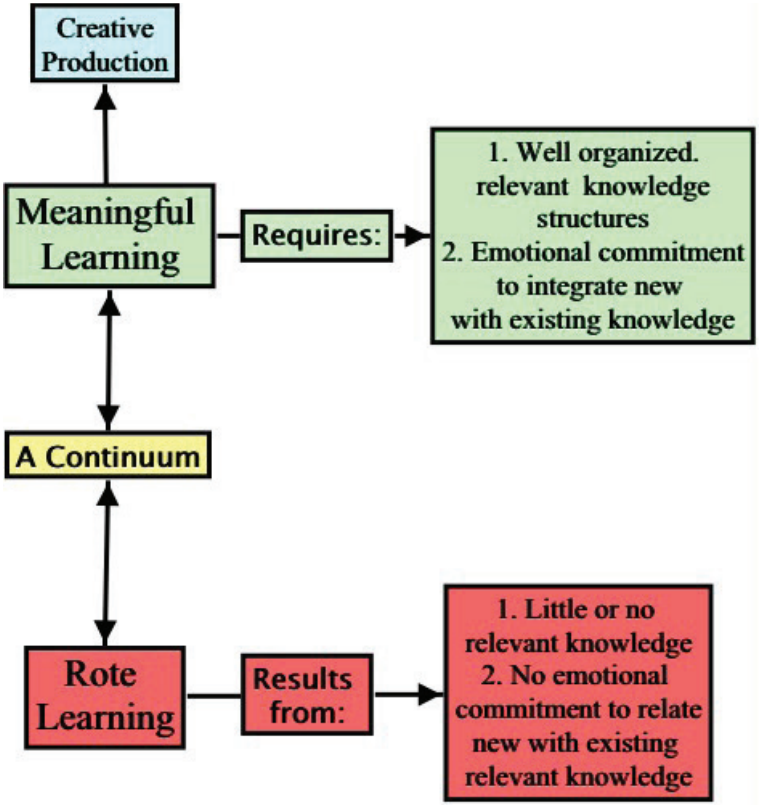
The second edition of Ausubel's Educational Psychology: A Cognitive View (1978)

Since 1963, Ausubel's assimilation theory of learning has been the principal psychological foundation for all of my work and the work of my students. It is called *assimilation theory* precisely because it explains how new concepts and propositions can be integrated with relevant prior learning into one's

cognitive structure, and explains why *meaningful learning* is more powerful, more enhancing, and more lasting than *rote learning.*

As I worked on revision of David's book, I argued that rote learning should not be seen as distinct from meaningful learning, but rather they could be better viewed as two ends of a continuum. Ausubel described rote learning as incorporation of new information into a learner's cognitive structure arbitrarily, with no effort to integrate this knowledge with related ideas in the learner's cognitive structure. This is what occurs in rote learning or simple memorization of information. In meaningful learning, the learner seeks to relate new concepts and propositions to ideas the learner already possesses. I think it is also important to emphasize that the learner must have an emotional commitment to seeking connections between existing concepts and propositions and the newly learned concepts and propositions.

I also argued that the learner's existing relevant ideas can be fuzzy, or they may be much refined and more like a network of related ideas, not just a simple one-to-one connection. These two factors, the strength of the learner's emotional commitment to integrate new with existing relevant knowledge, and the degree to which relevant knowledge is well organized can vary greatly. Thus in my view it is best to see the difference between rote and meaningful learning as two ends of a continuum. Initially Ausubel was reluctant to accept my view, but later he did accept this view and presented it in his writings, such as his 2000 book, *The Acquisition and Retention of Knowledge: A Cognitive View.* Later I added that we could view creativity not as a special ability, but rather as a very high level of meaningful learning. David never accepted this view. I have found the figure below to be helpful in explaining Ausubel's views, and my addition of the important role of feelings in both meaningful learning and creativity.



The rote-meaningful learning continuum. Initially Ausubel rejected this continuum. Later he agreed with me, but not on the continuum to creativity. This simple diagram captures the essence of the profoundly important concept of meaningful learning. It is something I would like to see posted in every classroom!

Unfortunately, after three years of publication, Holt, Rinehart and Winston decided sales were too low to warrant their continuation of publishing our book. Other recent behaviorally oriented books were strongly outselling our book! Editorial Trillas in Mexico City published a Spanish edition of the book, and that continues to sell hundreds of copies each year, even though references in the book are now way behind the times. No doubt this is due to the strong following our work has in Spanish speaking countries! There the book has become a "classic".

After we invented concept mapping, a knowledge representation tool I shall discuss at length in chapter 10, we found that this tool could be very useful in helping to explain Ausubel's theory and to illustrate explicitly the differences between rote and meaningful learning. Concept mapping also can be a

powerful instructional tool to help teachers and students move toward more effective meaningful learning.

Over the years, Joan and I got to know Ausubel quite well, and also his wife, Gloria. We enjoyed an Upstate New York winery tour with them on one occasion, and the photo below shows us at the Four Chimneys winery on this tour.

David had converted from Judaism to Catholicism when he married Gloria. He and Joan often got into some lively discussions on the Bible and Catholic beliefs. Since Joan had spent 12 years in Catholic schools and done extensive Bible study in later years, bright as David was, he usually lost out in friendly arguments with Joan. On one occasion, Ausubel told Joan he opposed gays because the Bible condemns gays. Since our son Bill is gay, Joan quickly responded: "The Bible also condemns shaving ones beard, lending money for interest, and it condones slavery. Do you agree with these passages?" David's response: "OK". We remained friends and exchanged holiday greetings until David's death in 2008. We continue to correspond with Gloria.

David Ausubel and his wife Gloria at Four Chimneys winery, 1985

My graduate students, many visiting professors who studied with us, and some other researchers embraced Ausubel's theory as a powerful and useful theory. However, most of my colleagues in Science Education and other fields of education in the US and some other countries rejected his ideas or simply ignored them. The work of Jean Piaget, a prominent Swiss developmental psychologist, overwhelmingly dominated thinking in Science Education in the US, England and some other countries. Piaget held that children's cognitive development progressed in stages that were highly age determined and could not be accelerated. I will discuss Piaget's work in later chapters.

Chapter 8

The World of Science Program and the Audio-Tutorial Elementary School Science Program: Dealing with the Politics of School Curriculum

Developing a New Kind of Elementary Science Program

In 1962, I was approached by Leo Gans, Vice President of Bobbs-Merrill Publishers, to serve as the senior author for the revision of an elementary science textbook series called *The Wonderworld of Science*, first published in 1941 by Scribner's Sons, and revised several times over the next 20 years. Initially I was very cool to the idea, since I felt that most elementary school science books presented little more than a litany of science "facts," with little effort to help students understand fundamental concepts of science. Gans indicated that the company was seeking to do a new kind of science series, and I would have the freedom to include whatever kind of science I thought was appropriate.

I met in New York City with Morris Meister, the former senior author of *The Wonderworld of Science*, and he also thought that a new kind of elementary science program was needed. Morris Meister was a retired principal of the Bronx High School for Science, a world renowned, publicly supported secondary school for outstanding students with demonstrated talent and interest in science. Meister agreed with and supported the new direction I wanted to take with the science series. I never had direct talks with the other two co-authors.

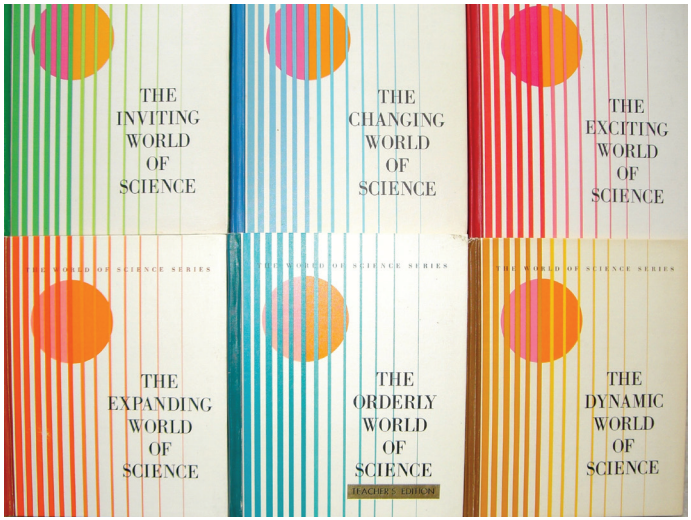
Although there were a few sections of the existing books that could be used as written, most of the writing for the six-book series had to be written from scratch. This opportunity to develop an elementary school science program that was consistent with my ideas of what should be taught, even though this would strongly push the boundaries of the usual elementary school curriculum, was a challenge worth pursuing. I also thought that, unlike the usual scholarly books I had been writing, the Bobbs-Merrill project could well pay for my children's college education, if it was successful.

I developed a scope and sequence plan that would introduce children to fundamental concepts of science such as the nature of matter and the nature of energy and energy transformations, using illustrative examples with activities that could be easily done in the elementary school classroom or in the child's

kitchen or yard. Building on Ausubel's theory of learning, I planned the sequence of topics so that important anchoring concepts were presented early at each grade level, and then progressively elaborated with a variety of examples and subordinate concepts as the books progressed. This also provided a curriculum plan that would be both interesting to children and psychologically sound, even though students had not studied the earlier books.

It was important to reintroduce key science concepts, using new examples, early in each grade. This is partly because children often change schools, and of course the program would be new to all students in all grades when these books were first adopted. Moreover, reintroducing key concepts with new examples helped to deepen the children's understanding of key concepts. Working with some talented writers and graphics people, we began writing and illustrating the books. It took over three years to complete the six books for grades one through six, and also a set of teacher guides for each grade level.

Since it was only a one-hour drive from Purdue University to Indianapolis where Bobbs-Merrill was headquartered, it was possible for me to have weekly or bi-monthly face-to-face meetings with the staff at Bobbs-Merrill. This was a tremendous advantage, since much of the science we were incorporating into the books was not well known by my editors. Writing progressed at the rate of about two books per year. By 1966 all books were completed and we were ready to go to market. We faced competition from publishers of 27 other elementary science programs, some of which were published by much larger organizations than Bobbs-Merrill Publishers.



The six books, Grades 1-6, of my World of Science series

In 1962 the National Science Teachers Association (NSTA) restructured its Curriculum Committee with the charge that the new committee should develop a plan that could serve to guide science instruction from grades one through twelve. Professor Donald Decker of the Colorado State University chaired the Committee, and I was invited to join the Committee in 1962. I argued that what was needed was not a "laundry list" of science topics, but rather a small number of truly basic science concepts, each of which could be taught at some level in primary grades with progressively greater depth in later grades. Professor Morris Shamos, Head of the physics department at New York University, supported my ideas, and it was decided to convene a panel of outstanding scientists to identify a small number of truly basic science concepts that would serve as the continuing conceptual threads for science courses from grades K through 12.

When NSTA approached National Science Foundation, requesting funding for a conference to identify key ideas to guide K-12 curriculum planning, NSF not only turned down the request, but also asserted that they thought the idea was bad, and that if NSTA went ahead with the conference, no one worth listening to would attend. This was further indication of the biases and naivety of NSF Science Education Directors in 1962.

As it turned out, NSTA not only recruited the directors of all NSF-supported high school curriculum projects, but also several outstanding scientists, including distinguished Harvard Astronomer Harlow Shapley. By the second day of the conference, we had received strong endorsement from all but two members of the group for a preliminary document we had prepared. We had sketched out 7 major *conceptual schemes* of science and 5 "processes of science" that also needed to be simultaneously addressed in K-12 curriculum design.

The Conference ended a day earlier than planned when we learned of the assassination of President John F. Kennedy, and we were all in shock over the tragedy. We completed the work through phone calls and sharing drafts of our report for comment. The report was published in the NSTA official journal, *The Science Teacher*, in October 1964, along with an introductory statement that I prepared.

Unfortunately, there was little effort made by NSTA to do follow-up work, and the effort was never seriously implemented by NSTA programs. However, I was in the middle of writing my elementary school science books, and the conference report helped me plan the Grade One through Grade Six science books. One participant at the conference, Paul Brandwein, was senior author for an elementary science series published by Harcourt-Brace in 1966.

He changed the title for a new version of his books to *Concepts in Science*, with company advertising citing the NSTA Curriculum Committee reports. In general, the content of the latter books followed the traditional topical sequence, with relatively superficial presentation of basic science concepts.

The Politics of Textbook Selection

With school textbooks, sales are highly dependent on approval of the book or series by state adoption committees. Usually one to three books will be listed as "approved" by the state, and therefore state funds could be used to purchase these books. With large states such as Texas and California, there is severe competition by publishers to get their books on the approved list.

I recall the presentation I made for my books to the Texas selection committee. One or more of our competitors had obviously hired consultants to peruse every page of my books for possible errors or flaws that might be negatives for selecting the book(s), and these were passed along to a friendly (or "bought off") Committee member. One member of the Committee asked me if I had written that corn kernels are not seeds but rather a kind of fruit, intending to embarrass me. I answered that corn is a kind of fruit called a caryopsis, or a fruit that contains a seed with an embryo, surrounded by stored food and the corn kernel husk that is derived form the walls of the pistil of the corn flower, the top of which is the corn silk that extends outside the cob that supports many small corn fruits. The questioner was obviously embarrassed, and I'm not sure if my answer won or lost votes. There were a couple of other questions that indicated the problems suggested were not with the accuracy of my books, but rather with faulty knowledge of the questioner (or the consultant hired by the publisher). Enough members of the Committee were supportive, however, and *The World of Science* was listed on the State approved list.

In his 1985 book *Surely You're Joking, Dr. Feynman*? Nobel prize winner Richard Feynman commented on his "unbelievable" experiences on a textbook selection committee for the State of California. The extent of incompetence on State textbook selection committees is legendary, and Feynman presents some of the nasty politics and absurdities he witnessed.

By 1967, a number of schools had adopted my elementary science textbooks, and it looked as though my rather revolutionary elementary science program would be successful. But in 1965 the Bobbs-Merrill Company was sold to Howard W. Sams & Company, a large publisher of technical manuals and other technical works. The company decided in 1967 that my books were not well suited to their elementary school marketing program, and they dropped

production and sales of the books. Four years of rather intensive work went down the drain, at least as far as book sales were concerned! Our hopes that the book sales might pay for our children's college education also went down the drain, and we had to find other ways to finance their education.

I considered seeking another publisher for the books, but by now I was deeply involved in developing our Audio-Tutorial Elementary Science Program. I thought putting my energies into this might have a greater positive impact on elementary school science teaching. The development of the Audio-tutorial program is described later in this chapter.

There was an unexpected positive from the publication of my science books. Son Bill was in first grade when the first book in the series was published in January 1966. He was having trouble learning to read, and both Joan and I were at a loss to figure out how to help him using the usual books from the school's reading program.

I thought I would have Bill try reading my grade one science book. I was taken back when I found that helping him with a new word on one page did not result in his knowing the word on another page. Puzzled by this, I began to ask him questions about the science ideas in the text and illustrated in the pictures. Much to my surprise, I discovered that he did not recognize that the words were symbols for concepts (things and events) illustrated in the text and pictures. Once this connection was made--the realization that words are names for things and events--he had no trouble reading these concept labels (words) when they appeared later. Since most books for beginning readers were of the "See Spot. See Spot run" variety, these books failed to build understanding of basic concepts. Much of their text was close to nonsense. The most powerful tool the young child had to "crack the code" for reading was missing. There was no progressive development of concepts. Within a few weeks, Bill was not only reading my science book and explaining what he read, but he began to do the same with other books.

Son Bill learned what it means to read when he began reading my first grade science book.

Two years later, after I had moved to Cornell University, one of my graduate students, Robert Hersey, who was interested in the problem of helping children who cannot learn to read, picked up on what I had learned. He designed a series of audio-tutorial lessons that used familiar things such as street Stop signs, McDonald's signs, and popsicle photos to guide children in learning to *read* the words for these concepts. (Audio-tutorial instruction is described more fully in the following section.) The lessons proved to be highly successful, and I was excited by the prospects for this work. In as little as two weeks of work with these Audio-tutorial reading lessons, children who were non-readers became readers!

Unfortunately, Hersey dropped out of sight and took the lessons with him. Busy with other projects and without graduate students interested in early reading problems, I never moved the work forward. I do not know if Hersey continued work on these on Audio-tutorial reading lessons. It remains a great opportunity for the right person to pursue, and now we could do a much better program using computers to guide the instruction.

Developing the Audio-tutorial Elementary School Science Program

As I mentioned in earlier chapters I spent a sabbatical year at Harvard University as a Research Fellow in 1965-66. This allowed me time to launch a new line of research with elementary school children. My primary objective was to determine whether or not first and second grade elementary school children

could learn basic concepts of science, and how this might impact later science learning. Based on Ausubel's theory, and using ideas that were included in my *The World of Science* books, I proceeded to design a series of Audio-tutorial lessons that could be placed in elementary school classrooms and used by students with little or no teacher support. My experience working with Professor Postlethwait on his Audio-tutorial botany course at Purdue University was invaluable in helping me design the lessons for first grade children. In fact, I used some of the same photos and loop films Postelthwait had developed in my first grade Audio-tutorial lessons on plants and plant growth.

My experience had been that most primary school teachers knew little of the science I wanted to teach. They are also preoccupied with teaching reading, and maybe arithmetic, so they needed science lessons that could be presented without their intervention. Of course, I did plan to have teachers monitor students' use of the Audio-tutorial lessons. The teacher's only responsibility was to assure that all students took their turns at the lessons.

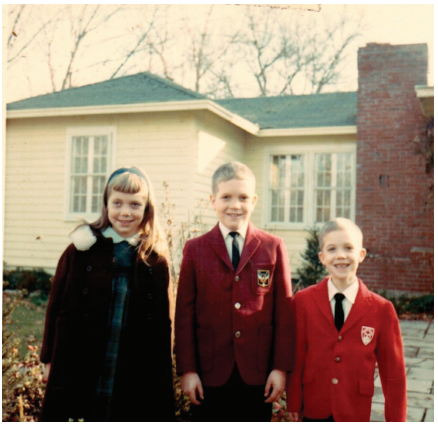
One of my research assistants at Harvard, Robert Brigham, had been a high school physics teacher. He developed some Audio-tutorial lessons on electricity, targeting these for second grade children. It was clear to me that the Audio-tutorial strategy we were developing could be used to teach any topic in science.

We needed an audio-tape player that could be easily operated by six year old children and would be easy to rewind so the lesson would be ready for the next child. We searched for a cassette tape recorder for this job. The only cassette audiotape player available in 1966 was this rather bulky and expensive RCA machine. We also chose to use a Kodak loop film projector that a young child could operate. The Kodak loop film player we bought held up to three minutes of film and required no rewinding.

A second grade student studying electric charge in Brigham's Audio-tutorial lesson

We rented a modest house on Mystic Lake in Arlington, MA. Since it was mostly unfurnished, we visited antique shops and picked up some very nice antiques for very little money. We shipped most of these back to Indiana, and most of these are still with our family. Our house was on US Highway 3, so there was a good bit of traffic by our house. Nevertheless, we twice had attempts at stealing our car, a 1957 Chrysler. Apparently Joan had forgotten to remove the keys after returning from shopping on one of these occasions. The theft failed when the robbers broke off the turn signal lever in flashing position. They did not know this car used buttons on the dash to shift the car!

On two occasions we had the Fire Department at our house, once when our sons started a campfire that quickly spread in the yard, and another time when I was helping the neighbor burn some brush and dead tree branches. I did not know there was an ordinance against open fires, and my neighbor wound up paying a fine. We had the police and fire department to our house on another occasion. Our two sons found the body of a woman floating just off our shoreline. Our daughter Barb was playing with a friend two doors away. She was sorry she missed all the excitement. Arlington had a very friendly Irish policeman who walked the road in front of our house. I met him late one night after walking our baby sitter home across the street. He explained that the body found on the beach by our house was that of a depressed woman who had lost her sister to cancer and committed suicide by just walking into the lake.



Our children in front of house in Arlington, MA 1965

When I returned to Purdue in the summer of 1966, my graduate students and I began to design and test additional Audio-tutorial lessons. We received good cooperation from area elementary schools and the West Lafayette school administration. The West Lafayette schools provided some financial assis-

tance to purchase equipment, using US Office of Education Title One funds. Professor Postlethwait visited one of our test schools and was impressed with how much these first graders knew about seed and plant growth as a result of our lessons.

Work to develop Audio-tutorial lessons with West Lafayette Schools continued for one year after I moved to Ithaca, New York in August, 1967. Superintendent Roger Bardwell became very interested in implementing the audio-tutorial program in Ithaca schools. With his support we obtained a substantial grant from the US Office of Education Title One program. The funding was primarily intended to fund purchase of equipment and supplies, not to support our research per se.

With a full-time staff member, Lou Giantris, and six graduate students, we began an aggressive program designing and testing Audio-tutorial science lessons. Photos below show children working with some of these lessons, and graduate students interviewing students to assess their learning. Each lesson had gone through four to six revisions, with classroom tryouts for each version followed by at least partial interviews with each student.

It took an average of about 200 person-hours to design, test, refine, and redesign each lesson. The care and testing built into each lesson was one reason the lessons were remarkably successful with 6-8 year old children when placed in classrooms. Each lesson took a student 15 to 20 minutes to complete, and they were designed so that the carrel unit would be ready for the next student without teacher intervention. We posted a list of students on the side of the carrel unit. Students crossed off their names when they finished the lesson. The teacher's only responsibility was to check that all students did the lesson in a two-week period, or to call our office if there were problems.

Effect of Racial Tensions on Our Program in 1968

In our second year of developing and testing Audio-tutorial science lessons, we encountered a problem that set back our progress. Cornell University was one of the campuses in the US that had major protests from activist students who demanded more opportunities for blacks and other minorities, and more rights for women. One night the building in which our laboratory was located was taken over by protesting black students. We were given one day to clear out all of our things, and the University found us a temporary location for our work in the Physics building. This was the first of several moves, finally ending with ample space in a Quonset hut on the edge of the campus.

Space is always a premium on university campuses, and this was certainly true at Cornell University. Although the Quonset hut was a rather shabby facility, we had ample space for our work, and it also provided office space for some of my graduate students and project employees. Over the years, my graduate students and I enjoyed the use of this Quonset hut for several projects, continuing work there until I retired in 1995.

Rather than seeking an alternative publisher for my *The World of Science* books, I devoted much of my energy to the development of the Audio-tutorial science lessons. Later I spent a good deal of time trying to market the program. An Indianapolis-based company, Imperial Equipment Company, was very interested in marketing the program. When we had some 60 lessons developed, with much of the support coming from the US Office of Education's Title 1 Program, we obtained permission from the US Office of Education for Cornell University to market the program.

Our team prepared a video and a slide show describing the program to potential funders and marketers. Later a somewhat modified program was used in sales promotions in schools.

Cornell University negotiated with Imperial Equipment Company and reached a contract agreement with the Company. The Company also hired one of my graduate students, Sharon Wagner, to visit schools and procure orders for the Audio-tutorial program. Some 50 contracts were written with New York public schools.

Imperial Equipment Company sold school furniture and portable school classrooms. The president of the company wanted to have products no one else could sell, to avoid the high competition in the school furniture business. Unfortunately, the week Imperial Equipment planned to sign a contract with

Cornell, they learned that their franchise for portable classrooms was cancelled by National Homes--and this was over 60% of their sales. The Company was in no position to launch a new project.

Once again my hope for improving elementary school science education was crushed by a corporate failure! I had explored marketing with several other school supply companies, but without success. A major problem was that some elementary school science projects had multi-million dollar grants from the National Science Foundation (NSF), thus gaining visibility and credibility we did not have. The bias at NSF against my research program's theoretical foundations also extended to our Audio-tutorial program!

None of those NSF-funded elementary school science projects were fated to survive real world competition. I stored copies of lesson kits we had developed in a Cornell University storage facility for several years, but then had to abandon the kits as mice and rats invaded the facility. I still have a notebook describing the lessons. Maybe someone will resurrect the program in the future, but using much more promising computer guided Audio-tutorial lessons.

Chapter 9

A Unique 12-year Longitudinal Study of Children's Learning: Putting Theory to the Test

Despite the failure to market our audio-tutorial program, the lessons we developed proved to be very useful research tools. Several of my MS and PhD students used these lessons to gather data on children's science learning. In addition to individual research projects, our group began in 1969 a research project that would take over 14 years to complete. I wanted to study whether we could demonstrate that children 6 to 8 years old could begin to understand a number of very basic science concepts, given proper instruction, and to observe whether this instruction would facilitate learning in later school science studies. If this could be demonstrated, it would indicate that Piaget's developmental stages did not apply to science learning when well-designed instruction was provided to young children. Most of the people in the science education community at this time thought this was a fool's adventure. Despite repeated efforts, we were unsuccessful in obtaining funding for this research project from the National Science Foundation or the US Office of Education.

One might ask, why should we bother to do a research project that would take more than a decade to complete? The answer is not simple; it involves several issues. First, acquiring an understanding of basic science concepts takes time, even with excellent instruction. We thought the two-year period of audio-tutorial instruction we planned should be adequate for most children to begin building a functional understanding of the basic science concepts we taught in our lessons. Secondly, if Ausubel's theory was correct, we should see some **facilitation** of science learning in later grades. Evidence of such facilitation would also demonstrate that Piaget's severe limitations on the age at which children can begin to understand basic, abstract science concepts was incorrect. Finally, it would demonstrate the effectiveness of our audio-tutorial science lessons and provide support for developing similar learning materials for students in later grades. Compared with conventional school instruction, such findings would be enormously promising!

With the strong support of the Ithaca Public Schools administration, we obtained funding from the US Office of Education Title One Program for production of audio-tutorial lesson kits, and for maintaining these lessons in the 13 Ithaca elementary schools. Title One provided funds for necessary science equipment and supplies. Superintendent Roger Bardwell was a great help

with this project. He visited classrooms and tried out the lessons on several occasions. I did not realize at the time what an extraordinary superintendent Bardwell was. In all of my subsequent work with public schools, I have never encountered a superintendent as concerned about children's learning--and as smart about what was needed to improve learning.

I also had small $5,000 to $10,000 grants from the Hatch Act research funds administered by the College of Agriculture, in which the Education Department was located. Some expenses and support for my research assistants came from small grants from Shell Companies Foundation, as mentioned in earlier chapters. We used a Sheltered Workers program in Ithaca to produce copies of the equipment we designed, and to assemble and pack lesson kits--all at very low cost.

A first grade child working with an Audio-tutorial lesson dealing with how seeds grow into plants.

Richard Rowell interviewing a first grade child after audio-tutorial instruction. His PhD thesis contributed importantly to the development of the Concept Map tool. This tool is further described in the next chapter.

What we were trying to do was rather extraordinary. So far as I know, no other research study dealing with children's science learning attempted to provide instruction to first and second graders and followed these students throughout their school career. Such longitudinal studies require a sustained effort and sustained funding--and this is not easy under the best of circumstances.

Fortunately, we had excellent support from Ithaca school leaders, and from Cornell University administration. On one occasion, Nyle Brady, Associate Dean and Director of the Agricultural Research Station at Cornell spoke with officials at the National Science Foundation (NSF). The Director of NSF Science Education told my Dean that they did not agree with my thinking, and therefore would not support my research. Brady was appalled at the blatant bias. He pointed out that in science we always seek to fund competing ideas, for only good research could determine which ideas are valid. His plea did not change the NSF Directors' bias and no funding was forthcoming from them. He continued to be supportive of my work, and the NSF continued to spurn my research proposals. Such blatant political bias in research funding should never occur in a federal agency, but it did! It is hard to imagine what we might have done for elementary science education if we had received the kind of multi-million dollar research grants that were received by other research projects.

I had become well acquainted with many NSF leaders through my work with NSF-supported teacher education programs and though professional meetings. Although these leaders would not support my research work, they did have high regard for other science education work I was doing. In fact when the National Science Teachers Association sought funding from NSF for a study of excellent school science facilities and programs, they declined support of the initial proposal, but said they would fund the study if Joseph Novak were selected to direct the project. I agreed to do this, and that project is discussed later in Appendix 1.

Returning to our 12-year study, we selected 5 elementary schools from the 13 Ithaca elementary schools as the sample for our study, since these were representative of all Ithaca elementary schools. We provided audio-tutorial instruction in 11 classrooms, with a total of 191 students receiving the lessons. Each lesson took a student 15 to 20 minutes to complete, and the audio tape recorders we selected allowed the student to automatically rewind the tape so that it would be ready for the next student. We used Kodak 8mm loop film projectors in some of these lessons with STOP signs at the end, so that child would stop the loop film, and it would then be ready for the next student.

We demonstrated to a class how the audio-tutorial lessons worked, and then each child did the lessons without aid from the teacher or our staff. Small glitches in lessons were soon resolved, usually after watching a few students do a given lesson. After a few lessons, all students were remarkably good at running through the lessons independently. Often children would come in

during lunch hour or recess to do an additional run through a lesson. The lessons were very popular with the students, and with the teachers.

We asked the teachers not to discuss the lessons with the students, because we found in pilot testing that many teachers had so many misconceptions about the science we were teaching that their discussions often were a source of confusion. Also, we wanted to control the science content that was being taught by limiting instruction to the audio-tutorial lessons, and this was the rationale we gave to teachers for not providing additional instruction. We never had a teacher decline participation in the project, and none dropped out as the study progressed. Refer again to the photos to see illustration of the lessons.

The work on the audio-tutorial project involved about a dozen people, most of them my graduate students who were also working on their thesis research, with some using data we were gathering in our audio-tutorial project for their research study. During the first two years, we provided audio tutorial lessons in 11 classrooms, changing lessons approximately every two weeks.

Within two school years, all 191 children in the sample with audio-tutorial lessons completed 23-26 lessons. All were evaluated using clinical interviews at least twice each semester, and some more often.

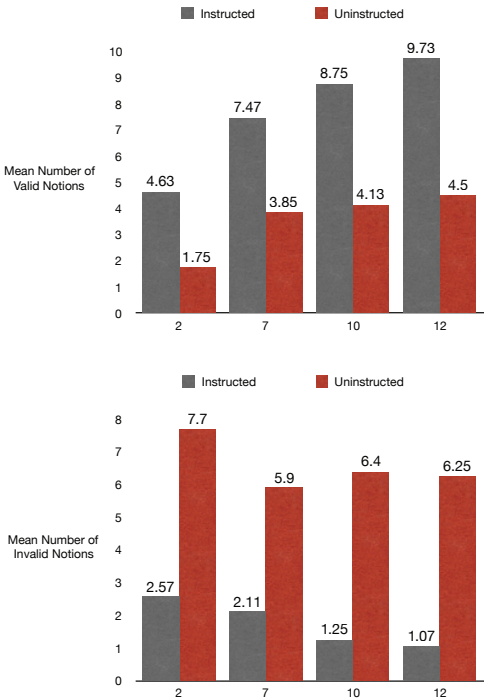
In the second year of the study, we began interviewing a sample of 48 first grade students who had the same teachers as the "instructed" sample, to serve as a *control group*. **However, no audio-tutorial lessons were provided to these students**.

Following science achievement by means of clinical interviews with the many students involved in this project was a huge job. Our research team had frequent meetings to plan the work and to discuss problems as they arose. Some of our meetings included wine and cheese or pizzas--combining research and sociability. On a number of occasions we met in my home or in other people's homes for social events. There were many close friendships, and some marriages, as a result of the social and personal meetings. Three times we met on a farm rented by one of the couples involved with our project and we used the abundant crop of apples on the farm to make pies, apple juice, and applesauce. Good times were had by all!

Our longitudinal study used 26 of the lessons we had developed in grades one and two, and then followed the achievement of these students throughout their school career. This was a study that was the most ambitious of my

career. For this reason, I devote this chapter to it. Not only did we gather a huge amount of data on children's learning of science concepts, but also out of necessity we invented a powerful new tool, the ***concept map***, to assess science learning. The invention of this tool is discussed later in this chapter and in the following chapter.

Initially in this study we interviewed students on a number of concepts, including the structure of plants and how they produced food, but due to limited staff resources, we had to limit interviews to dealing with the nature of matter and energy, and with energy transformations. These were the most controversial ideas, since according to Piagetian theory, students under age 14 lacked the cognitive capacity to learn these abstract concepts. After we had invented concept mapping, it was relatively easy to concept map these interviews and to identify specific valid concepts and propositions, and **misconceptions** (or faulty concepts and propositions). We could review the students' concept maps, and count the number of valid and invalid ideas held by each learner as they progressed from grade 1 to grade 12. The figure below shows the results from this research.



Audio-tutorial instructed children (grey bars) had progressively greater numbers of valid notions and fewer invalid notions about matter and energy and energy transformations than uninstructed children (red bars) as they progressed from grades 2 through 12.

The data in the above figure clearly show that the audio-tutorial lessons taken by students in grades one and two were effective in teaching basic concepts about matter and energy. Moreover, this early instruction provided what Ausubel called **subsuming concepts** that facilitated learning in later science studies, as would be expected from Ausubel's learning theory. The data also strongly refuted Piaget's ideas that young children cannot learn these abstract concepts in early grades.

Incidentally, research done by dozens of researchers in cognitive psychology that became popular after the 1980's confirmed our findings. No competent psychologist supports the restrictive ideas on children's learning put forward by Piaget in the 1930's and 40's.

This study was remarkable in another way. So far as I know, no other researcher has used instruction in science in early grades and then followed the same student's understanding of concepts taught through grade 12. In fact, I am not aware of any such study in any subject field, primarily because it is so difficult to finance and sustain a study that requires 12+ years to complete! The remarkable nature of this study has been discussed in a number of reports by other scholars reporting on longitudinal studies in education.

However, the most remarkable outcome of this study was the invention of a new tool, the **concept map**, to represent knowledge held by people in any subject area and at any age level! This work is discussed in the following chapter.

Chapter 10

The Invention of Concept Maps and Concept Mapping Software

The Search for a Better way to Interpret Interview Data—Leading to the Invention of Concept maps

Assessing what someone learns from instruction at any age is not an easy task, especially if you want to be sure the assessment is both valid and reliable. Widely used multiple-choice tests are fraught with validity problems when used with older subjects, but they are almost useless with 6 and 7 year old children. It was evident to us that children were learning a good deal of science when they used our Audio-tutorial lessons, but how could we produce evidence that would persuade our critics that this was the case. We had chosen to use modified Piagetian interviews as a better tool, but these also created problems for us. It was difficult to listen to an audiotape of an interview and be sure we were adequately capturing what a child knew, or what faulty ideas he or she held. Working with typed transcripts of interviews was a little better, but even these were not easy to interpret.

We kept asking ourselves, what is really going on in this child's brain? What does she or he really believe about atoms, energy, seed growth, or whatever we were testing for? We struggled with this problem for several months, and it was a major topic in our weekly research team meetings. For some 75 years, behavioral psychologists argued that it was impossible to assess what someone is thinking, and therefore they required that all psychological research must deal only with manifest behavior, like lever pressing, seeking food, or choosing a particular alternative word or answer. We thought we could do better; we thought we could show that the child's conceptual understanding was improving, and we sought to do this!

I suggested to my research team that we go back to our theoretical foundations and consider what these tell us, pertinent to our assessment problem with our children. From our philosophical foundations, we discussed these elements:

1. Knowledge in any domain consists of concepts and propositions in organized structures. Concepts are perceived regularities or patterns in events or objects designated by a label, usually a word. Propositions are comprised of two or more concepts connected with words to form a meaningful statement

about events or objects. They are the fundamental units of meaning, and they may be stored in an individual's cognitive structure.

2. From Ausubel's theory of learning, we have these elements to consider: Each learner must choose to acquire new concepts and propositions through meaningful learning. This means the learner must choose to connect new concepts and propositions (presented in the lessons) with existing relevant concepts and propositions she/he already knows (i.e., they are part of existing cognitive structure.) New concepts and propositions acquired by rote will not be integrated with existing concepts and propositions. Consequently they may be soon forgotten or linked arbitrarily and incorrectly with existing knowledge. The latter are commonly observed as misconceptions, and these may actually increase with rote learning. We found many examples of this in our interviews.

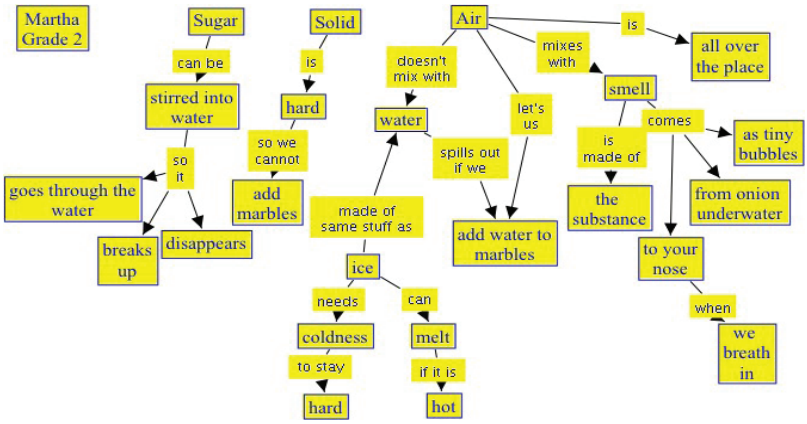
Furthermore, Ausubel argued that knowledge acquired through meaningful learning is stored hierarchically with more specific concepts stored subordinately to more general, more inclusive concepts. Our interviews with children always presented objects or events. We asked the child to interpret what the object was, or what was happening in the event. It was clear from the children's responses that the audio-tutorial activities we provided were engaging to the children, and they were gaining new concept meanings. We had to find a way to show explicitly that this had occurred.

Given these theoretical foundations, it was clear that we needed to identify all the relevant concepts and propositions in the transcript of the answers provided by children, and to identify each pertinent concept and each pertinent proposition. Leon Pines, one of my PhD students, chose to focus his analysis on the propositions given by the children. He compared the accuracy and relevance of the child's proposition as she/he progressed through the audio-tutorial lessons. Richard Rowell, another of my PhD students, chose to focus his research on the pertinent concepts given by the child and how that child related concepts to one another. Both approaches appeared to have value, but over time, we found that focusing on the concept words given by a child and how the child linked each concept word to other related concept words appeared to give a more accurate picture of the child's understanding of the object or event we were dealing with.

Furthermore, Ausubel's view that knowledge is stored hierarchically in cognitive structure meant that we should seek to show the concepts and propositions in an interview transcript in a hierarchical manner. This kind of struc-

ture we called a **concept map**. And this was the way my graduate students and I invented the knowledge representation tool we called a **concept map**.

Simply put, a concept map shows the concepts and the linking words used by a child to describe objects and events similar to those presented in the science lessons. Moreover, we found we could map these concepts and propositions hierarchically, as Ausubel proposed they existed in the learner's cognitive structure. The figure below shows an example of a concept map constructed from the interview transcript with a second grade child after two years of audio-tutorial instruction. Initially all of our concept maps were hand drawn, but later we redid these concept maps using computer software, such as the map below.



A concept map made from an interview with a second grade child after two years of audio-tutorial instruction. Note how clearly the map shows both valid and a few invalid ideas held by this student.

We were familiar with other graphic representations of information, such as semantic nets, but these were developed for tasks such as computer language translation and had little to do with the kind of learning we were interested in assessing. Our concept maps showed precisely the way the child was building their cognitive structure in their brains.

In 1974, Buzan put forward his Mind Maps, but these also had little to do with assessment of the learner's conceptual understanding. Mind Maps have nodes and linking lines, but the nodes may contain anything from a word to a sentence or figure, and linking lines have no words on them to specify the relationship between nodes. Thus they lack the fundamental requirement for representing knowledge; they have no propositions or knowledge statements. They also lack hierarchical organization that provides additional meaning.

Nevertheless, Mind Maps are easy to build, and Buzan has made a fortune selling his software and conducting workshops using his tools.

At the time we were developing the concept map tool, we did not realize that we were breaking new ground in terms of knowledge representation tools; we were simply applying our epistemological ideas and Ausubel's learning theory to create a tool that would allow us a better window into children's minds as they were learning science.

We looked at a number of ways to represent what we thought was occurring in children's minds as they acquire new concepts and concept relationships. A variety of the methods of representation were explored, including Donald Hebb's neural net ideas published in the 1940's and 1950's. In my own writings, I tried to show how Ausubel's learning ideas could be represented using different knowledge representation schemes. Once we settled on concept maps as the best way to study changes in children's understanding of science ideas, concept mapping became the primary tool we used to gain insights into children's learning.

Careful and Precise Definition of Concepts and Propositions

As we began using concept mapping more extensively, it was imperative that we define more precisely what we mean by concepts and propositions. Drawing on the writings of philosopher Stephen Toulmin and others, we came to define concept as: **a perceived pattern or regularity in objects or events, or records of objects or events, designated by a label, usually a word**. The word perceived is important in this definition since it is a person who must perceive the pattern or regularity, this depends on what that person already knows that is relevant. It is the learner's feelings that drive the person to seek out the particular pattern. Meaningful learning requires an emnotional commitment to trying to tie new concepts and propostions to relevnt concepts and propositons that learner already knows. This relationship between thinking and feeling is a key aspect of the learning theory and theory of education I have constructed.

In many cases, there are specific skills that are also needed, such as skill in using a microscope or a camera. A creative person who identifies a new pattern or regularity is in some novel way combining her/his thoughts, feelings and actions. We also had to consider that sometimes the learner is looking at records of events or objects, such as a thermometer reading or a photograph, so we added this to our definition of concepts. The child's success in the acquisition of new concepts and propositions, and the hierarchical organi-

zation of these in their minds is precisely what is needed for very high levels of meaningful learning in any domain. Simply put, concept maps were an explicit, clear way to represent this knowledge.

We define propositions as: two or more concepts linked together with appropriate words to form a meaningful statement. Grass is green is an example of a valid proposition, whereas the door grew rapidly is not a valid proposition; doors do not grow! When we are teaching any subject, we are mostly trying to help the learner gain the meanings of propositions, and from this learning we hope they will also build valid understanding of the concepts in the propositions. The above definition of concepts and propositions is what I have tried to use consistently throughout this book.

Our development of the idea of concept mapping began in the early 1970's and became the key tool in my thinking about learning and instruction by the mid 1970's. Although I wrote the first draft of my Theory of Education book in 1974, I had not yet fully integrated the role that concept mapping would play in my thinking until the later 1970's. Partly, this integration occurred with Joan's prodding me by saying, "You really have something important with concept mapping; you need to emphasize these much more!" Once again, Joan's counsel was right on target!

The use of concept maps to study misconceptions

In the early 1980's, we began to focus more attention on learner's misconceptions. We found that concept maps were a great tool for identifying learner's misconceptions. In a series of studies, we found that using concept mapping during instruction was a good way to help learner's recognize and overcome their misconceptions. With the help of visiting professor Hugh Helm from South Africa, we organized our first international seminar on student misconceptions in 1983. The conference attracted some 150 people interested in this topic, including a group from Harvard Smithsonian Institute, *The Private Universe Project,* who subsequently prepared a widely circulated and acclaimed video dealing with misconceptions about why we have seasons. In interviews with 24 Harvard faculty, graduate students and alumni, 21 of the group failed to give a satisfactory explanation for why we have seasons, including a student graduating with a physics major and who recently took a course in the Physics of Planetary Motion. We subsequently held four additional international conferences, the last being in 1995, in part a tribute to my work, arranged by my former students. This recognition is described further in Appendix 5. All five conference Proceedings can be viewed at: http://

mlrg.org Robert Abrams, one of my former PhD students, maintains this site. He continues to support my work in a variety of ways.

A paper presenting my ideas on dealing with student misconceptions was published in 2002 and is listed in Appendix 6.

Robert Abrams, former PhD student helped with our international conferences on misconceptions.

Developing Concept Mapping Software

All of our early concept maps were drawn using paper and pencils or pens. With small concept maps containing 15-20 concepts with appropriate linking words to form propositions, it was relatively easy to redraw segments of a concept map, or even the whole map. Making a good concept map from a student interview or a section of text usually requires 2-4 revisions, and sometimes even more.

When we began to make larger concept maps, building and revising a map could be very tedious. When Minnesota Mining and Manufacturing Company invented Post-Its™ in 1980, we used these to make concept maps, especially when working with student or professional teams. Placing concepts on Post-It notes made it easier to move concepts around on paper or white boards, but once linking lines and linking words were added, changing the map was not so easy.

In 1984, Microsoft marketed Mac Draw, and this software made it much easier to build and modify concept maps. The problem was that most students did not have computers, and computer power was limited in the 1980's. One of my graduate students, Howard Stahl, created a software program, Cmap, specifically designed to build our style of concept maps, namely concepts linked with lines and linking words and arranged hierarchically. It was relatively easy to build concept maps using this software, but it worked only on Mac computers and most students did not own such computers.

In 1983, the College of Agriculture and Life Sciences was offered 30 IBM PC computers and a $100,000 grant to demonstrate the use of PC's in college instruction. Dean Call was aware of the work I was doing, and he asked me to design a project in biology, using these computers.

With the cooperation of staff for the Introductory Biology course, we planned a study using these computers, and requiring students in one sample group to build concept maps. I had underestimated the difficulty of creating this software, partly because I knew nothing about writing software code. I also underestimated the difficulty of finding a programmer to write the software. I terminated the first three programmers I hired after a month or two.

Finally I found a good programmer who knew biology and understood what we were trying to do. She had transferred to Cornell from Michigan State University. The software she wrote was relatively easy to use on the PC computer for making concept maps. She also wrote a program for making Vee diagrams, a learning tool described in the next chapter.

Working with one of my PhD students who was a teaching assistant in the biology course, we randomly selected a group of students that she instructed to use the computer software. Martha's study showed that using the software and making concept maps and Vee diagrams led to significantly greater improvement in learning when compared with students using standard course instruction. These differences were most pronounced when assessment test questions required "deeper" understanding.

Unexpectedly Good Fortune Working at the University of West Florida

In 1987-88, I was invited to spend a year on sabbatical leave at the University of West Florida. We rented a house on Pensacola Beach, one of the nicest white sand beaches we had ever seen. Joan had a lot of free time, since I was spending much of my time at the University. She had done some painting previously, but she really became serious about painting during our stay on

the beach and did a number of watercolor and oil paintings that year, many of which we enjoy in our homes today. My concern that Joan might be bored living on the beach in the winter months proved unfounded--Joan loved living on the beach.

Our hosts for this sabbatical were Bruce and Denise Dunn. Bruce and I collaborated on some research, using concept maps with upper elementary school students, and then we brought them into Dunn's laboratory to perform electroencephalographic studies comparing the best concept mappers with the poorest mapper. We found highly significant differences in EEG patterns between these children, but we were not sure how to interpret these differences other than to say that there was much more brain activity indicated in the brains of the best concept mappers. This research is described more fully in Appendix 2.

Preparing student for EGG scans while she looks at her concept map in Dunn's lab.

Bruce's friend, Ken Ford, had joined the University faculty in 1988 and was building a research program to study how computers could be used to aid human thinking. Ken became interested in concept mapping, for he saw it as a tool to solve a difficult problem in artificial intelligence (AI), his field of study. Concept maps could be used to represent expert knowledge in a clear and concise way, and this was the first requirement for creating an AI program dealing with that expert's domain of knowledge.

Kenneth Ford, Founder and Director of the Florida Institute for Human and Machine Cognition (IHMC) in Pensacola, Florida.

As I got to know Ken better, I was impressed with his keen intelligence and his insights on better ways to use computers, not to replace human beings but rather to enhance their abilities, as do microscopes or hearing aids. By 1990, Ken had persuaded the University to form the Institute for Human and Machine Cognition. He became Director of the Institute, and in December, 1989, he brought in a friend who had similar interests, Alberto Cañas, to serve as Associate Director of IHMC.

In 1990, Alberto Cañas obtained a grant from IBM to develop computer software that would bring concept mapping into a number of schools in several South American countries. Under the name of Project Quorum, the IBM funded project rapidly moved forward. Since Alberto was raised in Costa Rica, he not only was fluent in Spanish, but he also understood Spanish cultures. The program was well received in the schools, but it faded away when IBM funding ended. Nevertheless, the project had succeeded in producing excellent software for creating concept maps. Moreover, this software allowed the attachment of various digital resources to a concept map by simply dragging and dropping the URL for the resource on a concept or linking word, making it accessible via the concept map in the future.

Ken Ford and Alberto Cañas began work on better software to facilitate construction of concept maps. Concept maps became a principal tool for representing knowledge in the newly created Institute for Human and Machine Cognition (IHMC).

Through Ken's contacts with the Department of Navy, Ken had learned in 1996 that Admiral Timothy Wright was about to retire. Ken succeeded in persuading Admiral Wright to join the administration of IHMC and to serve as Associate Director. Ken saw that with Admiral Wright's broad experience, he could provide the wise counsel and the kind of leadership that would benefit the IHMC. Over the years, this proved to be the case.

The Development of CmapTools software

Under the leadership of Alberto Cañas's, the Institute developed, over a span of ten years, an outstanding package of concept mapping tools called CmapTools. Since most of the funding for this development came from Federal research grants, IHMC provides the software to any user at no cost. It can be downloaded at: http://cmap.ihmc.us Thus by the mid 1990's, we had free computer software that could be used in schools, corporations and homes anywhere, anytime, on almost any computer. This achievement helped to shape the remainder of my career as an educator. There are now over 40,000 downloads of CmapTools from the IHMC server each month, and probably many times more from servers located elsewhere around the world. Software to set up servers for CmapTools is also provided at no cost. In so many ways, the Institute has been supportive of my work.

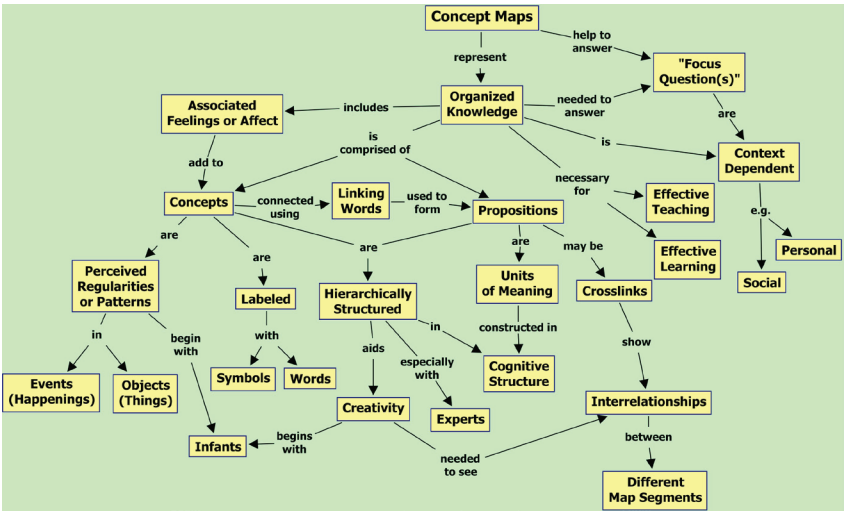
Alberto Camas was the key architect for the creation of CmapTools including the idea of providing the ability to attach any kind of digital resource to any concept or linking word to create a "Knowledge Model."

The IHMC team that worked on the creation of CmapTools.
I am in the center in a white shirt, in the side yard of IHMC.

As my Learning How to Learn book became known worldwide, I received increasing requests for assistance in developing and applying knowledge mapping tools. Among these was a series of exchanges with Donald Helfgott, the founder of Inspiration™ software. Helfgott sent me early versions of his mapping software, and I made suggestions I thought could improve the software, most of which were incorporated into later versions. Current versions of Inspiration™ software are widely sold to schools and corporations. The company has been effective in marketing their software. SemNet™ is another knowledge mapping software developed in the late 1980's by a good friend, Kathleen Fisher and her colleagues at San Diego State University. It is now successfully marketed by her SemNet company.

In the past 35 years, I have done hundreds of training sessions on the nature and use of concept maps. I have found that it is helpful to begin by introducing the Ausubelian learning theory and constructivist epistemology that were fundamental to our development of this tool. I developed the concept map below to describe what concept maps are. In 2004 Alberto Cañas and I published a paper, Theory Underlying Concept Maps and How to Construct Them. The paper is available on the site where CmapTools can be downloaded at no cost: http://cmap.ihmc.us The figure below was given as an overview to ideas in the paper, and this is the most requested figure for re-

production from any paper we have published. We continue to find it useful when we introduce concept mapping at workshops.

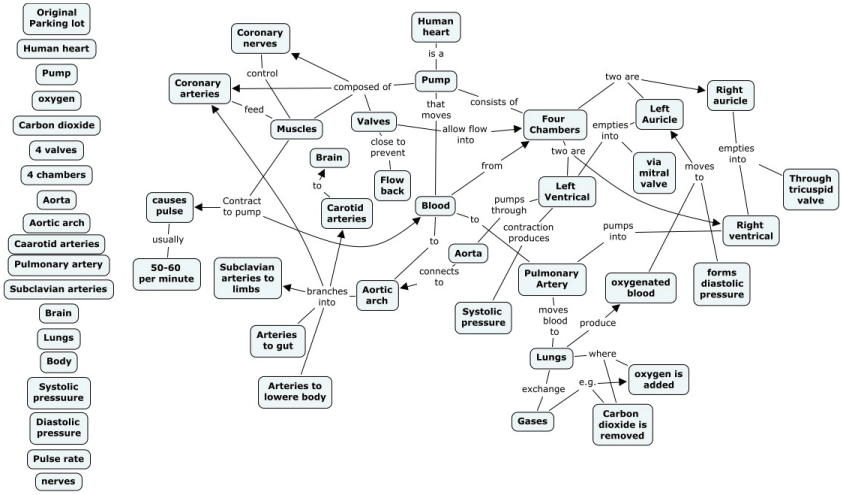


A concept map showing key features of the theory underlying concept maps and how to construct them

Both my wife and I find concept mapping a useful tool if we are trying to understand some complex ideas. Joan's continuing battle with heart disease was aided by preparing her own concept map for understanding heart functions. She first recorded a number of concepts she knew were important in what we call a "Parking Lot." These are concepts that she knew had to be properly related to be understood more deeply. Joan is a strong advocate for always building a "Parking Lot" of pertinent concepts as a starting point, and I always suggest this when I do a workshop on concept mapping.

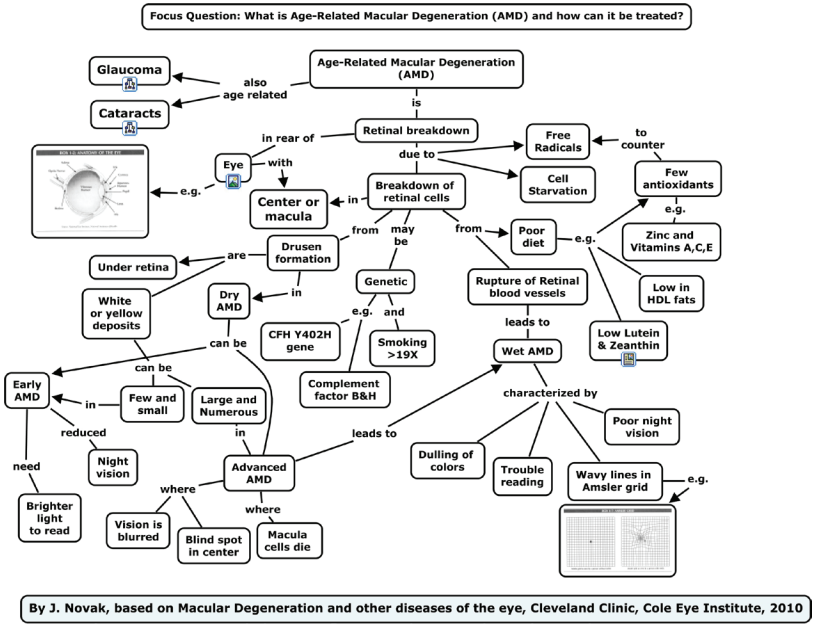
The concepts in the Parking Lot can be reordered with the most general, most inclusive concepts at the top, and the most specific concepts lower in the list. This follows the Ausubelian learning principle that more general concepts need to be presented first to facilitate meaningful learning of more specific concepts. It is one illustration of how Ausubelian learning theory helped to guide our research and instructional programs.

We have also found that it is very helpful to define carefully a Focus Question that indicates what is the problem or domain of knowledge we want to understand. CmapTools software askes the user to provide a Focus question for every map constructed.



Joan's concept map for the human heart with her Parking Lot on the left. Other maps she prepared dealt with the functions and disease of various heart structures.

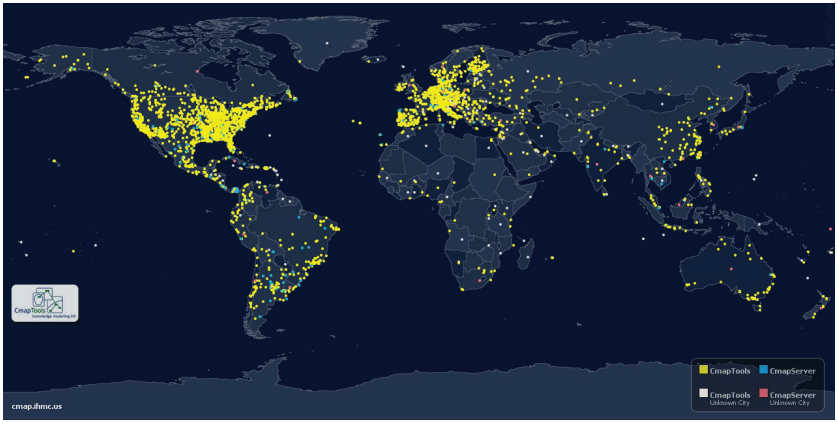
When I was diagnosed with early stage Age Related Macular Degeneration in 2006, I began reading books and WWW articles on the disease. Because I found some of these confusing, I made my own concept map for AMD, shown below. My first map started with a Parking Lot, but this was not included in later versions. I did add links to other resources, and they are accessed through the icons attached to concepts. This figure also shows a few of the added resources opened up.



My concept map for Age Related Macular Degeneration that helped me to understand the disease and to ask better questions of my ophthalmologists

For a time, the Florida Institute for Human and Machine Cognition had sufficient funding to maintain a computer that registered every download of CmapTools. The figure below shows a screen shot from this computer showing where CmapTools had been downloaded in the past year. When this computer was running, a person could put their computer curser on any dot and get the name and location of the site where the tools were downloaded.

It's been so gratifying to see that concept mapping is being used all over the world, in almost every country of the world! Although it would be naive to assume that all of the people downloading this software are using it in an optimal fashion, we know from e-mails received almost daily that some significant percentage of the people are using the tools constructively.



A screen shot of the IHMC computer showing locations where CmapTools software has been downloaded in the past year. It shows that the use of this software is truly worldwide.

Currently some 40,000 copies of the software are dowloaded from the IHMC server each month, and thousands more from other servers located around the world. If my research group at Cornell University had done nothing more than invent this powerful knowledge representation tool and help create CmapTools software, I would be satisfied that my lifetime of work to improve education was a success.

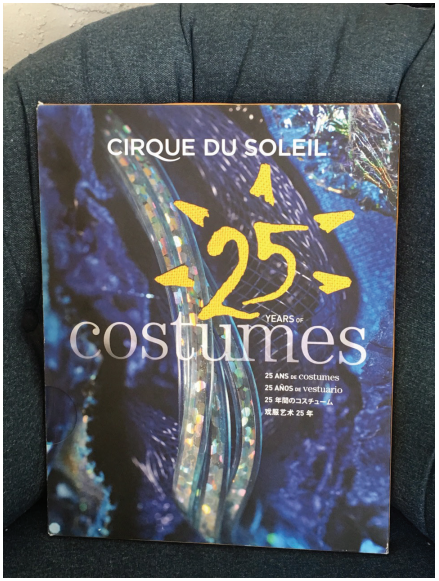
Some of our colleagues and I began using concept maps with corportions in the early 1990's. A book describing some of this work was published in 2011: *Applied Concept Mapping: Capturing, analyzing and organizing knowledge*.

The distributions of CmapTools by IHMC has been enormously gratifying to me. Almost every day I receive several e-mails from people all over the world expressing pleasure and rewards derived from using concept mapping in a wide variety of settings. In the Scandinavian countries, many business consultants use concept mapping in collaboration with a wide variety of corporations and other organizations. Thomas Fresendal's book: *Design Thinking Business Analysis: Business Concept Mapping Applied (Management for Professionals)*, was published in 2012, and continues to be a best seller on Amazon.

As the use of concept mapping as a tool to facilitate meaningful learning has become more common, numerous research studies have shown that the tool not only facilitates meaningful learning, but also leads to more creative productions. Perhaps the best illustration of this is the adoption of concept mapping in all departments of Cirque du Soleil, as they demonstrated in the 2008 meetings of the International Conference on Concept Mapping in Chile. Jacques Simard presented a video show interviews with the directors of

every division of Cirque du Soleil indicating how valuable concept mapping has been to their division. The management of the Cirque du Solieil also gave me a signed oil painting created for them, and a signed copy of a book showing the costumes created by them over the past 25 years.

The signed mixed medial painting given to me in 2008 by the Cirque du Soleil in appreciation of the contribution our work has made to them.



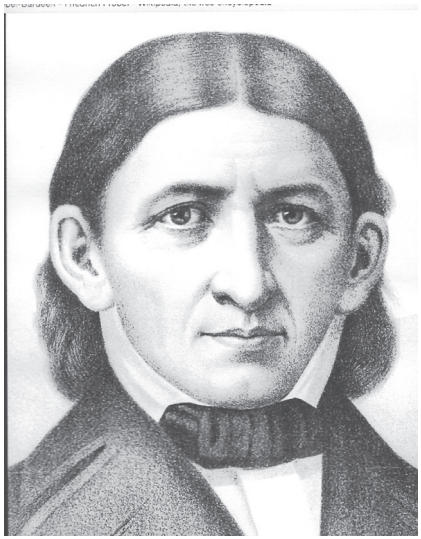
A signed copy of a limited edition book given to me showing costumes createdby the Cirque du Soleil . Concept maps are used to organize and archive consume information

Chapter 11

A Lifetime Spent Constructing a Theory of Education to Guide Research and Practice in Schools, Corporations, and Other Organizations

Early Efforts

From my first days as an undergraduate student in education classes, I was struck with the fact that unlike the sciences, education as a field appeared to have no basic principles or basic concepts. Also unlike the sciences, there appeared to be no theory or even major principles that might guide educational practices. In a history of education class, I learned about the writings of famous educators such as Johann Pestalozzi, his student, Friedrich Froebel, and Jacques Rousseau. But what these famous educators had to offer was primarily a discourse on educational practices that they promulgated. None of these famous educators presented anything that looked like solid data supporting practice A over practice B.



Friederick Froebel is credited with establishing "kindergartens" for young children.

The course I took in Educational Psychology did present something like theories and principles, but much of this was borrowed from behavioral psychology research dealing with rats or pigeons, the learning of nonsense syllables, and word-pair associations. The primary assumption of behavioral psychology is that we can only study behavior that can be observed. Unfortunately,

most of what humans do when they are acquiring new knowledge or using prior knowledge cannot be directly observed. These kinds of phenomena are essentially excluded from consideration. It continues to amaze me that in spite almost a hundred years of behavioral psychology research, producing essentially nothing of value for understanding human learning, this kind of research continues today.

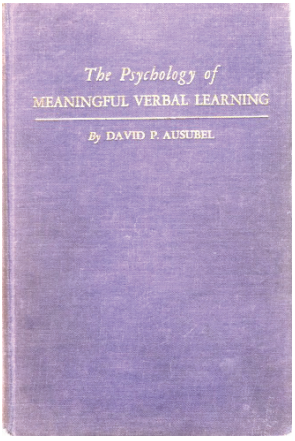
As noted earlier, it was our good fortune to encounter David Ausubel's cognitive learning theory in 1963, when my research group had become skeptical of the value of cybernetic models for understanding human learning. Also, by 1963, there was a growing move in the field of philosophy away from positivistic models of knowledge and knowledge creation, and toward what has become known as *constructivist* models, where knowledge is seen as a human invention, always imperfect and constantly evolving. Behavioral psychology remains locked in rigid positivistic views of knowledge.

James Conant, a brilliant chemist and later President of Harvard University, pioneered this movement with his 1948 book *On Understanding Science,* a book that strongly influence my thinking even as an undergraduate student. Conant described what he called conceptual schemes, such as the idea that all substances are made of molecules. He illustrated how these conceptual schemes are modified over time. These ideas were further advanced by his protégé, Thomas Kuhn, in his 1962 book *The Structure of Scientific Revolutions*. I learned of none of this work in my course studies, but rather in my extensive reading in search of a better way to understand how humans acquire, create, and use knowledge.

I had read Conant's book in 1949 during my second year at the University of Minnesota. Since I was rather bored with many of my courses, I found inexpensive paperback books in the bookstores more interesting. Unlike my earlier school years when I read relatively little, in college I always had two or three books on the shelf above my bed, including some famous literary works. It was these readings more than the coursework that shaped my thinking, especially as a graduate student.

James Conant (in 1948), whose book On Understanding Science deeply influenced my thinking in 1949

As noted earlier, it was not the psychology and educational psychology courses that strongly influenced my thinking about how people learn, but rather David Ausubel's 1963 book *The Psychology of Meaningful Verbal Learning*. This was the first book that showed in an explicit way how humans learn and construct new meanings in science or in any other discipline. It became the foundation for reshaping my ideas on human learning and how they relate to improvement of school learning. As indicated in earlier chapters, Ausubel's 1968 book *Educational Psychology: A cognitive view* further clarified how humans learn new meanings and how they create new knowledge.

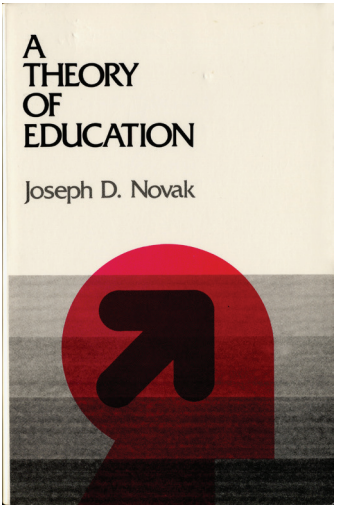


Ausubel's first book presenting his Assimilation theory of learning, 1963

A Theory of Education

When I was working in 1973 on a draft of my book, A Theory of Education, I was struggling to connect Conant's ideas on the nature of science with Ausubel's ideas on the nature of human learning. I was delighted to read a review in the journal, SCIENCE, of Stephen Toulmin's book, *Humand Understaning: The collective use and evolution of concepts*. It seemed to me that this book clarified the relationship between learning concepts and creating new concepts. I immediately purchased Toulmin's book.

When I read Toulmin's book, a lot of pieces of the puzzle came together for me! I wanted to devote my next sabbatical leave writing a book on my theory of education. Once again I was grateful to the highly supportive administration of the College of Agriculture. Normally the university grants a one semester sabbatical leave with full pay, or a full year sabbatical at ½ salary. I knew I could not finish the book I planned in one semester, nor could we afford to live on ½ salary, so I appealed to Dean Brady and he asked my Department Chair to assign me the job of working on my book for one semester. I completed a draft of my book that would become my *A Theory of Education* while on sabbatical leave in 1973-74. Then I began using it as a textbook in the graduate course I was teaching, Theory and Methods of Education. This helped me to refine my thinking on a number of issues. In 1977, Cornell University Press published the book in hard copy, and a paperback version was published in 1986.

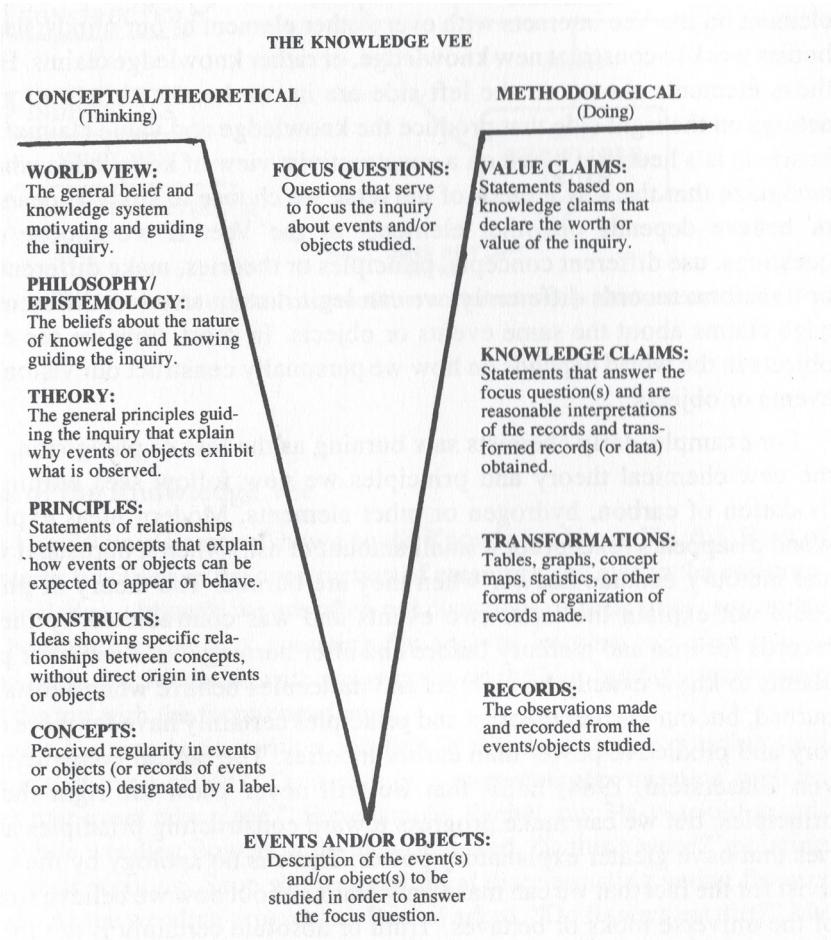


My first effort to put forward a theory of education, 1977

Ralph W. Tyler, one of the nation's most repected educators in 1977, wrote a very complimentary Foreword to the book, saying that, "This book explicates more concretely the learning theory of Ausubel than Ausubel himself has done." He continued, "Readers concerned with teaching practices in any field of education will find the clarity of presentation and the concrete illustrations helpful in suggesting relevance to the widely varied situations found in schools and colleges."

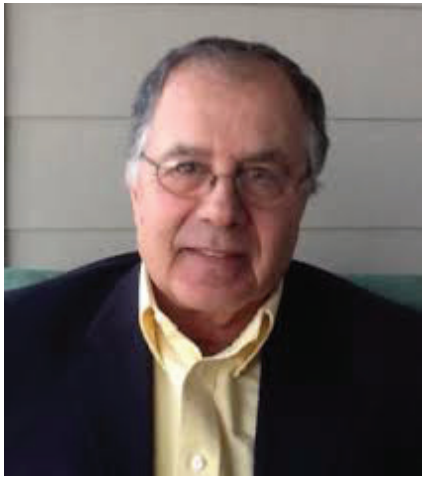
I was interviewed for an hour about the book on the national television program, Ask Washington, in August of 1978. Depite these good indicators, the book was never widely cited by other educators, and a few indicated it was foolhardy to suggest education could or should be guided by theory. Translations of the book were published in Spanish, Portuguese, and Basc. Today there are more than 100 books on theories of education limited to a single field that attempt to present theoretical foundations for instruction in that field. None of these that I looked at present a comprehensive view applicable to all fields of education.

During the period 1972- 77, my research group was working on the 12-year longitudinal study of children's learning in science, decribed in chapter 9. During this period, I was slow to see all the implications of the concept mapping tool for fields of education. I had been working with Hebb's 1949 model of learning that sees learning as the development of neural networks. I had used this model to illustrate Ausubelian principles in my *Theory of Education* book. Recent brain studies show the enormous interconnectivity of neurons in our brains. In our current work, we are seeking ways to integrate or work with concept maps with brain imaging studies. Some of this is discussed in Appendix 2, page 208. As we gained experience in using this tool in our research, and especially in my course, Learning to Learn, I began to see how concept mapping could be far better than other tools I was using to clarify and present both a theory of education and improved educational practices. Another tool to illustrate the creation and structure of knowledge was invented by my colleague, D. Bob Gowin in 1977. I began using this tool along with concept mapping in my classes.

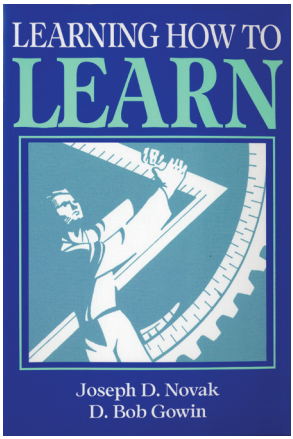


Gowin's Knowledge Vee, showing the twelve elements that are involved in new knowledge creation. Each element interacts with all the other elements in the process of knowledge creation.

While on sabbaical leave at the University of North Carolina-Wimington in 1981, I prepared a draft of the book *Learning How to Learn* that included extensive use of concept mapping, and also the Vee heuristic invented by my colleague, D. Bob Gowin in 1977. I used the draft copy as a text in my Learning to Learn course, and gained more insight into how concept mapping could be a central feature of my evolving theory of education. Some of these insights were included in *Learning How to Learn,* published in 1984, and subsequently translated into 8 other languages.



Joel Mintzzes helped to arrange for my 1981 sabbatical leave in Wilmington, NC. We later collaborated on publication of two books and other work.



Published in 1984, this book showed how use of concept maps and Vee diagrams could help students become better learners. It also presented elements of my evolving theory of education and showed school applications in Chapter 8, "Improving Educational Research." Translations of the book were published in 8 languages. The book continues to sell today.

By 1990, I saw the need for writing a more comprehensive book updating my theory of education and including examples of application to corporations based on the increasing work I was doing with corporations, and on my experiences co-teaching a course in the Business School at Cornell University with Profeessor Alan McAdams.

From the 1980's to this day, the concept mapping tool has played an important role in my thinking about school learning, corporate R&D, and learning

in a wide variety of organizations. These experiences also helped to shape my thinking about the theoretical foundations for education.

From the 1970's and onward, I continued to teach a graduate course I called Theory and Methods of Education. Each student in the this course was required to do a small project applying the theory to an area of their interest. They were also required to interview 10 subjects on any topic of their choosing, and to concept map these interviews. They were asked to do both oral and written reports on their projects. These projects were 50% of their course grade, so all students took their projects seriously.

Many of these class projects evolved into MS or PhD research projects. Many of the students who took this course chose me to supervise their MS or PhD theses, including a number of students whose major work was in other departments. As noted elsewhere, none of the students working with other professors in the areas of Science and Mathematics education or Educational Psychology permitted their students to take a course with me--one of the nasty results of academic politics. I also had one to four visiting professors studying with me, often continuing work they had begun at Cornell when they returned to their home universities. Over my career, I supervised or contributed to the research of more than 350 students and visiting professors.

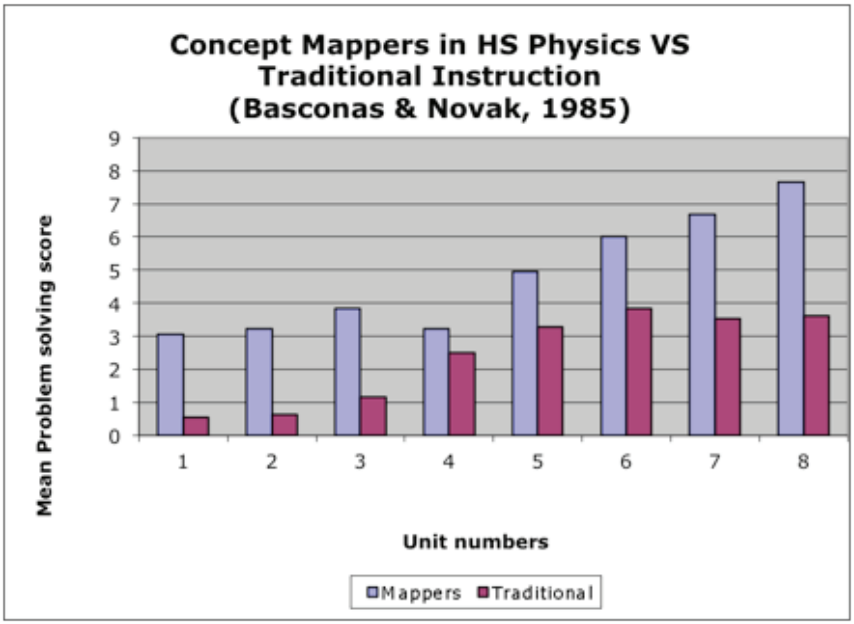
One of the wives of visiting professors who worked with our group was Jeannette Basconas. She was a science supervisor in the public schools of Maracay, Venezuela. She was intrigued by Ausubel's learning theory and with the use of concept mapping.

Jeannette arranged for a group of teachers in her home school system to work with her in an experiment with high school physics teachers. The study involved a group of teachers who taught high school physics in the traditional way, and another group who used concept mapping for every unit of study. These teachers also used a modified curriculum developed with Jeannette, trying to optimize the application of Ausubel's principle of progressive differentiation. In these experimental classes, lesson materials were sequenced in a way that would present an introduction to basic physics concepts, and then successively build on these basic ideas in subsequent instruction.

Jeannette Basconas was the wife of a visiting professor from Venezuela.

The study took place over the 1983-84 school year. The results were remarkable in the extent that the modified instruction in the experimental classes led to enhanced problem solving for each study unit, and these gains increased as the year progressed--exactly what Ausubel's theory would predict!

The results are shown in the figure below. The figure shows the marked improvement in physics problem solving test scores for classes using concept maps and an Ausubelian sequencing of topics (blue bars). These students performed much better than students using traditional instruction, and their superiority increased as they progressed through the eight study units during the school year. This is exactly what we should expect based on Ausubel's learning theory. The results strongly affirmed the value of his theory for the improvement of education.



High school physics students who did concept mapping in each study unit (blue bars) had higher average problem solving scores than peers who did not do concept mapping (red bars), and the differences increased as the school year progressed.

Many of the projects which I directed, or in which I participated, described in a later chapter, also used the ideas and tools we were developing in our research program. Most years I was supervising 10 to 15 graduate students and participated in three to five projects. My typical work-week was 50 to 60 hours, but I had only myself to blame for much of this workload.

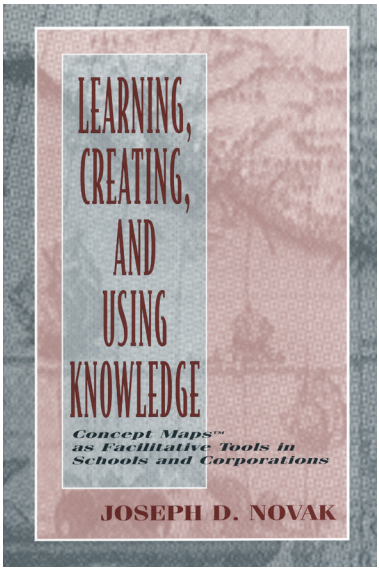
One positive outcome of this extensive research and development work was the opportunity to test theoretical ideas in many different subject matters and many different settings. From projects with public schools to projects with NASA, Department of Navy and other organizations, to efforts to improve learning and R&D work in corporations, I consistently tried to apply the theoretical ideas we were developing, and thus gained knowledge that helped to refine the theoretical foundations.

In 1983 I began working on an update of my 1977 *Theory of Education.* With the press of work on various research projects and other projects described in a Appendix 1, my work on this revision was delayed. I finally completed a draft in 1997. The book was published by Lawrence Erlbaum in1998, *Learning, Creating and Using Knowledge: Concept maps as facilitative tools in schools and corporations.* The book was translated into 4 other languages.

This book sought to show that thinking, feeling and acting are always integrated as we seek to learn, create or use knowledge. This integration can range from highly positive and productive work to conflicting and counterproductive activities. The key factor necessary for highly productive learning is the extent to which the learner employs high levels of meaningful learning. [OR: Learning is productive only to the extent that it is meaningful.]

Thus my theory of education can be summarized by this statement: Meaningful Learning underlies the constructive integration of thinking, feeling and acting, leading to empowerment for commitment and responsibility.

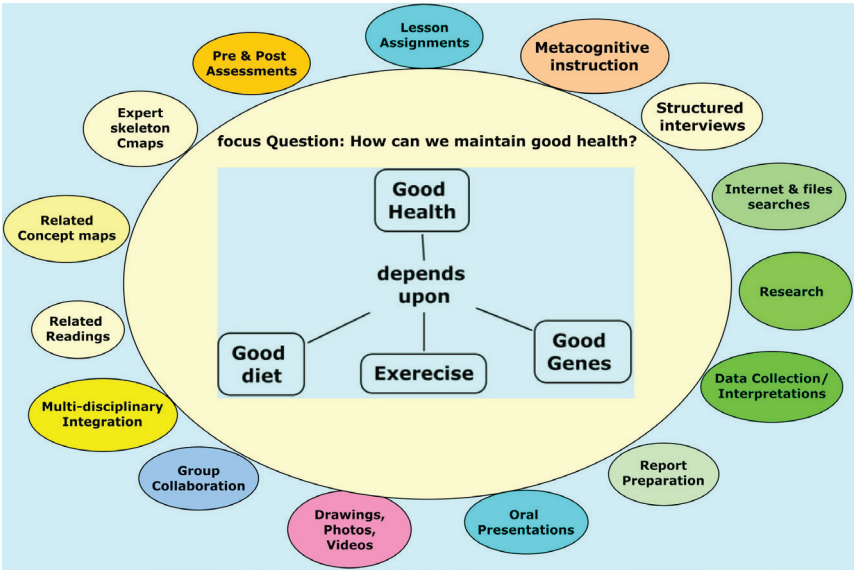
Simple as this statement may appear, what I have found over the years is that **meaningful learning** is really a very complex phenomenon. It can take a lifetime to understand it, and to do it well. Even after more than a half-century of working with this idea, I find that I still get new insights from research and projects in which I engage.



Published in 1998, Learning, Creating and Using Knowledge: Concept maps as facilitative tools in schools and corporations updated and extended my 1977 A Theory of Education.

Although I retired from Cornell University in1995, I continued to work as a consultant or staff member with schools and corporations and the Florida Institute for Human and Machine Cognition (IHMC), based in Pensacola, Florida. An ongoing activity with the IHMC was the continued refinement and improvement of CmapTools software.

As CmapTools software evolved, there were opportunities to incorporate new materials into any concept map, creating in effect a digital "knowledge portfolio." It occurred to me that these new capabilities would allow for presenting students with what I called a "skeleton" concept map that could serve as a valid starting point for creating a much more complex concept map or "knowledge portfolio." To build this knowledge portfolio, individual students or groups of students could incorporate products from a whole range of educational activities, such as those shown below in the smaller ovals. My colleague at IHMC, Alberto Cañas, came up with the idea of representing this New Model for Education with the scheme shown below. This helps to illustrate what I now call A New Model for Education.



My New Model for Education, showing an "expert skeleton" concept map to aid in beginning the map. Ovals around the main oval are suggested activities that individuals or groups can use to gather further information and add this to the initial concept map to create a Knowledge Model or Knowledge Portfolio for good health. Such a project may run for a few days, to a few weeks, or even months.

Since IHMC provides access to use of CmapTools at no cost, it is easy for learners, classrooms, schools or corporations to use the tools to build knowledge models in any domain of interest to them. These can be stored electronically and serve as a way to orient new students, teachers, employees, or managers. Thus the New Model has these critical features:

1. It employs a small "expert skeleton" concept map to facilitate the initial phase of work. This might be provided by the teacher or project manager.

2. It employs CmapTools software to facilitate web searches, and to organize additional knowledge gathered into a clear *conceptual* framework.

3. It can utilize a wide range of learning activities to gather new knowledge and make use of the diverse talents available in groups.

4. It encourages and facilitates high levels of meaningful learning.

When a school employs my New Model, the teacher's role changes from information dispenser at the front of the class to learning coach, mingling with student work groups working a tables, not at individual desks. Students do not spend time memorizing information for multiple-choice tests, but rather they are gathering and sharing information to build knowledge models to solve problems. This closely mirrors what these students will do one day when they are employed in any professional job, or even in many jobs in the blue collar trades.

There is today much talk about the need to engage students in ***active learning***. When individuals are involved in the use of our New Model, they will be engaged in the best kind of ***active learning***!

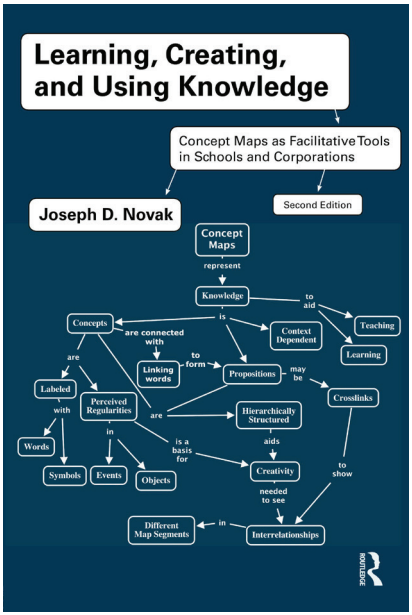
My Latest (2010) Version of My Theory of Education with Illustrative Examples

As I continued to work with schools, universities, corporations, and other organizations in the 2000's, I sought ways to implement my theoretical ideas into projects, both to test the validity of the ideas and also to facilitate the work on projects in which I was engaged. While I found that the basic theoretical ideas put forward in my 1998 *Learning, Creating and Using Knowledge* book were only slightly modified, there were new examples of implementing the theory into practice that I wanted to present. This will probably be my last comprehensive statement of my theory, partly because I have reduced significantly the number of projects in which I will engage, and partly because I have less energy to devote to this work at this stage of my life.

The new book was published by Routledge, Francis & Taylor in 2010, and an Italian translation was published by Erickson in 2012. A Chinese Translation was published in 2016. The book presents an updating of my Theory of Education and introduces A New Model for Education. Throughout the book, I have tried to show more clearly how this key idea is central to achieving high levels of learning, creating and using knowledge:

A Theory of Education

Meaningful Learning underlies the constructive integration of thinking, feeling, and acting, leading to empowerment for commitment and responsibility.
J. Novak



A second edition of my Learning, Creating and Using Knowledge book was published in 2010. It presents an updating of my Theory of Education and introduces A New Model for Education.

This was the book that Professor Jinshan Wu of Beijing Normal University first read in 2012. He e-mailed me, indicating that he believed this book described exactly what was needed to improve education in China. Professor Wu invited me to lecture on my work at his University, but since I no longer did international travel, I invited Wu to visit my home in Florida to discuss my work and to see how we could collaborate to bring this work to China. This work is described further in Chapter 14 and Appendix 1.

Jinshan Wu visited with us for 6 days in February, 2013. We planned for further collaboration, which is continuing today.

Chapter 12

The Remarkable Power of Concept Maps and Learning Ideas to Help in Other Educational Settings

What I Learned from My Students

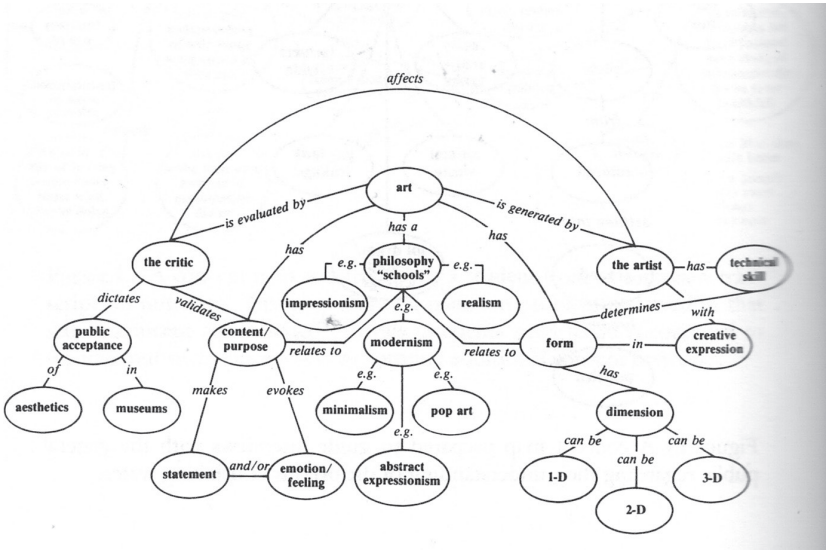
As noted in earlier chapters, the discovery of Ausubel's assimilation theory of learning lead in part to our development of the concept mapping tool. The human constructivist model for human knowledge creation also contributed to the creation of this tool. These two lines of thinking guided my work in every project I undertook after 1975, and also all of my teaching. In turn, feedback from colleagues working with me and students in my classes assured me that we were on the right track for improving teaching and learning.

In both my undergraduate Learning How to Learn course and my graduate Theory and Methods of Education course, described earlier, I required my students to do a project that involved interviewing 10 people, concept mapping those interviews, and preparing a report on what they learned. Year after year I saw how powerful the concept map tool was at capturing people's thoughts and feelings, and also how well the studies supported Ausubel's assimilation theory of learning. Many students commented on how these courses really changed their lives by changing the way they learned.

For several years before my retirement in 1995, the President's Office asked graduating seniors to name the professor who had the most influence on them. The professors named were honored by the President at a special luncheon and ceremony, which the nominating student and professor were invited to attend. In spite of the fact that I offered my only undergraduate class (Learning to Learn) just once a year, with 25-35 students enrolled, I received this award three times. The photo below shows President Rhodes (left) and Dave Smith (my student), another student and me (right) in 1991. So far as I know, no other professor in my Department ever received this recognition by their students.

President's Award for most influential professor, 1991

The range of topics and age groups chosen for interviewing by students in my Learning to Learn course varied from pre-school children's knowledge of numbers or nutrition, to college students' concepts of American government and what is a beautiful woman. Students were asked to make a concept map and Vee diagram to aid in planning their interview. They were also required to select "props" that would facilitate the interview. The latter would be the objects or events the interviewee was asked to comment on. Following the interview, students were asked to draw a concept map and a Vee diagram from the interviewee's transcript, showing the interviewee's knowledge and feelings about the object or event discussed. The figure below shows a concept map prepared by one of my undergraduate students to guide her in the process of interviewing students on their understanding of art.

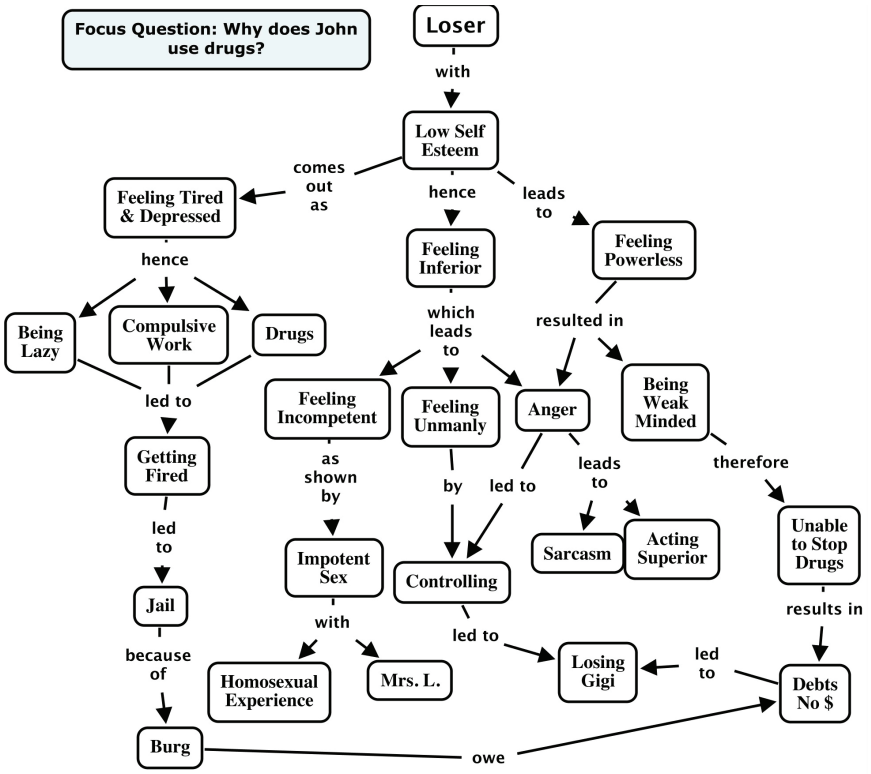


A concept map drawn by my student showing the ideas the interviewee had about art.

Without exception, students became very successful at this task, and their feedback from this work was very positive. Students reported to the class on their work as it progressed, and the discussions following proved to be helpful in refining the presenter's interviews, and in helping others with their interviews.

One of the students in my graduate class, Theory and Methods of Education, was Joan Mazur. She worked as a counselor in a drug rehabilitation program. Mazur taught her counselees how to make concept maps, and each participant made one or more concept maps describing why she/he used drugs. Although some of her subjects were reluctant to participate at first, they were under considerable pressure to cooperate with counselors, since their alternative was prison.

In the end, all nine agreed to participate and all felt the interview and concept mapping sessions were helpful. In a matter of weeks following counseling, with the subjects using their own concept maps, all of her subjects were released from the program. Two years later Mazur found that none of her subjects had been readmitted because of drug use, although one was in prison for an unrelated crime. Given that the recidivism rate after drug therapy is about 94% nationwide, Mazur's results were quite remarkable. The figure below shows the concept map created by one of her subjects.



John's concept map for why he uses drugs

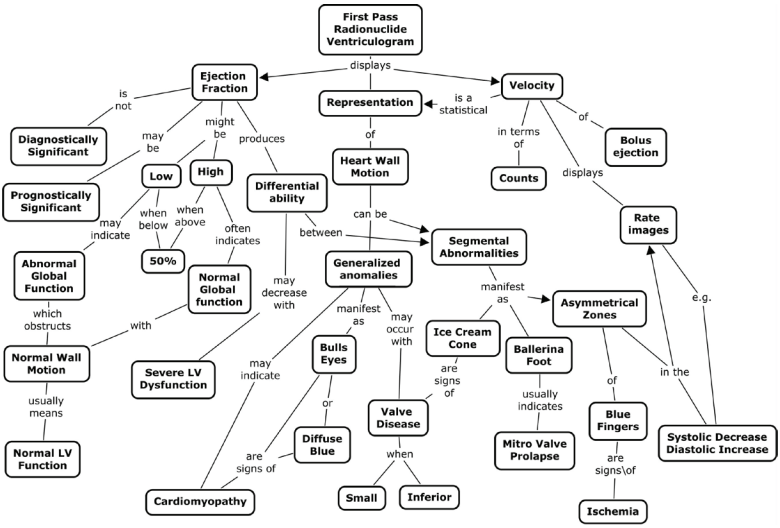
Capturing and Archiving Expert Knowledge

As our work with concept mapping progressed, we found that we could design good interviews to probe the minds of students or experts in any field, and represent their expert knowledge precisely and concisely with concept maps. As noted earlier, Ken Ford had joined the Computer Science faculty at the University of West Florida in 1988, the year I was there on sabbatical leave from Cornell University, hosted by Ken's good friend, Bruce Dunn.

Dunn knew that Ken was interested in finding better ways to capture and represent expert knowledge, and Ken Joined a seminar group I was conducting at UWF. He immediately saw concept mapping as a good tool for dealing with a fundamental problem in artificial intelligence (AI), his field of expertise. Ken had been working with a cardiologist in Pensacola (Dr. Andrews) to find a better way to train other cardiologists in the use of a diagnostic technique Andrews had helped to create, called First Pass Functional Imaging. The technique involved the use of radio-active isotope injections which

then allowed a camera to create images of the heart structures as the isotope traveled through the heart and associated arteries, detecting faulty structures if they existed. Since Joan was having heart troubles at the time, we were also curious how Andrews' technique would diagnose her heart. Dr. Andrews ran Joan through his tests and found heart problems similar to what had been diagnosed at Strong Memorial Hospital in Rochester NY. There she underwent a procedure that involved inserting a catheter into a leg vein and up into her heart--a much more invasive, more expensive, and more risky procedure.

Working with a textbook Dr. Andrews and a colleague had written, and from interviews with Dr. Andrews, we created a concept map that captured the key ideas and relationships needed to understand First Pass Functional Imaging technology, as shown in the figure below. CmapTools also allows one to access any kind of digital resource to a concept, and that becomes part of the file for the map. Using CmapTools, these resources can be accessed by clicking on the icon for a given type of resource and selecting the desired resource for study. Using this concept map and some guidance in reviewing video-taped recordings of cases Dr. Andrews had studied previously, even computer technicians working on the project had a high rate of success in diagnosing coronary disease using Andrews' technology. A paper reporting on this work was published in the Journal, *Knowledge Acquisition* in 1991, and this was the beginning of a series of projects dealing with capturing and archiving expert knowledge using concept maps.



A concept map showing the key ideas needed to understand and interpret First Pass Functional Images for coronary disease diagnosis

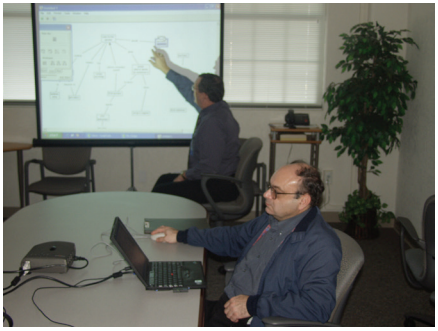
Following this successful work, a whole series of efforts began with various governmental agencies, including the Department of Navy, NASA, and the National Security Agency, to train staff in using concept maps as a tool for capturing, archiving, and using knowledge. Grants from these agencies and other sources permitted IHMC to refine and further develop CmapTools software. At one point there were 38 staff working on the development and use of CmaptTools software. A photo of this team was presented in page 126.

Robert Hoffman joined the IHMC faculty in 1999 and soon became a skilled coworker on a number of projects involving knowledge elicitation and concept mapping of expert's knowledge. We collaborated on several projects and a number of publications

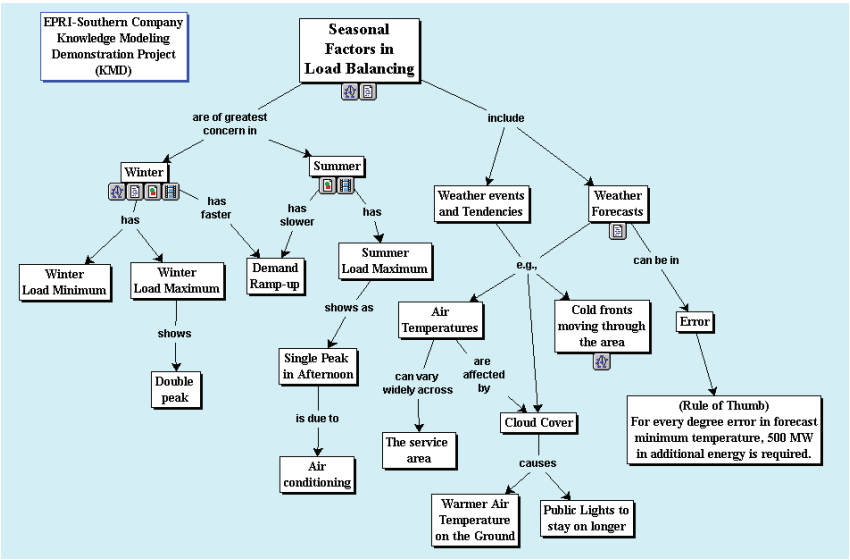
Professor Robert Hoffman

I know nothing about programming. My contribution to these efforts to improve CmapTools was primarily to guide the development so that CmapTools followed the strictures of the learning theory and theory of knowledge that led to the origination of concept mapping. I also helped to lead knowledge elicitation sessions (see photo below), thus training both IHMC staff and various agency staff in knowledge elicitation and concept mapping. The first figure below shows me leading a knowledge elicitation training session with a group of staff members associated with the Electric Power Research Institute (EPRI). The second photo below shows one of the EPRI trainees doing the knowledge elicitation and another participant recording the concept map being produced on a computer with projector running. Our team became quite skilled in running these knowledge elicitation sessions in a wide variety of disciplines.

Me (in blue sweater) leading a knowledge elicitation training session.



A knowledge elicitation training session with EPRI staff. After staff members learned how to use CmapTools, they could record ideas elicited from one of the team members and project this on the screen as a concept map was developed.



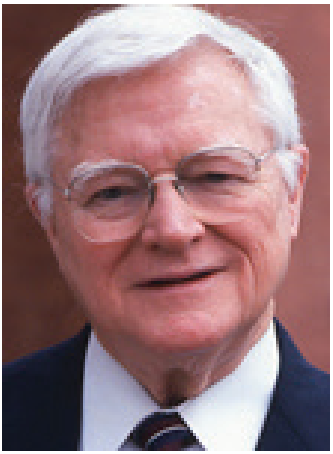
A concept map produced by an EPRI team showing the ideas needed to understand seasonal variations of electric power demand. Note the many icons attached to some concepts. When selected and clicked, additional charts, photos, videos, texts, etc. could be observed and related to the larger picture captured in the map.

Use of Concept Mapping in the Business Setting:

In 1991, Alan McAdams, a professor in the Johnson School of Business and Management at Cornell, suggested that we co-teach a course he called Advanced Consulting. He was interested in exploring how concept maps and education ideas might be applied in the business world. We began the course with McAdams lecturing on the enormous increase in the importance of knowledge and knowledge creation in the business community. I presented key ideas about how people learn and how new knowledge is created. We then proceeded to introduce the students to concept mapping and the use of clinical interviews to study current problems in selected corporations.

One of McAdams' former students, Vernon Dyke, was Vice President of Kodak's Sensitized Components Manufacturing. He had expressed concerns about difficulties in getting his team leaders to understand the mission of the Division, and to work more effectively as a team. We concept mapped a position statement Vernon had presented to the managers, and he was surprised to find that some of the key ideas he thought he presented were not in his statement. We interviewed all of the key managers and concept mapped their views on the Division goals. There were wide differences in their ideas, which also differed from Vernon's goals. It became very evident that there

were communication problems in the Division, creating some of the problems the group needed to address.



Professor Alan McAdams, 1930-2013. He helped me understand how to work with people in corporations, as well as in university business programs.

I co-taught this course with McAdams for three years. Class projects dealt with interviews and concept maps with a dozen or so business organizations. It was manifestly obvious that the same knowledge elicitation and concept mapping strategies we had developed in educational settings were equally effective in business settings.

Chapter 13

My Third Career: Applying Concept Mapping and Educational Ideas with Procter and Gamble, NASA, National Security Agency and Other Organizations, 1992 to 2008

Work with Procter and Gamble

From May 31 to June 3, 1993, in Cincinnati, OH, I attended a workshop sponsored by Procter and Gamble. The goal was to introduce university faculty members and administrators to business ideas such as Total Quality Management. One of the P&G presenters was Larry Huston, Vice President for Knowledge and Innovation at P&G. He described some of the strategies P&G had employed to improve research productivity. He also commented that they needed better tools to facilitate their work, and were looking for such tools.

As Huston was walking out of the lecture hall, I gave him two of my papers dealing with concept mapping and Vee diagramming and suggested that he might find these tools useful. He thanked me and abruptly left the auditorium. I thought, well there goes nothing! I was surprised to find a message on my hotel phone at lunchtime, asking if I could come to Huston's office that afternoon. I spent about an hour with Huston and his assistant, Lindsey Wood, and they expressed enthusiasm about concept mapping as a tool they might use. I said I would be happy to meet with a P&G team to build a concept map for one of the projects where they needed help.

I did not hear from Huston for a number of months, and assumed they had lost interest in our work. But in December, Huston called and asked if I could meet with a team concerning a paper product they had been trying to create for some two years. On December 28, after signing necessary confidentiality papers, I met with a team of 18 P&G researchers, mostly PhD's in chemistry or chemical engineering. The team had been charged with the task of creating a toilet paper that could hang on a bathroom dispenser, but would have the properties of wet tissue. Such a paper would appeal to the Japanese, and other societies where consumers usually wet their toilet tissue before use.

Initially, some of the team members sat with their arms folded across their chests, obviously not happy to have interrupted their Christmas holiday break. Later in the day I learned that I was about the 10th person who had presented

some kind of gimmick for improving research, none of which they found particularly useful. I began by introducing the team to the learning theory and theory of knowledge underlying concept mapping, then showed them examples of concept maps that came from various educational and corporate research settings. I demonstrated how concept mapping software could facilitate building concept maps. We began work with the team by identifying a good "Focus Question" to address their problem and 6 or 7 major concepts that were necessary for understanding the problem. By lunchtime we as a group had built a concept map with 30 or so concepts and propositions.

After a buffet lunch, I divided the group into three subgroups, each of which were to work on refining and elaborating a section of our concept map that was in their area of expertise. We did this with team members using Post-its™ for each concept and arranging these on butcher paper taped to the walls. All groups worked conscientiously. With my assistance, three good subgroup maps were prepared. We met again as a group and agreed on ways to combine the sub-group maps into one "global" concept map for the problem identified.

All team members were surprised at the way the concept map clarified the group's problem and suggested possible solutions. It also made evident that the strategy they had been pursuing could not possibly work. One of the most expensive aspects in any corporate innovation is pursuing strategies that cannot work; identifying these saves huge amounts of money. They also found that the group was missing the expertise of a colloid chemist who could help them with the selection of an appropriate hydrophilic gel that could be used to create the new paper product. Two months after our meeting, the group had succeeded in creating the new paper product and were looking at test market feedback on the product. Joan and I tried a sample of the new product in our home. I thought the new toilet tissue worked well, but Joan found the product unsatisfactory when used after urinating. This may have been the reason Procter and Gamble never sought to market the new product.

Houston's assistant, Lindsey Wood, left the company before my first meeting with a P&G research team, and I was concerned that I may have lost a strong supporter for the work. However, Edward Rogers, an enthusiastic supporter of my work, took over Wood's job. I met again with another research team in April, 1994, and this session also proved successful. After this session, Larry Hughes became Huston's primary assistant. He was later promoted to Associate Director for Knowledge and Innovation. Larry Huston, Larry Hughes, and I worked together on a number of projects, including a major effort to introduce our work to Japanese teams on Riker's Island and Osaka, Japan. Ed

Rogers had left P&G to pursue a PhD degree at Cornell University. Ed wanted to work under my supervision, but I was already thinking about retirement and did not want to accept new students. Incidentally, Ed later took a position with NASA as Chief Information Officer at Goddard Space Center. He often uses concept mapping to solve difficult problems in his work with NASA, and in consulting work.

Larry Huston was Vice President for Knowledge and Innovation at Procter and Gamble. He proved to be a great leader for applying the tools and ideas I brought to Procter and Gamble. He later formed a corporation to further advance the kind of work we did together (see http://www.4inno.com)

A few months later Huston asked me to lead another concept mapping session with another P&G group dealing with a tissue towel product that needed improvement. We proceeded in a way similar to what we had done with the paper product group, and by the end of the day we had developed a good comprehensive concept map dealing with the tissue towel product problems. It was evident that P&G was finding value in the work we were doing, and they sought more of my time for leading sessions. Since I was still doing full time work at Cornell, continuing the work with P&G was challenging--but very interesting!

In March of 1995, I led a group dealing with a bleach product that needed improvement. The session went well. We built a useful concept map by the end of the day's session. I recall one of the team members, recently transferred to the Bleach group from Hair Care, was a PhD in dye chemistry. She observed that if we think of a stain as a dye, certain principles for dye chemistry could give us a new way for thinking about stains and bleach. She built a "sub-map" on dye chemistry, and we fitted this into to the global map as an alternative to the concept "stain." Again, this group found a solution to their

problem in a matter of days. In interviews with team members some months later, one member of the group commented that he had been working in the Bleach group for twenty years, and yet he was surprised at the new insights about bleach he gained the day of our group meeting. The woman with a PhD degree in dye chemistry commented in a later interview that she had worked in Hair Care for 2 years but felt she did not have a grasp of problems in that area nearly as good as what she gained with the Bleach group in our one-day meeting.

Joan had heart surgery in January of 1994 at Cleveland Clinic, giving her a new St. Jude artificial aortic valve and triple bypasses of occluded coronary arteries. We spent most of the 1994-95 school year at the University of South Florida in Tampa, FL, where I was a visiting professor on sabbatical leave. While we were there, Joan suffered a heart attack, caused by the occlusion of the mammary artery bypass vessel. Although she did not voice her concern that she might not live much longer, she did think she might do better in the winter at a place that was warm, flat, and at sea level, in contrast to Ithaca, NY. She asked me if there was some way we could spend winters in Florida.

Dr. Bruce Lytle performed thousands of heart surgeries at Cleveland Clinic. We were fortunate to have him as Joan's surgeon.

I had served 28 years as a professor at Cornell University, and this made it possible for me to retire with full benefits. I decided to resign my position at Cornell so that I could retire and work on various projects dealing with applications from the work we had done in education, business, and other settings--but especially to work with Procter and Gamble. I also became eligible for Social Security and Medicare benefits in December,1995. Though these benefits didn't match my Cornell University salary, we thought we could

manage financially, especially if I had significant consulting income. Moreover, I had accumulated considerable TIAA-CREF retirement funds that I could draw upon after retirement.

I was surprised to learn that with state and federal taxes and Social Security deductions for self-employment, I would have to pay about 103% of my consulting income in taxes and penalties. My accountant advised me to form a corporation that would reduce many of the payments. I set up a Sub-S corporation, Joseph D. Novak Knowledge Consultants, Inc. This corporation also allowed me to recruit some of my former students to help with some of the work and pay them as employees of my corporation. Thus from the summer of 1995 through December of 1998, I devoted full-time and more doing consulting work with Procter and Gamble, the Florida Institute for Human and Machine Cognition, and other organizations.

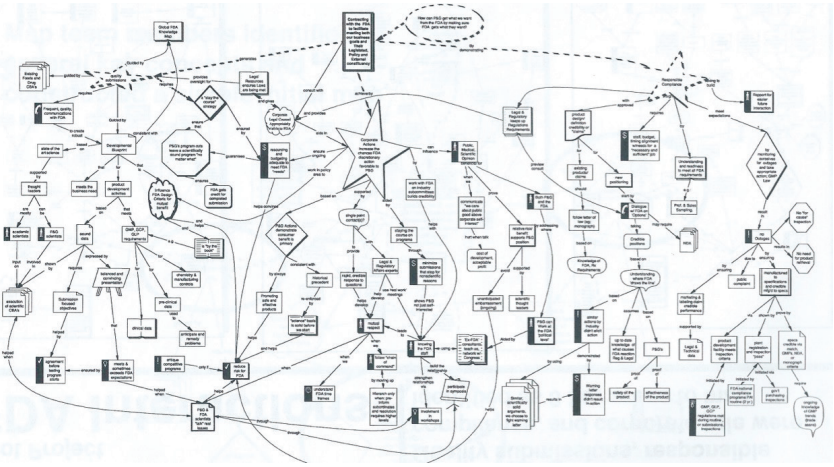
P&G has a Division of Health Products. We were asked to help them with a product for relieving postmenopausal infections. The company hired a team to do a review of pertinent literature. They gathered over 1,000 pertinent research papers, and summarized this literature in a 38-page, single-spaced report. However, the P&G health team found even this summary overwhelming. We were asked if we could condense this into a single concept map.

I hired one of my former PhD students to help with this, and she created a concept map that fit on one opened standard file folder. In a meeting with the top leadership of P&G, we showed the concept map to the officers present. Chairman John Pepper looked at the concept map and remarked, "I don't know much about vaginal infections, but it is obvious from this map that vaginal pH and Lactobacillus are very important, since so many lines on the map connect to these two concepts! Pepper was right: vaginal pH rises in post menopausal women, and this leads to proliferating growth of monilia (yeast) causing a variety of problems. Lactobacillus prevents the growth of monillia.

John Pepper, CEO, Procter and Gamble, was supportive of our work with concept maps.

At the same meeting, CEO Pepper said he had spent much of the morning on the phone with officials at the Food and Drug Administration (FDA) in Washington, trying to resolve some problems with P&G applications for FDA approvals. Pepper asked me, "Could you make a concept map that might help us deal with the FDA applications?" I assured him that this could be done.

A few days later I had a call from Ray Ludwa, a senior P&G staff member who had participated in one of our other concept mapping workshops. He asked, "Do you remember when you met with John Pepper and he asked if we could make a concept map to help us deal with the FDA?" I said I remembered that very clearly! "Well," Ray said, "John asked me to do this and I need your help!" Ray and I met to work out a Focus Question or two, and we identified several major concepts that needed to be considered. We held a one-day workshop with a group Ray had selected, and produced a relatively comprehensive concept map showing important ideas that needed to be considered. Ray subsequently found this concept map to be very helpful in training sessions he did with novice P&G employees.



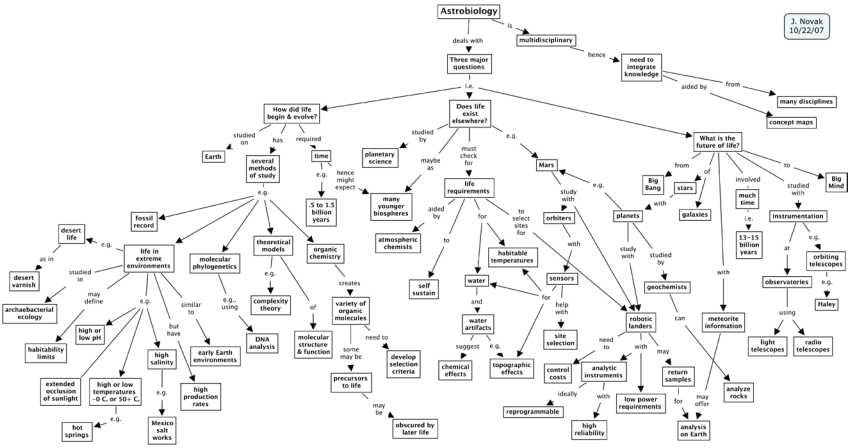
Ludwa's concept map for writing FDA applications shows the complexity of the problem (purposely unreadable).

In another P&G project, we met in Mexico City with Latin American marketing people and diaper manufacturing engineers to concept map solutions for the following problem: How can we double the sale of diapers to Latin American households? One problem was Latin mothers' view that using Pampers delayed toilet training. Building better examples of how to pay for diapers was another issue. This was one of only a few 2-day workshops we held, but in the end the group had constructed several concept maps that pointed to a variety of new marketing ideas, and some ideas for adapting diaper manufacture to the Latin market. We dealt with similar problems in a series of meetings in Riker's Island, Osaka, and Kyoto, Japan, also with a high degree of success. I was impressed with how task oriented the Japanese workers were, even though some had limited English proficiency.

Concept Maps Applied in Work with NASA, Department of Navy, and Other Organizations

As noted earlier, my experiences with Procter and Gamble and other corporations helped me to perfect techniques for eliciting expert knowledge and working with teams to create concept maps that would lead to problem solutions. As my work with the Florida Institute for Human and Machine Cognition continued, I applied a good deal of what I had learned with P&G to problems that IHMC was dealing with, such as a series of projects with NASA. A team of researchers at NASA's Ames Research Center in California was interested in finding a better way to integrate research workers' projects dealing with astrobiology. The director of this program asked me to interview

various team members and concept map their research programs. Then I was to combine the individual concept maps into a "grand overview" concept map for the program. The director thought this overview map would help individual researchers see the "big picture" of the Astrobiology research program, to facilitate communications between researchers, and to help them gain new insights. This project required several trips to the Ames Research Center. In the end, the consensus was that the project was fruitful. The figure below shows the composite map I created for the group.



A "global" concept map for the NASA Astrobiology research program.

Between 1998 and 2005, many of the research projects undertaken by IHMC required additional tools or improved tools to be developed, such as tools that permitted easy collaboration between individuals in creating concept maps and problem solving. This was especially the case with projects funded by the National Security Agency (NSA). After the September 11, 2001 airplane attacks on the World Trade Center and the Pentagon, NASA was under great pressure to improve the capturing and use of intelligence information, to improve collaboration among agencies, and to "connect the dots" within the huge web of intelligence information. Concept mapping proved useful, and NSA provided funding for a number of training workshops and improvements of CmapTools.

On one occasion I asked Steve Cook, the NSA program officer we were dealing with, just how they were using concept maps. Steve replied. "Joe, if I told you, I would have to shoot you!" Nevertheless, Steve believed the use of concept maps helped NSA capture a number of bad guys. The fact that no similar attack has occurred since 2001 is also evidence that they were doing something right! I am proud to have played some small role in this.

Throughout the many visits to Pensacola, FL and other places I have worked, Joan not only accompanied me; she also was my wise counselor, especially when it came to judging people. Joan has what I think is unusual sensitivity to the character and integrity of people. I recall one person we were dealing with who was supposed to seek ways to bring CmapTools to market, thus providing income for future refinement of the tools. I thought the person was really eager to help accomplish this, whereas Joan saw him as fraudulent, and clueless about how to market the program. In a few months, Joan's assessment proved to be true--the person had to be terminated by IHMC. Many people I was dealing with quickly warmed up to Joan and discussed things with her that they never mentioned to me. Over the years, Joan has not only been my loving wife; she has also been my best counselor!

Chapter 14

A Look to the Future

Work with Chinese

Currently I am working with a team of professors at Beijing Normal University (BNU) to demonstrate the value of concept maps as a tool to foster meaningful learning. The collaboration began with Jinshan Wu's invitation in August, 2012 to come to BNU to lecture on work presented in my 2010 *Learning, Creating, and Using Knowledge* book. Jinshan, a professor in quantum physics, did his PhD studies at the University of British Columbia, so he is fluent in English. He saw the theory and tools presented in my book as just what was needed to improve education in China. I explained that I no longer travel overseas, but I would be happy to have a Skype conferences with him and his colleagues, or meet with them in them at my home in the USA.

Jinshan obtained funding from the University for him and three colleagues to come in December, 2012, but Visa problems delayed a planned visit until February, 2013. Even then, only he received visa approval in time to do this trip. We spent 6 days together reviewing some of the research and writing I had done, including the elementary science books that were also of interest to Jinshan. He has two daughters then ages 2 and 5 and he saw the ideas in my elementary science program as just what was needed in China, with some updating, of course.

Jinshan Wu and me during our summer workshop in Ohio, 2013

During his visit in February, we planned a second meeting and workshop to be held near our home in Cleveland, Ohio on August 12-17, 2013, with funding from BNU. Four of his colleagues had problems obtaining visas, or had to cancel due to personal problems. Jinshan and his three colleagues

arrived in Cleveland on August 12, and we held all day workshop sessions the four following days. Alberto Cañas came from Pensacola, Florida to assist with the workshop and to bring his expertise with CmapTools, since he directed the team that developed this software.

All participants prepared concept maps on topics of interest to them. We also discussed ideas on how to help students learn how to learn. We considered ways in which both concept mapping and learning how to learn could be woven into courses they were teaching. We discussed plans for future workshops to be held at BNU in 1914-15. Participants were all very enthusiastic about the ideas developed in the workshop and were committed to helping with future efforts.

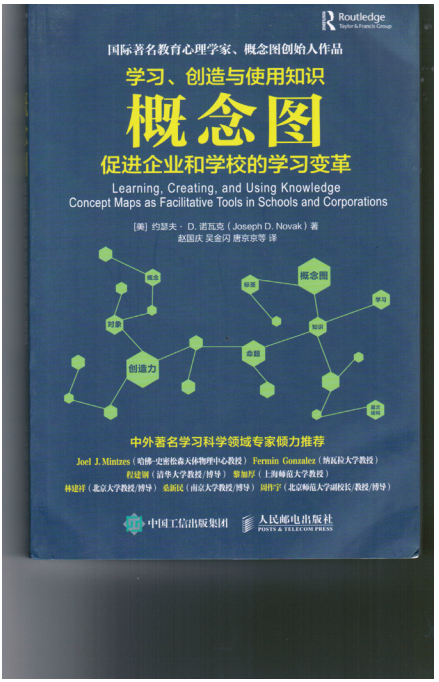
Jinshan, between Alberto and me, and three of his colleagues from Beijing at our workshop at the Union Club in Cleveland.

Jinshan (far left) and his team at our house in our condominium complex prior to dinner at our complex at the Stonewater Grill, 2013.

The first workshops held in Beijing took place in October 2013. Alberto Cañas led these workshops, assisted by his wife, Carmen, and by Jinshan. The workshops dealt primarily with developing skills in using CmapTools and ways to incorporate concept mapping into their classes. The reception to these workshops was overwhelmingly positive. Additional similar workshops

were done at BNU in the 2014-15 school year. These included workshops that combine instruction in basic concepts in several subject matter fields together with learning to learn ideas, and, of course, instruction in the use of concept maps.

Jinshan and his colleagues have translated and arranged for publication of my *Learning, Creating, and Using Knowledge* book, and the book was published in July, 2016. Two other books dealing with learning to learn ideas were completed by members of our team and were published in 2016. Even at this early stage, book sales look promising. We are planning continuing the classes combining learning to learn ideas with subject matter instruction in future years.



The Chinese 2016 translation of my 2010 book

Organizing a New Research Program

In the summer of 2016, I shared a paper published in the journal SCIENCE that presented a summary of some of the recent advances in work done using functional magnetic resonance imaging (fMRI). First developed in the 1990's, this technology allows for imaging brain activity with high resolution of brain areas studied. With vastly improved computers and this new technology, it is possible to make far, far better images of brain cell activity than Elec-

troencephalographic **(EEG)** studies Bruce Dunn and I were doing in 1987-8 (See Appendix 2), during my sabbatical leave at the University of West Florida). We instructed 5th grade children in the construction of concept maps and then recorded their EEG readings when they performed tasks with their own concept maps in Dunn's laboratory. While we found huge differences in EEG readings when we compared those for children simply replacing a concept we had removed from the concept map they had constructed, versus EEG readings when we asked them to add a **new** concept to their map. We were observing only whole brain activity, since the equipment could not record specific areas of the brain, as do fMRI studies. We could only guess at reasons why we saw the large differences in brain activity in our EEG studies.

We also believe that the psychological and epistemological foundations of our work could benefit fMRI research. We see all knowledge as concepts and propositions organized hierarchically in cognitive structure. We also see feelings playing a role during knowledge acquisition and retrieval, and hence expect interactions with the amygdala regions of the brain. In a manner somewhat similar to the X-ray diffractions studies and their contribution to the elucidation of the structure of DNA genetic material by Watson and Crick in 1953, our studies on the structure of cognitive knowledge organization and fMRI studies on neuronal activity might help to "crack the code" of how our brains acquire, store, and use knowledge?

I shared some of the work we had done at the University of West Florida with our Beijing Normal University team and suggested that we should explore in collaborations with teams using fMRI. We hope to show them how concept maps might aid fMRI studies in identifying what their readings might mean in terms of cognitive activities. Jinshan and some of our team members were enthusiastic about seeking such collaboration and soon identified some possible fMRI groups in China and Taiwan who were interested in such collaboration. As of this writing, we have not initiated any collaborative studies, but our group is actively exploring possibilities. If we find the funding to move this work forward and if the studies are successful, the use of concept maps in fMRI studies may serve as a kind of Rosette Stone to help make sense out of fMRI data. If so, this could be revolutionary!

Chapter 15

Honors

Honorary Doctorates

The award of Honorary Doctorates first began in the Middle Ages, usually as a means of gaining political, financial, or other favors from royalty. Since the 16th century, the award has become much more selective, and the selection process can be quite rigorous. For most Honorary Doctoral awards, some distinguished contribution to society is required. Currently, only a small percentage of university professors are ever awarded an Honorary Doctorate. So far as I know, none of my colleagues in Education at Purdue University or Cornell University have received an Honorary Doctorate.

Often these awards are made during the annual graduation ceremony. Other times the awards are made on special occasions. The frequency with which a college or university awards honorary doctorates can vary from annually to only on special occasions. The number of awards made on any one occasion varies from one to a few. Usually the awardee also becomes an honorary faculty member of the college or university, but no salary is paid nor stipend offered with the award. Travel expenses, if incurred by the honoree, are paid by the college of university and may include payment for a spouse or other family members. Generally, universities nominate several persons for honorary degrees; these nominees usually go through several screening committees before receiving approval. Those who are nominated are generally not told they are candidates until a formal approval and invitation are made. It is common for honorees to present a lecture or some other service.

I feel especially grateful for having been selected for an Honorary Doctorate at three important universities in three different countries. All of these awards occurred after my retirement from Cornell University in 1995. Joan accompanied me when I received awards in Argentina in 1998 and Spain in 2002, and my two sons accompanied me when I received the Honorary Doctorate in Italy in 2006. Joan had had some coronary incidents, and we did not want to risk her health on a long international trip.

Universidad Nacional de Comahue, Neuquin, Argentina, 1998

In March of 1998, I was invited to do a series of lectures in Buenos Aires, Argentina, and to do a workshop on learning tools at the University of Comanhue in Neuquin, Argentina. The travel for myself and Joan was paid for

by several groups, and I also received an honorarium for doing the workshop in Neuquin. The Argentinian economy was not good in 1998, and there were also a considerable number of protests and rallies by the people. We were advised not to walk anywhere by ourselves, and not to use taxies. Government vehicles were provided for local travel in Buenos Aires. Even with these cautions, we were surprised to hear gunshots outside our hotel room one evening. We saw hundreds of people protesting in the streets below for recognition of the many missing husbands and others that had disappeared during earlier revolutions. We were happy to be on the 6th floor, and we stayed away from the windows for the evening. Things were much more peaceful in Neuquin, where we felt safe walking around the city, especially during the day.

A former student and visiting professor, Ricardo Chrobak, played a major role in promoting my selection for this award. There were several other colleagues at universities in Argentina who were familiar with my work, and they arranged for several lectures, lunches, and dinners in Buenos Aires. I was awarded a Key to the City at one of these occasions. After one of the luncheons, Joan and I were pleased to see street dancers doing the Argentinian tango—very impressive and memorable!

Ricardo Chrobak and I in his home in Nuquin, 1998. A former student and visiting professor, Ricardo was instrumental in promoting my receipt of an Honorary Doctorate at his Universidad National de Comahue in Nuquin, Argentina.

There was no special occasion on the day I received the Honorary Doctorate. I later learned that the award had been approved by a national committee. It was the 4th Honorary Doctorate awarded by the University in its 25-year history. The ceremony was held in the office of the President of the University with about a dozen invited administrators and faculty present. A hearty lunch followed the award ceremony. Professor Ricardo Chrobak played a major role in advancing my nomination for the lecture and workshop activities in Argentina, and also the Honorary Doctorate from his University. We shared a

number of meals in Irene and Ricardo Chrobak's home, and enjoyed several meals with his family.

Economic conditions remain difficult in Argentina even today. Protests by various organizations are common. When we visited the University, the library had relatively few books and only 7 computers for a student body of some 20,000. Most science facilities were also limited. None of the public bathrooms had toilet paper or paper towels. Many toilets were missing seats. Security was a constant problem. In spite of these difficulties, our reception was very warm, and we enjoyed some excellent meals in a public cafeteria in a huge shopping mall in Comahu, selling everything from food and clothes to automobiles.

Universidad Public de Navarra, Pamplona, Spain 2002

Through the efforts of Professor Fermin Gonzales and some of his colleagues, I was approved to receive an Honorary Doctoral Degree from the Universidad Publica de Navarra, in conjunction with the 25th Anniversary of the University. In coordination with other Anniversary ceremonies at the University, arrangements were made to award me an Honorary Doctorate on April 10, 2002. I received the 4th Honorary Doctorate conferred by this University.

The ceremony took place in a large auditorium with some 250 faculty and university officials present--all in full academic gowns. I was surprised to learn that I was the only person receiving an Honorary Doctorate at this ceremony, along with two other recognitions for senior friends of the University. A student choir sang *Dream the Impossible Dream* from Man of La Mancha, and a student orchestra played this and other songs before and after the ceremony. Joan and our son Bill accompanied me to Pamplona for the ceremonies, with their expenses covered by the University.

President of the University reading Honorary Doctoral citation

Professor Gonzales with Joan and Bill in Pamplona, 2002

Alberto Cañas also came to Pamplona for the event. He had other meetings with colleagues at the University. Subsequently, Alberto arranged for a sabbatical leave at the University of Navarra in 2002-3. He and his wife spent most of a year in Pamplona. During his stay, Alberto did a number of workshops on concept mapping at several universities in Spain. Since Spanish is Alberto's and Carmen's native language, they managed very well during this leave. Alberto also worked with Fermin to plan the First International Conference on Concept Mapping, held in Pamplona on September 4-9, 2004. The first conference was very successful. Alberto Cañas and others have organized 6 additional conferences, held biannually. The 7th International Conference was held in Tallinn, Estonia on September 5-9, 2016. Information on this conference and copies of proceedings from earlier conferences can be seen at: CMC.ihmc.us

The lecture I presented at the ceremony was well received, and some good questions were asked following my lecture. This discussion continued at an elaborate luncheon hosted by the President of the University, with some 50 administrators and faculty at the luncheon. I was very impressed with the quality of the questions raised by a number of persons at the luncheon.

I was also presented with several gifts, including a model of a bull fighter and a bull as might have been seen in Pamplona's famous Feast of San Fermin holiday. Joan and I had visited Spain on several previous occasions. On one of these trips we happened to be in Pamplona in July for the world famous "Running of the Bulls" as part of the festivities. Safe in our hotel room, we watched television coverage of the bulls running down city streets. The evening fireworks, with loud amplified music coordinated to the fireworks, was

the most impressive we have seen before or since this Festival. They occurred every night for the week.

Also in the evenings there were street dances in several parts of the city, and these continued until 3 or 4 in the morning. It was the first time we had seen 6 to 10 year-old children dancing the macarena along with the adults.

The Spanish people are very warm and friendly. Joan and I will always treasure our visits there, and all the things we saw. From the world famous Museo Nacional del Prado to spectacular churches and cathedrals, to the friendly people on the streets of Madrid and other cities, Spain is a great place to visit!

On one of our trips to Santiago de Compostela--where I lectured to a group of some 1500 people--we had a translator who was also a lifelong resident of the city. She gave us a personal tour of all the major sights, and also some places that tourists never get to see. If Joan did not now need to take so many coronary medications on a rigid schedule, I'm sure we would return to Spain again, as well as to other European cities.

Joan and I celebrating the Feast of San Fermin with Fermin Gazales and his two children, 1990

Hundreds of children danced to the Macarena and other songs until one or two AM during the festival.

Universita' Degli Studi de Urbino "Carlos Bo", Urbino, Italy

I had lectured at several universities and at conferences in Italy on three previous trips, including the University of Urbino. Professor Giuseppe Valitutti at the University of Urbino had been a strong supporter of my work. Professor Liberato Cardellini at the University of Ancona also strongly supported my work. Both Giuseppe and Liberato live in Osimo, Italy and they are good friends. Both families were with us when we had a sumptuous dinner, first at the Valituttis' and then at the Cardinellis' homes. Giuseppe's family was in the wine business, and Giuseppe was quite the wine connoisseur. He served a different wine with each of the seven or eight courses of the dinner at his home. Even though Joan speaks no Italian and Giuseppe's wife, Enza, speaks no English, they somehow communicated with each other. Joan and Enza became good friends in the course of three different visits to Italy. Our daughter-in-law Liz is of Italian decent. She is about the same size as Enza and has some of the same warm expressions. We are reminded of the Valituttis every time we see Liz.

Giuseppe and Liberato were friends of the editor for Erickson Publishers. With their support, Erickson published Italian translations of my first and second editions of my *Learning, Creating and Using Knowledge* books. They were also instrumental in getting an Italian translation of *Learning How to Learn*, through Societa Editrice Internazionale in 1989. Giuseppe is highly regarded in national education circles and has close ties with many of the leading educators in Italy. It was largely through his efforts that I was invited to accept an Honorary Doctoral Degree at the University of Urbino on March 12 of 2006. The University was celebrating its 500th anniversary in 2005-2006, and my award was part of the anniversary activities supported by the University. Because Joan had had some coronary incidents earlier in the year, we thought it may not be wise for her to accompany me on this trip. Sons Joe and Bill did accompany me, expenses paid by the University.

President of the University presented Honorary Doctorate Diploma at a ceremony attended by my sons and about 100 faculty of the University, all wearing their doctoral robes.

1506

Repubblica Italiana
In nome della Legge

Noi Professor Giovanni Battista Bogliolo Rettore della

UNIVERSITA' DEGLI STUDI DI URBINO "CARLO BO"

ai sensi dell'art. 169 del Testo Unico delle Leggi sull'Istruzione Superiore, approvato con R.D. 31 agosto 1933, n.1592
veduto l'art. 19 del Regolamento didattico d'Ateneo, emanato con decreto del decano 15 ottobre 2001, n. 1374;
veduta la delibera del Consiglio della Facoltà di Scienze della Formazione n. 84 del giorno 31 maggio 2005;
veduta l'autorizzazione Ministeriale espressa con nota prot. n. 67 del giorno 12 gennaio 2006;
conferiamo a

Joseph Donald Novak

nato a Minneapolis - Minnesota (U.S.A.) il 2 dicembre 1930

la Laurea "ad honorem" in
Scienze dell'educazione

Il presente diploma si rilascia a tutti gli effetti di legge

Urbino addì 12 maggio 2006

Il Direttore Amministrativo

Il Rettore

n. 1404 Reg. Gr. Acc. 2006

Il Preside della Facoltà

Honorary Doctoral Diploma received in Urbino in 2006. While all three diplomas were hand crafted and large (about 18X24 inches), the Urbino diploma was the most ornate.

Given that my Honorary Doctorate was to be one of the University's 500th anniversary events, I thought there might be several persons receiving this honor. There may have been similar ceremonies for others, but I did not hear about them, and I was the only person so honored on March 12.

In Urbino there is a very famous castle, Palasso Ducale. Construction of the castle began in the mid 15th Century. We had a private tour of the castle by our host, Segio Giombini, who was also a docent for the palace. Sergio, a professional architect, pointed out many unique features of the palace's construction that were centuries ahead of their time. We also had a personal tour of the paintings and wall murals in the palace. For centuries the castle had preserved rare books. In some ways it was the center from which the European renaissance emerged in the 16th and 17th centuries. Although Urbino is a relatively small city of 15,000, there is a great deal of important history there.

Sergio, with sons Joe and Bill, entering the castle for a private tour

Bill, Joe, and I touring the castle with Sergio

Sons Joe and Bill and I also had a few days to tour Rome on this trip. We got to see the Vatican, the Coliseum, the Parthenon, and a number of other buildings and churches. Since both studied architecture, they found it fascinating to walk in buildings they had previously known only through photographs. Each took more than 100 photos, one of which I include here.

The Parthenon dome, one of many buildings we visited in Rome.

Since all three of my Honorary Doctorates were received after I retired from Cornell University, there was no special recognition of these in the Department of Education. So far as I know, I was the only Department of Education faculty member with an Honorary Doctorate during the 28 years I was on the faculty at Cornell. I'm not sure my colleagues would have celebrated these awards anyway, because there were jealousies and animosities in the Department.

Distinguished Alumni Award, 2015. University of Minnesota, College of Education and Human Development. One of 25 graduates selected for this award from 72,000 alumni.

In August of 2015, I was surprised to receive a letter from the Dean of the College of Education and Human Development at the University of Minnesota, informing me that I had been selected to receive a Distinguished Alumni Award at ceremonies to be held in November, 2015.

Although I had kept in touch with a few colleagues at Minnesota after I graduated with my PhD degree in 1958, I had never previously received any recognition of my work, even though I had sent some news items on my accomplishments to the College and University Alumni Associations. I had never heard that these were cited in alumni publications, nor did I receive any other feedback indicating someone had taken note of my work.

Professor Fred Finley, a colleague in Science Education for many years, invited me to lecture to his graduate students in Science Education in 2003, but there was no follow-up on this visit. When my former Head of Biology, Henry Koffler, was Vice President for Academic Affairs at the University of Minnesota and was seeking a new Dean of Education, he asked for my assistance in identifying a top flight candidate, as I have noted earlier. When all the first rate candidates I suggested refused to be considered for the position, Koffler asked if I would apply for the position in 1980. For a number of reasons, I declined, not the least of which was that I felt trying to provide innovative leadership for a faculty of 240 professors would be an impossible challenge. So for many reasons, Joan and I were most pleased to attend the November ceremonies to receive this award.

The Awards Dinner on November 19 was attended by almost all of the awardees. Recognitions varied from distinguished service as a Minnesota school superintendent (most common) to one awardee who recently earned an Olympic Gold Medal in basketball. None of the others were cited for scholarly contributions to education, as was the case for me. Dean Joan Qualm called forth each awardee and read the citations for each. Among my achievements cited by the Dean were my receipt of three Honorary Doctorates and my "landmark contributions to science education and to theories of knowledge creation and communication." A photo with the Dean and other photos were taken following the citations. Two of these are below:

Dean Quam, Me with my Award, and Joan, November 19, 2015

Nineteen of the awardees, with me sitting in the center, November 19, 2015

It should be noted that my lifelong efforts to move education toward a theory-based enterprise that advanced in ways more like the sciences was not mentioned by the Dean. Unlike the three Honorary Doctoral Degrees I received, where my theoretical contributions to education were cited, my efforts to create a theory of education were not cited here. In this respect, the saying "Never a prophet in your own country" has so far held true for me.

In addition to the above awards, I have been blessed with a number of other citations for my contributions to education. These are presented in Appendix 5.

Appendices

Appendix 1

Selected Projects I Worked On Over the Years

As a graduate student, I became familiar with many of the research projects being done by the Botany Department faculty. In most cases, these were research projects in the professors' area of expertise, such as plant and microbial photosynthesis, morphology and genetics of corn plants, plant succession in regions of glacial retreat, taxonomy of the willow family, etc. Most professors had one to four or five graduate students working with them, and perhaps some technician help in the laboratory or fieldwork. I found this also to be the case in the biology department at Kansas State Teachers College, Purdue University, and Cornell University.

I found that many of the professors at Purdue University and most of the professors at Cornell University were engaged in projects that involved two or more departments, and sometimes collaboration with colleagues at a number of other universities. This was clearly the case with projects using the particle accelerator at the Wilson Laboratory in Ithaca, the large disc radio-telescope in Arecibo, Puerto Rico, the Manhattan Nuclear Bomb program at Oak Ridge, Tennessee and Los Alamos, New Mexico, the National Aeronautics and Space Administration (NASA), and similar large scale projects. Many of these projects required professors to take a leave of absence so that they could work full-time on a project. In many of these projects, graduate students also were part of the effort, as they simultaneously pursued advanced degrees.

My most extensive project was the development and testing of Audio-tutorial lessons for elementary school science. This project began when I was on sabbatical leave at Harvard University in 1965-66, and continued until a final report on the project was published in 1991. I have previously discussed this project and the development in 1972-74 of the knowledge representation tool we call a *concept map*. It was the development of the latter tool and a computer application, CmapTools, developed in collaboration with the Florida Institute for Human and Machine Cognition, that altered the course of my career and continues as central to my current work.

The Biological Sciences Curriculum Study (BSCS)

During most of my tenure at Purdue, I was also involved with various aspects of the Biological Sciences Curriculum Study (BSCS) project based in Boulder Colorado, and later in Colorado Springs, Colorado. The BSCS program created 3 different high school biology programs to bring instruction in high school biology more in line with where the discipline had moved during the past half-century. The BSCS program grew out of recommendations that originated at the "feasibility conference" held at Douglas Lake, Michigan in 1955. I mentioned in earlier chapters how the leaders of this conference would later be the biology department heads who hired me to join their departments--John Breukelman at Emporia State Teachers college in 1957 and John Karling of Purdue University in 1959. These events left me with an appreciation of how almost chance encounters with people early in one's career can have profound consequences on the course of events later in one's career.

Over a period of more than 20 years, I was involved with various projects and programs of the BSCS, including serving on the Board of Directors for 4 years in the late1980's. Most of my involvement with BSCS was with various teacher education projects, where I urged more emphasis on acquiring a deep understanding of a few basic concepts of science, and applying our growing knowledge about the psychology of learning. I was offered a position with the BSCS in Boulder to head their teacher education efforts, but my Biology Head at Purdue University, Henry Koffler, persuaded me that I could accomplish more by creating a model program at Purdue and disseminating this model. Based on the program I had developed at Purdue University, my book *The Improvement of Biology Teaching* was published by Bobbs-Merrill in 1970. Unfortunately, marketing of this book also stopped soon after Bobbs-Merrill was acquired by Howard Sams Company.

Team members for the BSCS Blue Version biology book concept mapping key ideas to be emphasized in a revision of the book

As a result of my work with BSCS, I came to know quite well Professor Joseph Schwab of the University of Chicago. Because Schwab was a prime leader of BSCS and an internationally recognized scholar in science education, I was very flattered when he urged me to apply for, and later to accept, a position in biology education at the University of Chicago in 1965. However, I was eligible for a sabbatical leave from Purdue University, and I did not want to lose this opportunity, especially since I had been offered part-time support working with a National Science Foundation supported project, the Harvard Project Physics, at Harvard University during 1965-66.

During my year at Harvard I had almost full time to devote to my own research and writing. I completed writing on a six book elementary science program, *The World of Science*, and also my book *The Improvement of Biology Teaching*. More important, I had time to begin a new research program developing audio-tutorial science lessons for elementary schools. This led to a 12-year study, described in Chapter 9, involving Ithaca Public Schools. That project led to the development of the concept mapping tool that changed the course of my career forever. I knew by the end of my sabbatical leave at Harvard that I did not want to continue at Purdue University, nor did I want to accept a similar position at the University of Chicago. Fortunately, Cornell University was looking for a person to lead the building of a strong science education research program, and I accepted that position in August, 1967.

The Ford Foundation Funded Airborne Television Project

During the 1960's there was great interest in expanding the use of television to improve education in the schools. A group funded by the Ford Foundation had the idea that some of the best science teachers could be hired to prepare and video-tape lessons that would then be broadcast from an airplane flying at 27,000 feet and reaching over an area with hundreds of schools. Purdue's President Hovde was supportive of this program, and Airborne Television was based at the University, with a DC-6 airplane flying out of the Purdue University owned West Lafayette Airport.

I was asked by the Vice President, Randal Whaley, to review the recorded TV lessons prior to broadcast from the airplane. We began with some biology lessons done by a veteran teacher from Cincinnati, OH. When I reviewed the first lesson, I was appalled at all the errors in the lesson. Not only were many of the statements wrong, but equally important, the presentation of key concepts was either absent or poorly done. When I reviewed the first General Science lesson done by an attractive junior high school science teacher, I found the lesson even more error filled and missing in substantive content.

The management of the Airborne Television Project was not happy with my criticism, and at first chose to ignore it. However, when the Vice President found out about my concerns, he insisted that the scientific accuracy of the lessons had to meet a higher standard. The result was that some of my graduate students and I essentially took over writing the lesson scripts and suggested demonstrations. Then the "expert teachers" video recorded the lessons.

Ken Jerkins, who was working with me, was interested in the use of television in education. We designed an evaluation program to assess the effectiveness of the Airborne TV lessons in area schools. Since it was clear from the literature that passive viewing of TV lessons has little positive effect on students' learning, Ken developed some "study sheets" to be used during the lessons and immediately following the lessons. As expected, Ken found that in those classrooms where no study sheets were used, students viewing the lessons did no better on post-tests than students who did not see the lessons. While the use of his study sheets did result in statistically significant gains with students viewing the lessons, the gains were still relatively small--as we expected. Needless to say, the managers of the Airborne Television Project were not happy with Ken's research results. When Ford Foundation funding was exhausted a year later, the program was shut down.

Developing an Audio-tutorial Program for Teaching Children How to Read

One of the first projects I was involved in at Cornell University was an effort to adapt audio-tutorial instruction to help students learn how to read. With funding from a fellowship program supported by the US Office of Education, PhD student Robert Hersey began to build and test his lessons in Ithaca schools. Unlike the usual introductory instruction that begins with learning the letters of the alphabet, Robert began with lessons that showed familiar objects, such as a McDonald's or Wendy's sign, a red Stop sign, a green light, and similar words or word phrases familiar to every child by age two or three. He then guided the students to learn that words are made up from letters and have spaces between them, and that a written sentence starts with a word with a capital letter and ends with a period.

Using multiple familiar examples, and ideas from Ausubel's cognitive psychology, Hersey guided the students to *learn what it means to read*. This is usually not done, and he found that even 6th or 7th grade students lacked an understanding of these basics needed to know that the strings of letters are called words and that most words are a label for an object (thing) or an event (happening); some words are the name of a specific thing and these names are capitalized. Hersey found that within two to three weeks of working with his lessons, students began to feel confident that they could read. His successes were really quite remarkable. Unfortunately, Hersey disappeared at the end of the school year and took all the materials he had prepared with him. I had no students interested in picking up on this work in later years. Now I am trying to get the work repeated with colleagues in China.

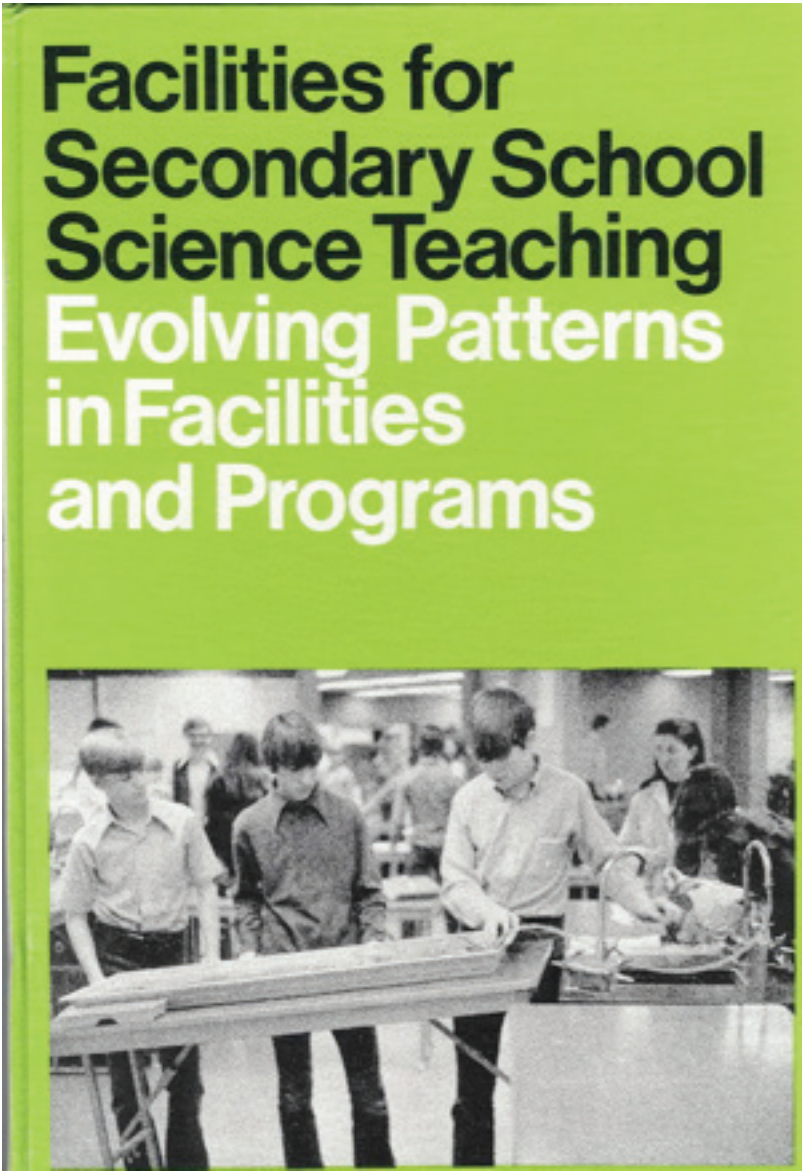
A Study of School Science Facilities and Programs

Another project undertaken early in my Cornell tenure was a study of outstanding school science facilities and programs. The National Science Teachers Association (NSTA) had approached the National Science Foundation (NSF) for funding for this study. I learned after the project was underway that NSF had declined funding for the original NSTA proposal, but indicated they would fund a proposal that had someone like me as the Director. This was interesting, because in those years my proposals to NSF for funding my research on elementary school science learning were repeatedly turned down.

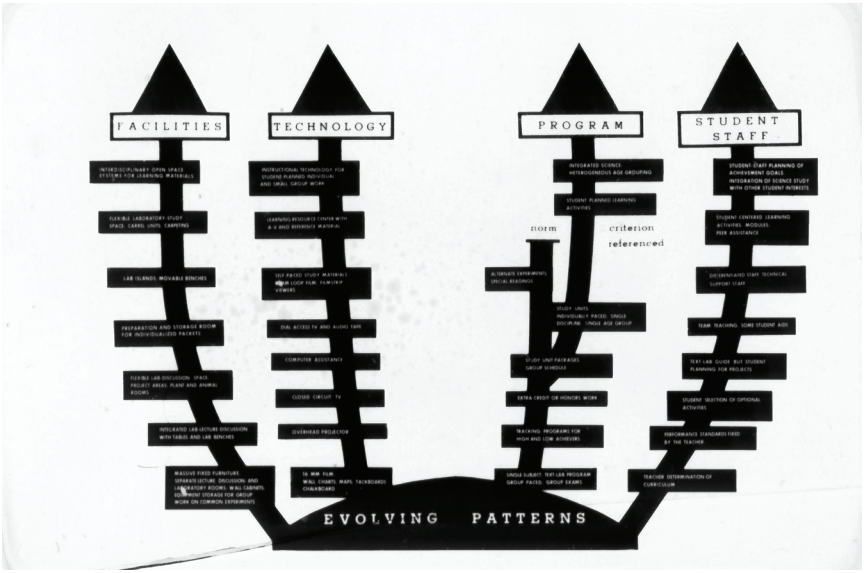
We formed a team of 6 active teachers and science educators, and I served as project director, assisted by two of my graduate students and clerical staff. We solicited nominations of schools with outstanding science facilities and

programs via several channels and received 600 nominations from all over the USA. After preliminary screening according to criteria the study committee had established, we selected over 140 schools and facilities. One or more Committee members or project staff members visited each of these schools, some of them on more than one occasion.

We were amazed at the degree of consensus among study team members as to what kind of facilities and programs were really outstanding, or lacking in one or more respects. The final report, published by NSTA in 1972, contained 173 large pages with numerous photos of desirable or less desirable facilities and program practices, all arranged into four "evolving patterns," with photos and text illustrating the patterns. Although all examples were from functioning schools, the study committee agreed that some facilities, use of technology, programs, and student-staff relations were superior to others. No school was first in all four patterns and most fell far short of excellence in one of more of these patterns. Although the study is over 4 decades old, the findings could be applied to improve today's school facilities and instructional programs. Since the Internet and personal computers did not exist in 1972, today we would see extensive use of these resources as indicative of "advanced" facilities and programs, especially for those schools which had moved toward implementing our "New Model" for education.



A highly illustrated report on our study was published in 1972. The photo on the cover shows a science facility ideal for a program that emphasized active student involvement in teamwork on projects. This kind of instruction today is taunted as Active Learning. Some schools have been doing this for 45 year! Most school remain at the lower levels of our "Patterns" in both facilities and instructional programs.



We identified four "evolving patterns" in our study of school science facilities and programs. They are shown here, moving from most traditional at the base and most forward looking at the top. Unfortunately, detailed text in the rectangles could not be shown. No school visited excelled in all four "patterns."

Perhaps not surprising, one can still find many school science programs and facilities similar to those shown at the bottom of our "evolving patterns." Moreover, it remains true today that very few schools excel in all four patterns, and though this study is now almost five decades old, many schools would profit from reviewing and reflecting on the "evolving patterns" identified in considering how they might improve their facilities and programs. It would also be wise to consider how new kinds of charter school and home schooling programs could be enhanced by using the findings of this study. Please note that the "best" programs in these "evolving patterns" would be similar to what we propose as a New Model for Education on pages 143-144.

The Land Application of Wastewater Project

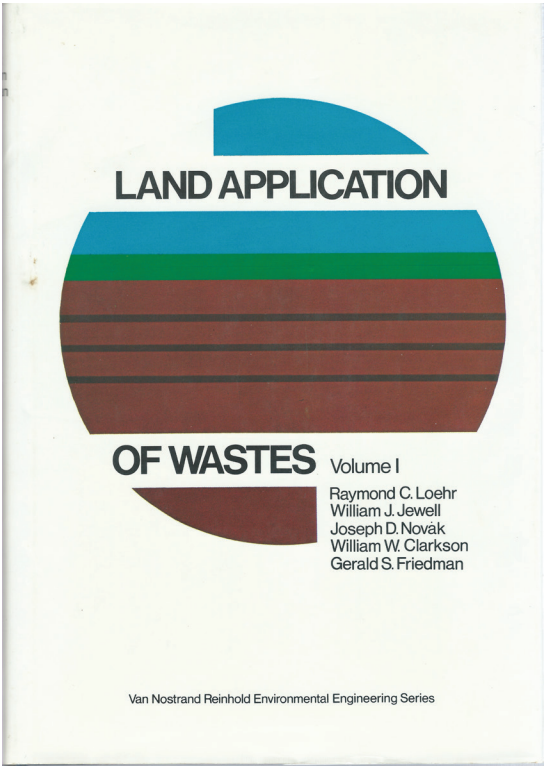
In the summer of 1977 Professor Ray Loehr and I were asked by a former student working with the Environmental Protection Agency (EPA) if we could develop a training program for waste management engineers and EPA staff to teach them about the use and management of farmland for wastewater treatment. This technology had been used extensively in Australia and some other countries for many years, but it was little known and little used in the USA. We submitted a proposal to EPA to create a program, test it, and train a sample of engineers and EPA staff. The project was funded for $250,000

and work commenced in the fall of 1975. Our first challenge was to gather pertinent literature and ascertain what was known about the pros and cons of using land to treat wastewater, rather than the usual methods of employing concrete tanks and extensive chemical treatment.

We gathered over 1,000 research papers pertinent to our work and found that although there was a good deal known about the use of this technology, there were also many conflicting reports, especially as regards the effectiveness for dealing with toxic waste and heavy metals. With many file drawers full of research reports, the challenge was to reduce this mass of information, some of it in conflict with others, into a form that could be used to design the training program.

After attempting several outlines for the program, we became aware that the conventional approach to planning a program was not going to work in the timeframe we needed to meet. We decided to concept map the information we had, building concept maps for the key ideas dealing with water pre-treatment, needed vegetation, heavy metal treatment, soil characteristics, etc. After only a few weeks of concept map development, we had resolved some controversial issues and were ready to move forward with planning the instructional program.

We decided to use Audio-tutorial instruction for the one-week workshops planned for waste water engineers and EPA staff. This proved very successful, with many of the participants saying they had never learned so much in such a short time. Using the prepared concept maps and our experience from the workshops, we prepared a two-volume textbook, *Land Application of Wastes,* which was published in1979. There was no funding available for assessing the effectiveness of our program, but we did learn via personal contacts that the City of San Jose, California installed a land application system based on our work, dropping the treatment cost of wastewater from about $.35 per thousand gallons to $.07. In one year this project alone saved taxpayers more than the quarter million dollars it cost to develop the program--and provided much needed treated water to some area farms. Other cities employing this system can be found via Google or Yahoo.



A two-volume book was published, presenting the program we developed.

Project to Improve Meaningful Learning at University of Florida Medical School

In the early 1980's I was invited to meet with faculty at the University of Florida Medical School in Gainesville to discuss how to increase meaningful learning in the College. Associate Dean Mani Suter and Professor Parker Small were interested in moving instruction and assessment away from an emphasis on memorization. I presented some ideas that might be useful, including the use of concept maps. The first meeting included both faculty and upper class medical students. The reception to my ideas was very positive and some of the faculty moved to implement some of the tools and ideas. I returned for a second set of meetings a few months later and was pleased to see the progress that was being made. In addition, plans were made to visit with the faculty at the medical college at Florida State University (FSU). The program there was only recently implemented and the faculty was struggling to raise standards in the program.

I was somewhat appalled at how resistant the medical students were to anything other than maybe tricks for faster memorizing of information, and many of the faculty shared their view. It was clear that the medical college at FSU would not be an ally for instructional innovation. In our drive back to Gainesville, Mani Suter and Parker Small expressed their disappointment with their colleagues in Tallahassee. Nevertheless, Parker and Mani pressed on with their efforts to improve instruction at Gainesville. The following year, Mani Suter retired and Parker Small went on sabbatical leave. Without their constant pushing and prodding for meaningful instruction and better assessment, the things we initiated soon fell by the wayside.

I had worked in previous years with medical schools in MacMaster University in Ontario, Canada, the Philadelphia College of Osteopathic Medicine, Cornell University Medical School in New York, Harvard Medical School, and Mercer Medical College in Macon, Georgia. In addition, I have communicated with faculty at another dozen medical colleges. None of these ventures progressed to the point of showing promise for real change. I had high hopes for the medical school in Gainesville because of the strong local leadership, but this too failed when Professor Small and Dean Suter retired. Part of the problem derives from the nature of final exams for licensing of doctors. These exams continue to place overwhelming emphasis on memorized information.

In Philadelphia, I attended a meeting sponsored by the Howard Hughes Foundation. The goal was to plan new medical school exams with more emphasis in basic science and medical concepts, but after several months of follow-up communications, this effort also went nowhere. I discussed earlier our family experience with medical incompetence; unfortunately my efforts to ameliorate the problems over the years have never born fruit. I continue to look for opportunities to make a positive difference in medical education. My most recent efforts with colleagues in the field of ophthalmology may bear fruit in time, but this remains to be seen. We did publish a paper in 2012 with Allen Brewer and his colleagues, showing applications for concept mapping in this field.

Developing Software for Concept Mapping and Vee Diagramming

Among the many projects done at Cornell University was an effort to create IBM computer software to facilitate creation of concept maps and Vee diagrams. One of my students, Howard Stahl, had developed a simple version of software for Apple computers. When IBM offered the College of Agriculture and Life Science 30 IBM desktop computers and $100,000 for a project using these computers to improve teaching, Dean Call invited me to apply for

this funding. I proposed a project to develop and test software for concept mapping and Vee diagramming in a first year biology course. I soon learned that the first two people I had hired to do the programming did not really have a clue as to how this should be done. Fortunately, I found a woman at Michigan State University who was highly recommended by colleagues there. With a competent programmer, we soon had working software for both concept mapping and Vee diagramming.

We began a semester long study with the biology 100 course, with my PhD student Martha Robertson Taylor collecting and processing the data. Her thesis work showed that both concept mapping and Vee diagramming enhanced achievement in the course, especially for those students who were most diligent in their work with these tools. Moreover, students' attitudes toward laboratory work was enhanced, with some students remarking that they never understood what they were doing in science labs before using these tools.

Project with Lompoc, California Public Schools

In the fall of 1988, I received a call from Henry Galena, Assistant Superintendent for Instruction for Lompoc, California Schools. He had read my book, *Learning How to Learn* and he wanted to implement the ideas presented in the book for all students in Lompoc.

I indicated that such an enterprise would take a period of years. He replied he was prepared to stay with the effort for however long it would take for implementation. We agreed to start with elementary school teachers and principals, and I traveled to Lompoc to begin the project. It takes most of a day to get to Lompoc, so I did not want to engage in this project if there was not a long-term commitment. Too often in the past I had met with school administrators eager to adopt some of our work, but after one or two meetings, the project was dropped--usually due to lack of funding.

We had an initial meeting with about 20 elementary school teachers and two principals in the fall of 1988. They were introduced to ideas of meaningful learning, concept mapping and the Vee heuristic. By the end of a two-day session, all of the teachers succeeded in making at least one concept map for subject matter they were teaching. The teachers recognized that what we were proposing to do was "revolutionary," and they expressed their enthusiasm for the work. I continued to return to Lompoc, meeting with groups of teachers and their principals about three times per year. There was high enthusiasm among elementary school teachers and principals who were working with the learning strategies and learning tools. I helped them find ways to incorporate

the tools and ideas into their instruction. We began to talk about expanding to the junior high schools in the coming year.

Promising as the innovation program with Lompoc schools appeared to be in 1991, we were again struck down by an unexpected external event. The decision had been made by the US Air Force to drastically reduce the personnel at the Vandenberg Air Force Base near Lompoc, California. This meant the hundreds of children of Vandenberg parents would no longer be attending Lompoc schools. Federal "Impact Funds" paid to Lompoc Schools were cut drastically as a result. Funding for our project was eliminated and the Assistant Superintendent I was working with left the system. Thus ended another project that for a couple of years looked as if it could become a national model!

Collaborative Project with Cornell University and Ithaca Area Public Schools

The majority of my PhD students had master's degrees in one of the sciences, plus additional graduate work in sciences and computer science. In their PhD research, they chose to study ways to improve teaching and research in their field of study. This led over the years to close ties between our programs and faculty in the various sciences and mathematics departments. Over the years I enjoyed good working relations with many of Cornell's most outstanding scientists and mathematicians.

Professor Roald Hoffman, 1981 Nobel Prize winner for chemistry was a strong supporter of my work at Cornell University.

My work with Roald Hoffmann was especially warm and encouraging. When I was approached 1986 by Provost Keith Kennedy to co-chair a Cornell com-

mittee to help area schools improve their science and mathematics programs, I was prepared to plead I was too busy to take on another job. However, the Provost indicated that Professor Hoffmann had agreed to co-chair the committee, but only if I would co-chair it with him. Given the many world-wide demands for Hoffman's time, I knew it was absurd to profess I was too busy. Over the two-year span I worked with Professor Hoffmann on this committee, my respect for him and his many talents grew considerably. In spite of his international stature as a Nobel Laureate, he was always modest, kind, and understanding in dealing with teachers, students and school administrators.

The Committee worked to offer a variety of resources to teachers and schools, including workshops on the use of concept mapping to help students learn, lectures by distinguished Cornell professors on topics of interest to teachers and students, and "opening doors" to some of the many classes and other resources available at Cornell University to area teachers and students. Later, David Burak was employed to coordinate activities and assist with administrative matters. One of the lessons from this work was learning once again how difficult it is to create positive changes in public schools. I did not resume work with the Committee when I returned from sabbatical leave in 1988, and Hoffman also terminated his participation.

Planning a Life Support System for a Lunar Colony

During the 1980's the successes of NASA's Space Shuttle program was opening up new possibilities for space exploration. NASA was interested in the possibility of establishing a permanent station on the moon. To achieve this, they needed a way to grow food, recycle oxygen and water, and enhance the living space. A group of professors in the College of Agriculture and Life Sciences formed a collaboration to prepare a comprehensive proposal for funding by NASA. I was asked to be part of the group, based partly on successful collaborations my students and I had established with other projects.

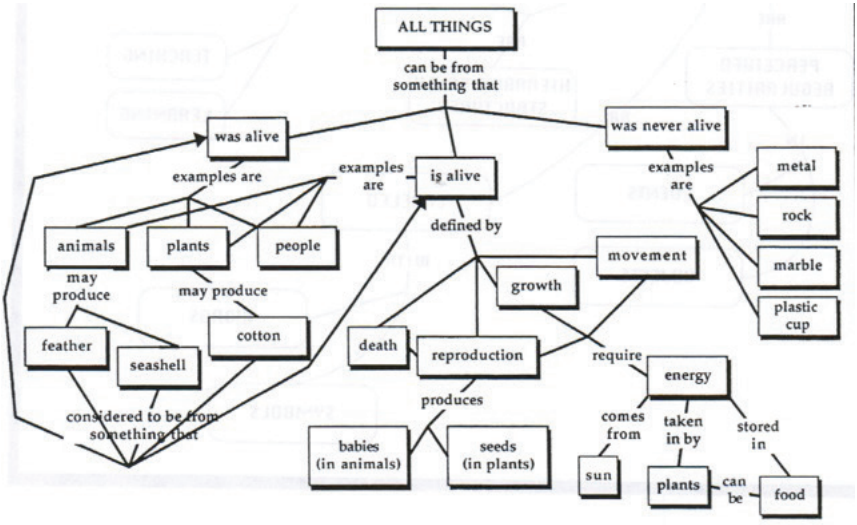
The space shuttle had a cargo bay 60 feet by 15 feet. This was the largest unit that could be shipped to the moon. Engineers at the Johnson Space center had suggested a horizontal plant growing chamber 12 to 15 feet high and 30 to 60 feet long. Unfortunately, plants do not grow in a semi circle. We almost immediately suggested a plant growth module that sat vertically instead of horizontally. This permitted plant growth "floors" spaced a foot or so apart and others with a larger separation. Spaces could be provided with varying heights to allow for growing plants of varying heights. Moreover, temperature regulation could be better controlled with those plants that do better at low temperatures grown low in the chamber and other plants higher up in warm-

er sections. This configuration would also allow for better control of various levels of temperature and humidity, capture of transpired water and oxygen, and other environmental variables.

The major challenge we addressed was the kind of plants that would be a good food source for humans, and possibly for chickens or other meat food sources. It was assumed that all plants would be grown hydroponically to make maximum used of space and best control of environmental factors. Cornell University had a very successful hydroponic program for growing lettuce, but unfortunately the nutritional content of lettuce is very low. In contrast, cabbage has high protein and other nutrient concentrations and could serve multiple dietary purposes. Working with cooperation from professors in human nutrition, our project came up with a list of candidate plants that showed promise for supplying a nutritious and tasty diet, and that could be grown in the kind of chamber we proposed. We were optimistic that our proposal to NASA to fund a center for testing our ideas would be well received. Unfortunately, the Chairman of the NASA committee for such projects was a politician from Wisconsin, and the University of Wisconsin was awarded a five-year multi-million dollar grant to develop a food supply program for a moon space station. So far as we know, nothing viable came from the Wisconsin program.

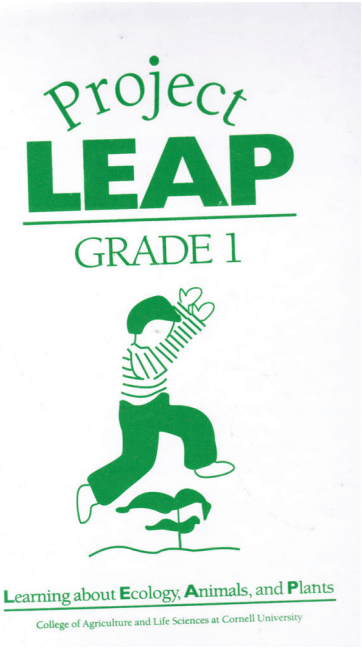
Project: Learning about Ecology, Animals and Plants (LEAP)

The last collaborative project I worked on before retirement in 1995 was a joint effort with colleagues from the Department of Natural Resources, Agricultural Engineering and Cornell Plantations. The project received some funding from the National Science Foundation, some from the College of Agriculture Hatch Program and some from Cornell Plantations, a Cornell University natural preserve program located on campus. Several of my graduate students and students in other departments were involved in preparing and testing lessons in Ithaca Public Schools. The major goal of the project was to involve children in hands-on experiences with plants and animals with both classroom and field experiences. The lessons were designed to incorporate several key concepts that were illustrated through study of plants and animals, their environment and the non-living things in the environment that plants and animals need. Some concept maps were used to illustrate the relationships between key ideas, and to help the children build their understanding. Teachers were encouraged to help children build their own concept maps, either individually or in small groups. The figure below illustrates the key concepts presented in the program.



The Principal Ideas Presented in the LEAP Program and Some of the Interrelationships

The original plan called for developing lesson packages for grades kindergarten through grade 6, with key ideas about plants, animals and their environment developed progressively through the grades. However, as a result of limited funding, only study units for grades K, 1, and 2 were competed and tested in 1994-95. The response from children and teachers was very positive. The schools that were in our development group continued to use the program for a time, but without our project staff to provide other support, the program probably faded away in a couple of years after I retired in 1995.



Project LEAP, Published by Cornell University in 1995 as a Notebook with Text and Worksheets.

Panamanian Grades 4-6 Conéctaté Project

The most ambitious project I have been involved with was Project Conéctaté al Conocimiento in Panama during the years 2004-2009. The project was funded by the Panamanian government and had strong support from President Torrijos and all members of his cabinet, especially Gaspar Tarte, Secretary for Education and Director of the project. The goal was to train all teachers and principals in grades 4-6 in 1,000 schools. Their training consisted of meaningful learning strategies, including concept mapping and the use of computers and the Internet. President Torrijos and Gaspar Tarte took a keen interest in the project and visited participating schools a number of times, as seen in the figure below.

President Torrijos (in front) and Gaspar Tarte (in rear) visiting a Project Conéctaté School

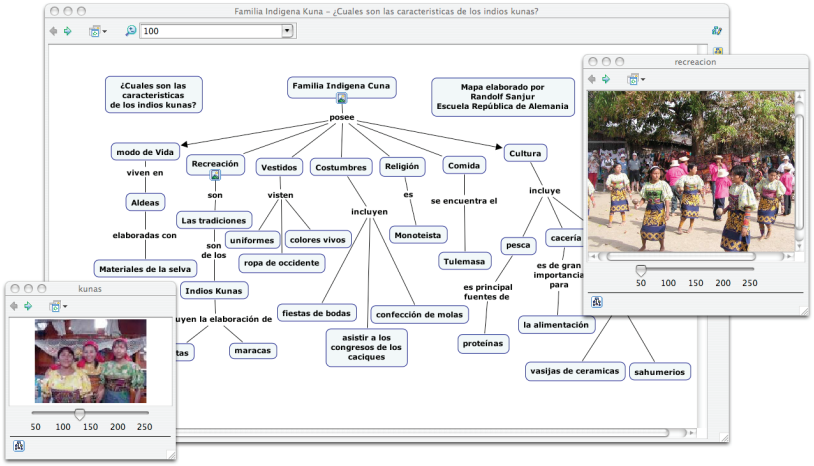
There were many challenges initially, since equipment needed to be purchased and installed in schools. In extreme situations, solar power facilities were needed for computers and satellite Internet connections. Alberto Cañas and his wife Carmen played a major role in training the leadership for the project, as well as conducting numerous workshops with teachers and principals. The staff devised many interesting training tools, including the use of a wooden die with words on the six faces. Participants could look for ways to build a concept map using the words that came up as the die was tossed. The game illustrated the many ways in which concepts can be combined into meaningful propositions.

As the project got underway, Joan and I were invited to visit Panama. We had plane problems and feared we could not make the trip, but fortunately the President was a friend of the President of Copa Airlines. They made room for us on a flight from Miami to Panama City. We were met at the airport by several Cabinet members and ushered into a private room where we were served tea and snacks while aids took care of getting our passports stamped and our baggage loaded into a limousine. The next day we met with President Torrijos in his office, and with Gaspar, Alberto and Carmen Cañas, and other key players in the project.

Joan and I met with President Torrijos and Gaspar Tarte in the President's office. Alberto Cañas (far right) and his wife Carmen (far left) were also invited to the meeting.

President Torrijos asked me serious questions about the rationale underlying the Project.

While the implementation varied in quality from school to school, by the end of the five-year effort most of the teachers in grades 4-6 in the 1,000 schools were successful in using CmapTools and other strategies to improve teaching and learning. Some remarkably good class projects were completed, such as the one illustrated in one of the photos below. Even in rural areas, teachers and students were successful in using computers and the Internet for learning. Parents in many communities used the facilities in the evening to contact family in other cities and countries. Joan and I visited Panama three times. I gave lectures to teams of teachers and principals, as well as to government officials and project managers. We were hosted most graciously, including a personal meeting with President Torrijos. Joan recalls talking with one of the students who was working on the Internet and building a concept map. He commented. "I really like learning this way!" We also enjoyed a private tour of the Panama Canal Exhibit, reviewing some of the history of the Canal and plans for a second larger canal, completed in 2016.



A concept map created by 5th grade children in a rural Panamanian school. Icons on concepts open up resources gathered from the Internet and videos recorded by the students, some of which are shown in the inserts.

A Project Classroom in Rural Panama that Required Solar Power for the Computers

The project was close to realizing its goals when national elections led to the loss of the Torrijos government. The new government, in typical Latin American fashion, tossed out all the programs of the Torrijos government, including Project Conéctaté. We do not know what happened to the equipment, but without governmental support of the program, we surmise that all of the accomplishments and hard work of Carmen and Alberto and the other team members was soon lost. This was one more disappointing experience I have had in working to improve education in a substantial way. Disappointing as this was, the record shows that this kind of radical improvement in school education, exploiting the use of new ideas and new technology, is possible. Had the project continued for another 5 or 10 years, it may have become the model for dramatic improvement of Third World education! It is possible that the model may be picked up by Costa Rica or Colombia, where many

are working to implement similar programs. There is also the chance that the Chinese government may choose to support a similar project in China – and they can marshal a sustained effort to accomplish this if they choose to do this!

The Genes to Cognition Project

In August, 2003, Dave Micklos invited me to join an Advisory Board for a project he was heading at Dolan DNA Learning Center, affiliated with the Cold Spring Harbor Laboratory in Cold Spring Harbor, New York. The objective of the project was to produce learning materials appropriate for high school advanced placement biology and psychology courses presenting the latest advances in research on human learning and mental diseases. At the first meeting of the Advisory Board I suggested that the project might benefit from using concept mapping and Ausubelian ideas in the program. This suggestion was accepted by the Board and became central to the program. Three other members of the Advisory Board were high school teachers who had participated in one of the summer teacher training programs we held at Cornell University, and hence they were knowledgeable about the tools and ideas I was suggesting. All had been using concept mapping in their high school courses.

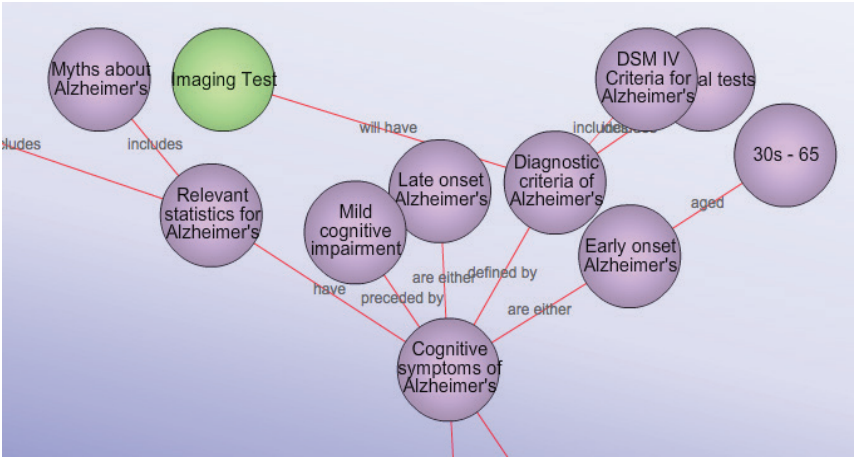
Our first trip to the Dolan Center was pretty awful, due to heavy traffic into and out of New York. We were advised that we could take the ferry from New London, Connecticut to Long Island. This proved to be a great way to go, since the short drive from our new summer home in Taunton, MA to and from New London and on to Long Island was scenic and pleasant, and the ferry ride across Long Island Sound was also pleasant. Since Joan could accompany me on most of these trips, we tried to make them more like mini vacations. Some of the suggestions Joan made during planning sessions were also incorporated into the materials.

The project began with a survey of recent literature dealing with the genetics involved in human learning and brain disorders. Concept maps were prepared by project staff for many of the research studies, and some of these were incorporated into the learning materials. Staff also conducted interviews with the researchers, who were doing research on the genetics of brain functions and brain disorders. Video clips from most of these interviews became incorporated into the lessons, some 200 in all.

Flash software was used for the program, since this was familiar to Dolan Center staff and worked well for this project. The materials produced could

be accessed through the concept maps produced for the project. The high school teachers also prepared guides for activities to further the students' understanding of the lesson materials. The materials were tested and evaluated in summer programs involving students and teachers, as well as in classes during the academic year. The materials proved to be very popular. They can be accessed at: http://www.g2conline.info/

The G2C project was one of the few national projects on which I consulted that proved to be a very productive effort. At least a dozen other projects proved in the end to have been a waste of time. You can never be sure when you commit to work on a project whether it will blossom into something great, or fizzle out. The G2C project was a very fruitful effort.



A Segment of a "Genes to Cognition" Overview Concept Map on Alzheimer's Disease
All materials produced can be accessed at: http://www.g2conline.info/

Appendix 2

Sabbatical Leaves

Most colleges and universities offer faculty sabbatical leaves with the intention of encouraging the development of new skills and experiences that will enhance the future teaching and research efforts of the faculty member. The common practice is to offer a faculty member, after six years of service, a one-semester leave at full pay, or an academic year leave at 1/2 pay. In the latter case, the faculty member would need either to cut back on expenses or obtain other financing, such as funding on a research project, or some other source of income.

The usual practice is that the faculty member must apply for a leave 6 or more months in advance and submit a study plan for the leave. Some colleges and universities grant fewer sabbatical leaves, while others are more liberal in policies. Both Purdue University and Cornell University encouraged faculty to take sabbaticals, but they do require a thoughtful application, and not all requests were approved by the administration. Faculty members are also encouraged to spend sabbaticals at another university or laboratory. This necessitated relocating the family in most cases, and for this reason, some faculty members never take sabbatical leaves. In my case, I was always eager to take a leave after each 6-year term of service. I was always fortunate in obtaining support for a full academic year's leave.

1965-66 at Harvard University

Through my activities with various science education organizations, I became well acquainted with Professor Fletcher Watson at Harvard University. I mentioned to him at one of these meetings that I was looking for a good place to spend my upcoming sabbatical leave, and he soon arranged for me to join his Science Education group at Harvard. Part of my responsibility for this support was to assist with a National Science Foundation funded project to develop a new high school physics course called Harvard Project Physics. Although my knowledge of physics was limited, I had had considerable experience in both high school and college curriculum development. I was also expected to offer seminars and to work with some of the graduate students interested in my areas of research. Harvard also offered some support for my research work, including funding for materials, a research technician, and one graduate student research assistant.

I had begun to explore the development of science audio-tutorial lessons for elementary schools while at Purdue University, building on experiences with an audio-tutorial botany course that I helped Professor Sam Postlethwait to design. We had published a book describing audio-tutorial instruction in 1964, as noted earlier. I wanted to focus my efforts on creating more elementary audio-tutorial science lessons and to work out new techniques for assessing student learning from these lessons. One of Professor Watson's graduate students, Robert Brigham, was interested in working with me and developing lessons dealing with electricity for grade two students.

There was a problem in finding a tape recorder that could be operated by first grade children without assistance, leaving the cassette tape ready for the next child. We bought two RCA cassette tape recorders that could be used. The recorders were rather bulky and costly ($165 each). A year later a much smaller and cheaper (about $70) cassette recorder came on the market, and we quickly switched to these. They were also easier for the students to use and took up much less space on the carrel unit (see photos in Chapter 9).

We lived in Arlington, Massachusetts during my leave, and I was fortunate to get the cooperation of some Arlington elementary school teachers and principals. During the school year, I succeeded in developing a half dozen lessons that worked well with first grade children, and Robert developed several lessons dealing with electricity that also functioned well. We found that any form of paper and pencil test failed to assess children's learning in a valid, reliable way. We resorted to using modified Piagetian clinical interviews, and while it was time consuming to interview children individually, we felt we were getting a pretty good understanding of what the children were learning.

We enjoyed living in Arlington in the house we had rented on Mystic Lake. We were only a few blocks from the local elementary school, so it was easy and safe for our three children to walk to and from school. We enjoyed weekend trips to the many interesting historic places in the Boston area. Joan and the children enjoyed taking the subway downtown for shopping. There was a Harvard Wives Club that met regularly, and Joan enjoyed meeting with this group, albeit there were times she did not think she would locate the home for the current meeting. Driving in Boston is a challenge for natives, and much more so for visitors. Harvard President Harvey Pusey's wife Anne was most cordial in meetings with the faculty wives, and she hosted them in her presidential home. We had some interesting encounters at home, as I discussed earlier.

For me the sabbatical at Harvard was everything I had hoped it would be, and more. Not only did I have a chance to sit in some classes of famous professors such as psychologists B.F. Skinner and Jerome Bruner, I got to know physicist and science historian Gerald Holton well, and learned a good bit of physics working on the Harvard Physics project. Most important, I was convinced that I could do some excellent science education research, and I became determined to find a position that would better offer this opportunity than the position I held at Purdue University.

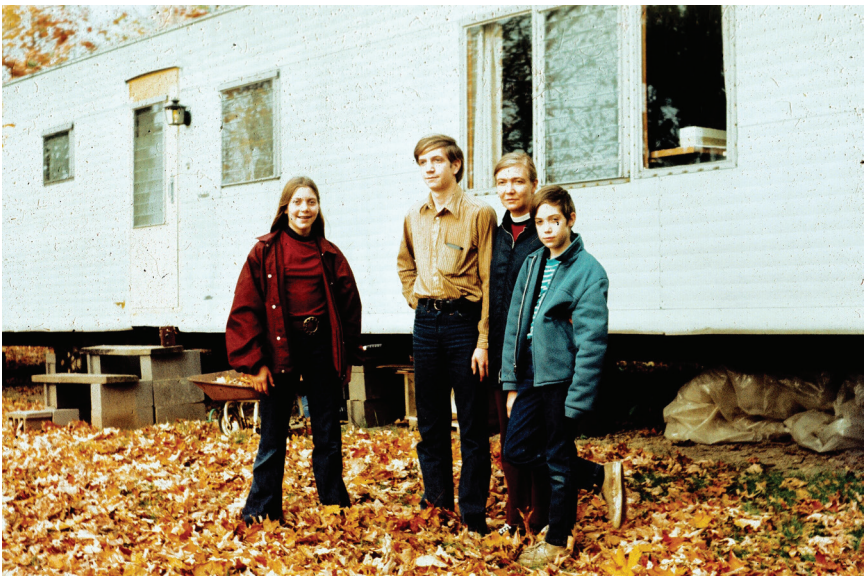
Prior to my leave at Harvard, I had explored other possible positions. I was offered a position at the University of Chicago, but I decided that the joint appointment in the Zoology and Science Education Departments would have many of the difficulties I had with my position in Education and Biology Departments at Purdue. Fortunately, I interviewed for, and was offered, a position as full Professor of Science Education at Cornell University, with the primary task of creating a world class science education research program--just what I wanted to do!

1973-74 Sabbatical at Cornell University

By 1973, the research work my graduate students and I had done suggested to me that it may be possible to undertake a challenge that I had first explored as a graduate student at Minnesota--to create a viable theory of education. I knew that I could not complete a draft of the theory in a single semester, since there was much library work to be done, and a good deal of work on rethinking the pertinent research and writing I had done. Moreover, it made sense to do this work in Ithaca, where all my files were located, and I had access to an outstanding library. I spoke to Associate Dean Nyle Brady about the project I wanted to pursue and the need for a full year to do this work. He was very supportive, and said that he would recommend to my Department Chair, Helen Wardeberg, that I take a full-time leave in the fall semester, and that she should assign me to my writing project for the spring semester, rather than teaching. This was a generous offer, and indicative of why I found Cornell such a wonderful place to work. This arrangement also allowed us to stay in our home at a time when our junior and senior high school children were engaged in many local activities.

I had purchased a used mobile home and installed it on a Cayuga Lake property we had purchased jointly with our neighbors, the Matyas family. It was nestled in woods overlooking Cayuga Lake, a delightful and serene setting during the school year. I installed electricity, but not water and sewer service. We used a porta-potty instead, and this was satisfactory for our needs. The oil

furnace in the home was adequate, also. I had used the mobile home during 1970-72 as a good location for displaying all the photos for writing a book on exemplary school science facilities and programs. I completed the book in 1972. Because there was no telephone, and cell phones did not yet exist, I could enjoy peace and quiet needed for writing, in a lovely setting about 20 minutes from our home. By the summer of 1974, I had completed a draft of what became *A Theory of Education*, published by Cornell University Press in 1977. I also completed several other papers during the year. All in all, it was a very productive sabbatical leave.



Erected on a lot overlooking Cayuga Lake, this mobile home was a great place for me to write and do other work. Occasionally the family used the home, but we never stayed there overnight.

1980 Fulbright Scholar in Australia

By 1980, our children were all in college, so Joan and I were free to travel anywhere. I had been encouraged to apply for a Fulbright Scholarship to Australia by colleagues in Melbourne. Several of them had visited our program at Cornell University, and they were also familiar with many of my writings. I won the Fulbright Fellowship and arranged to spend the fall semester in Australia, based at Monash University. The Fulbright program provides travel support to and from the sponsoring university, and also to other universities in the host country. In the course of our 5-momth stay, we visited universities in all of he state capitols except the Northern province.

Australians are very friendly, fun loving people. We enjoyed many good times everywhere we travelled. I also found the faculty to be more probing and challenging of ideas than is common in the US. This was a great opportunity to refine both my theoretical ideas, and ways of implementing "learning to learn" strategies. I also did a small research study with elementary school students with Professor David Symington. In so many ways, it was truly a great learning experience for both Joan and I.

1981 Distinguished Visiting Professor at the University of North Carolina - Wilmington

After returning from Australia, I continued my sabbatical year, and we moved to Carolina Beach, North Carolina. We had purchased a triplex on the beach a few years earlier as a possible retirement home. Now we had a chance to live there full-time for several months. I had accepted a position as Distinguished Visiting Professor at the University of North Carolina at Wilmington for the spring semester. I did a number of workshops for faculty at the University, and also for teachers in area public schools. Most of my time, however, was spent writing a draft of a book based in part on my experiences teaching a course, "Learning How To Learn" at Cornell University.

We enjoyed living on the oceanfront in Carolina Beach. I was a little concerned that it would be lonely for Joan, since I spent a good bit of time at the University. Joan loved walking the beach, and soon got to know some of the regular beachcombers. She also got interested in doing more painting, since the ocean views were so great from the front porch of our home. The oil painting below is one she did during our stay on Carolina Beach. We made a number of new friends, and I continued to collaborate with Professor Joel Mintzes, my host for the semester at the University. Joel was the first PhD student of my first PhD student, Darrel Murray. All in all, it was a very pleasant and very productive sabbatical.

Our triplex on Carolina Beach where I wrote Learning How to Learn, and Joan did many paintings.

One of the paintings Joan painted during our stay on Carolina Beach, in 1981

We had not realized that Carolina Beach was one location most hit by hurricanes in the summer months. We sold our triplex and purchased a newer condo in a complex on the beach, reducing our maintenance problems. In 1985 while we were hosting a bridal dinner in Cleveland, Ohio prior to our son Joe's marriage to Elizabeth Di Marco, a hurricane struck our condo and essentially destroyed it. After a year of fighting with the insurance people, we restored the condo and sold it. We never bought an oceanfront property after that!

I had presented some of the themes of the book I was planning in Australia, so my writing progressed rapidly. A draft of the book was finished by the end of the school year, and I used copies of this book in my Learning to Learn course when I returned to Cornell University. I finished a final draft of the book in 1983. Through contacts with Susan Milmo, an editor for Cambridge University Press that I had become acquainted with at national meetings, the book was published by Cambridge University Press as *Learning How to Learn* in 1984. In subsequent years the book was translated and published in Spanish, Portuguese, Finnish, Thai, Arabic, Japanese, Italian, and Chinese. Most of these translations were arranged with help from colleagues I had worked with in visits abroad, and as visiting professors with my research group at Cornell.

Against Joan's advice, I invited my colleague Bob Gowin to be listed as a coauthor on the book, in recognition of his work in creating the Knowledge Vee. Very little of his writing was included in the book, and all the figures, and tables were done by me or my assistants. When it came time to consider a second edition of the book, I could not reach an agreement with Gowin, so a second edition was never published. Nevertheless, the book has become a "classic" and continues to sell today!

1987–88 Sabbatical at the University of West Florida

As note above, I spent the first half of this sabbatical leave as a Fulbright Fellow in Australia. The second half was spent in Pensacola, Florida. Professor Bruce Dunn had completed his PhD studies at Cornell University in Educational Psychology, but as with all students in this program, he never took a course with me. He was familiar with some of my work and thought it would be good if we could collaborate on a project, so he invited me to spend my sabbatical leave at the University of West Florida, where he was a full professor. He also helped to identify support for my work so that I could spend most of a year at UWF. I was also sponsored by the College of Education, in exchange for doing some seminars at the University and some workshops for area schools.

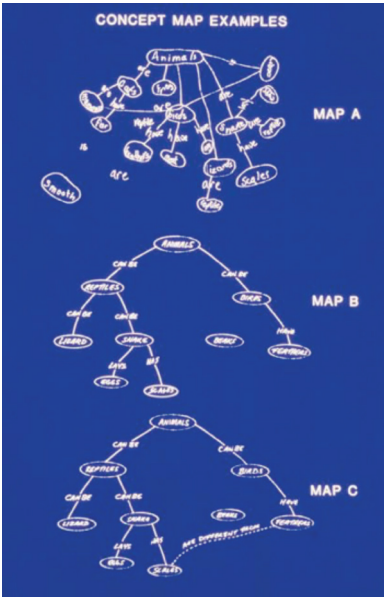
We rented a house on Pensacola Beach, about 20 miles from the UWF campus. At this time I had begun work on a revision of my Theory of Education, but this book was in the early formative stage at this point. I felt the need to better integrate Ausubelian ideas with newer research on brain functions, and I thought working with Professor Dunn would be a good opportunity for this. Bruce had developed a brain research laboratory. We decided to try combining the insights from my work in concept mapping with the work Dunn

was doing on brain imaging, using the Electroencephalographic (EEG) brain imaging equipment he had assembled in his laboratory. Dunn was pushing the edge of this technology at the time and had to assemble his own computers and data storage units to process and store the enormous amount of data produced in these studies.

In EEG studies, a subject is fitted with a special cap that has electrodes distributed around the scalp (see photo on page 123). Wires from these electrodes pass to an amplifier that multiplies the electrical signals many times until they can drive a recorder that captures changes in voltages from each electrode and passes this information to a recorder, much like electrocardiogram (EKG) machines in a doctor's office record signals coming from the heart.

The major problem in EEG studies is interpreting what the various brain signals produced actually represent in terms of brain functioning. Over the years, we had become pretty confident about what subjects were thinking, in some domain of knowledge, by the structure of the concept maps they produced. We thought that if we had subjects do things with concept maps while we recorded their EEG readings, we might get some insights into the relationships in cognitive thinking and brain neurological functions. The way we proceeded is that I trained some 5th grade students in a local school to make concept maps, and then we asked volunteers from these classes to come to Bruce's lab for EE studies. We found almost all student were eager to participate. The photo below shows me teaching students how to build concept maps. These maps were later used during EEG studies in Dunn's lab.

Me teaching 5th grade students how to make concept maps. Their maps were later used in EEG experiments in Dunn's lab



Examples of concept maps produced by children that were used in EEG experiments.

The experiment was to modify the students' concept maps in two ways. First, we removed one or two concepts from a student's map and asked them to think about where they would place these concepts in their map, now projected on a computer screen. This was a rather simple cognitive task, and the students responded rather quickly. Then, using the same students, we selected a concept that was related to those on a student's map, but was not one they had previously included. We asked the student to think where they would add this concept to their map. This was a more difficult cognitive task. In general, it took students longer to identify where and how they would link these concepts into their original map.

A 5th grade student set for recordings of her brain EEG while considers her concept map.

The EEG data showed an enormous difference in the strength of the EEG reading obtained during these two different kinds of tasks, and the strongest signals were coming from a different part of the brain. In short, we were moving toward beginning to link neurological events in the brain with psychological processes. Dunn did present a preliminary report on our work at a Florida conference before his death.

Promising as this work was, Dunn could not continue, due to illness, and then death from cancer. Since I did not have access to this type of equipment, I did not pursue this work at that time. However, currently we are exploring ways to resume those studies. Present day EEG equipment and frequency magnetic resonance imaging (fMRI) equipment is thousands of time more sensitive. Some truly remarkable work might be done. I mentioned some of our planned work in Chapter 14.

Another of my activities at UWF was to present seminars on concept mapping and Ausubelian theory. One of Dunn's close personal friends, Kenneth Ford, had recently completed his PhD on artificial intelligence (AI). Ford was building a research program in the Computer Sciences Department. Ken said that a major problem in the field of AI is to obtain a good record of an expert's knowledge that in turn might be used to program computers. He saw concept maps as a powerful tool for capturing expert knowledge.

Ken had been working with a local cardiologist who was seeking a better way to train physicians in the use of a coronary disease diagnostic machine that he had co-invented. We did several interviews with Dr. Andrews, and drew on information in a book he had published on the use of the technology. The concept map we produced was shown on page 151. Dr. Andrews was impressed with how concisely and clearly our concept maps presented the key ideas that needed to be understood to use his equipment. Ken and Andrews, with help from other staff, used the concept maps to prepare a training program to teach the use of Andrews' technology. They found that even grad students in computer science could be taught to interpret with 90+% accuracy records that Andrews had created from his patients. Thus began a whole series of projects on the capture of expert knowledge in which I collaborated, some of which have been described earlier. I felt my time in Pensacola was not only pleasant, but also highly productive. Joan still misses living on the Gulf, although the home we had rented was destroyed by a hurricane a few years later.

1994-95 Sabbatical at the University of South Florida (USF)

Joan had had open heart surgery in January, 1994. She found walking up and down the hills of Ithaca too taxing, especially in winter. She wondered if it would be possible for me to retire so that we could spend winters in Florida. Given that Procter and Gamble was interested in my helping them to use tools and ideas we had developed to improve proficiency in new product creation, I thought we could manage even if I took retirement from Cornell. Since I was due for a sabbatical leave in 1994-95, we thought this would be a good chance to explore possible retirement in Florida.

Over the years, we had explored various locations in Florida as possible places for our winter home. We had spent a week or so at locations from Stuart, Florida to the Florida Keys, and from Naples to Tampa on the west coast. For various reasons, we had decided the Tampa area might work best for us. I needed access to a good airport for my consulting work, and Joan needed easy access to a good coronary care hospital. We thought it might be wise to explore living in Tampa while I was on leave.

Professor Barbara Spector, Head of Science Education at the University of South Florida (USF), wanted me to spend time helping with her programs. Professor Spector could provide some salary support, so together with half-time salary from Cornell University and some consulting work, we thought we could manage well. I would also have time to work on a new version of my Theory of Education book that I had begun a few years earlier, but had too little sustained time to make good progress with that writing.

We rented an apartment on a small lake in Tampa, about 10 miles from the USF campus. The sabbatical I planned at USF would not offer the kind of professional learning opportunities I had experienced with other sabbaticals, but given our primary interest in a place that would be best for Joan's medical care, and would allow for easy air travel to Procter and Gamble in Cincinnati, the arrangements we made with the University proved to be most fortunate. As it turned out, Joan had a heart attack in January of 1995. It was fortunate she had quick access to very good coronary care at Tampa General Hospital.

My work with Procter and Gamble, and other consulting work, provided many excellent learning opportunities. I thought the tools and ideas we had developed in our education research programs should be applicable and valuable to corporations, and this indeed proved to be the case. I think I learned as much--or more--in my first year of consulting work than I had learned in

any of my professional activities at other universities. In some ways, this was perhaps my most productive sabbatical leave.

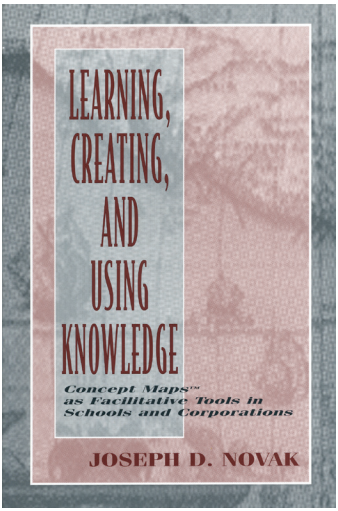
My writing progress was less than I had hoped for, partly due to Joan's health problems, but mostly due to the increased demands for my consulting services. In addition to work with Procter and Gamble, I was doing a variety of other consulting work via my recently formed company, Joseph D. Novak Knowledge Consultants, Inc. The work I was doing with the Florida Institute for Human and Machine Cognition included projects with NASA, National Security Administration, Department of Navy, and other organizations. In every one of these projects I was learning new things about how concept maps and our ideas could be utilized to help organizations learn more effectively.

Our academic year in Tampa convinced us that we wanted to spend winters in this area. We had visited various locations around Tampa on weekends and found that our favorite places were in the area of Tarpon Springs. There were many recreational opportunities in the area, excellent parks and beaches within a few miles, and a small town atmosphere with the amenities of a big city. The UWF library was more than adequate for my needs, especially with inter-library loan resources

We found a very nice condo complex in Tarpon Springs and made arrangements for renting a unit beginning in January of 1996. As it turned out, Joan was so happy with our condo in Lake Tarpon Sail and Tennis Club that we bought the condo we had rented for only a month, and this has proved to be a happy solution for a winter residence in Florida. We sold our home in Ithaca in August of 1998 and moved our summer residence to a condo in Taunton, Massachusetts, close to the home of our daughter and son-in-law and their two children.

The courtyard of our condo complex showing the heated pool surrounded on three sides by condo buildings. Our unit is an end unit on the third floor and faced Lake Tarpon.

While on leave in Tampa, I completed about half the chapters of a book that would update and expand my 1977 *A Theory of Education*. With so many consulting commitments in the next few years, the book was not completed until 1997. It was published by Taylor and Francis in 1998 as *Learning, Creating, and Using Knowledge, Concept Maps as Facilitative Tools in Schools and Corporations*. Spanish, Portuguese, Italian and Finnish translations were published later.



Published in 1998, this book updated and expanded my 1977 book, A Theory of Education, and also included extensive examples of application to corporations.

Following our move to Florida as our winter home and Taunton, Massachusetts as our summer home, many happy events occurred. Joan and I had time to do much international travel, including trips to accept Honorary Doctorates and other awards. I did some exciting consulting work with the Florida Institute for Human and Machine Cognition. Our granddaughter, Rachel, was married to Christopher Durocher in May, 2008. Rachel and Chris gave us our first great granddaughter, Noelle, in May, 2014, and our son Bill married his partner Mark in May of 2015.

We continued our summer residence in Taunton until 2010. Our grandchildren had moved out on their own, and our daughter and son-in-law had purchased a summer home in Maine. Given our continuing concerns about good coronary care, we decided to move our summer residence to the town of Highland Heights in the Cleveland area. Joan had had open-heart surgery at Cleveland Clinic in January, 1994. The Clinic is continuously ranked number one in the world for coronary care. Our oldest son, Joe, and his wife

Elizabeth lived 15 minutes away, and our younger son, Bill, lived two hours away in Columbus, Ohio. It was nice to have family nearby.

By 2016, we were finding the move back and forth to Florida to be just too difficult. Moreover, maintaining two residences was not only challenging at times, but also relatively expensive. It was clear that we could not continue the routine of moving twice a year and we had to choose between Ohio and Florida. We decided we would prefer warm or even hot weather to cold, snowy weather. Moreover, son Joe's wife Elizabeth decided to retire in 2016, and they planned to sped several months each winter in Sarasota Florida, about a 1 ½ hour drive from our Florida condo. Our daughter, Barbara, and her husband Bill had purchased a large winter home in Lake Placid. FL, about a 3-4 hour drive from Tarpon Springs. Making Florida our year-round residence just made more sense. So far we are very pleased with this decision. We are spending more quality time with our children that we were when we were commuting back and forth. When Joan was hospitalized in November and December of 2016, Barb came over twice to provide support and her husband also visited with us. For the first time in years, we had all of our children together for a great Christmas dinner and holiday visit!

Appendix 3

Designing Instruction to Enhance Learning Introduction to Botany

In order to conduct the PhD study I planned, I needed to design an Introduction to Botany course that would present the same materials as the standard Introduction to Botany taught to 16 laboratory sections in the regular Department of Botany course. All sections would take the same written and laboratory tests. However, in the Winter quarter. my Experimental class would complete instruction on these topics in 12 weeks instead of the usual 18 weeks, allowing 6 weeks for work in individual research projects. This meant that somehow I had to make the presentation more efficient for learning.

To make learning more efficient, I planned all of the lectures to center clearly on the key concepts to be learned on a given topic, as well as illustrative materials that would enhance understanding of these concepts. For the laboratory work, I chose to prepare a study guide that would use labeled photomicrographs of plant structures studied in the laboratory, and more explicit guidance in other laboratory work with a strong emphasis on the pertinent concepts illustrated in the work.

These challenging tasks occupied much of the summer of 1956, with many late evening hours spent in the Botany Department's photography laboratory preparing labeled photomicrographs of plant structures and other materials. This work considerably enhanced my photographic skills. The completed new laboratory manual was included as an appendix in my PhD thesis. Other details relevant to this study were presented in Chapter 4.

In addition to the use of labeled photos and drawings of plant structures, I introduced the students to examples of research studies that dealt with some of the botanical concepts we were studying, such as the effect of several nutrient additions on final dry weight of plants. These studies were chosen because they were similar to research projects the students might use in the 6-week research study they were asked to do instead of attending standard lecture and laboratory sessions.

As students began to formulate their projects, we discussed plans in class time, helping to improve the students' work much as might occur in weekly meetings in actual research groups headed by a scientist or team of scientists. All students in the experimental section of the course were successful in de-

signing and conducting their individual research projects. Most presented oral reports on their research and all prepared written final reports. In general, the students were pleased with this kind of work and were very positive in their summary comments. While the six-week project work did not significantly increase these students' performance on the problem solving test I had devised, it became clear in our subsequent research that such a change was far too much to expect from a single research experience of this type.

Methods and Materials for Teaching Biology

I first organized this course in the Biology Department at Kansas State Teachers College in 1958. My approach was to review each of the key ideas of biology, such as cells, genes, and evolution, presenting ideas on how to better teach these ideas. In addition I required each student to build a resource file for each of these topics, drawing on many free materials available from biological supply houses and other groups.

For some students, this approach helped them to understand that just memorizing information on various topics of biology was not sufficient to be an effective teacher, and some came to realize how poorly they had been prepared for understanding the major concepts of biology.

Preparing the resource file also helped them learn where they could get much material to augment their teaching. We also built a plant growing chamber on one side of the classroom. The chamber allowed students access to fresh plant materials for observation and experimentation, a facility that could be duplicated in most school biology laboratories. The course was well received by undergraduate prospective teachers, and by experienced teachers who took the course in our National Science Foundation-supported summer programs for high school biology teachers. It was also a way for me to keep up on my on my own mastery of biology ideas.

When I moved to Purdue University in 1959, my principal assignment was to prepare high school biology teachers. One of the requirements for certification in Indiana was a "methods" course, often taught with little more than lectures. I presented essentially the same Methods and Materials course I had developed in Kansas. The course also served to review major ideas of biology and became the cornerstone for our biology teacher education program. Further information on this program was presented in Chapter 5.

My experience in teaching this course led to the preparation and publication of a book I had planned to use in this course, *The Improvement of Biology*

Teaching. However, by the time the book was published in 1970, I had moved to Cornell University, and I no longer taught a science teaching methods course.

Theory and Methods of Education

When I moved to Cornell University in 1967, my primary responsibility was to build an internationally recognized research program in science education. Since I was building a research program based on the cognitive psychology of David Ausubel, and since no courses at Cornell presented this work, a good portion of the course dealt with understanding and applying Ausubel's theory to improve research and practice in education.

In the first few years, much of the first 6-7 weeks of the course dealt with reading and understanding Ausubel's cognitive learning theory. From 1975 onward, I used at first duplicated copies of my forthcoming, *A Theory of Education.* After its publication in 1977, this was the primary text for the course.

Since there is good evidence that students working in pairs or small groups benefit from such interaction, I took advantage of this in all of my education classes. Given the busy schedules of college students, a group size of two was the only realistic size for relatively extensive interaction.

To facilitate group formation, I asked all students to prepare a 1-2 page biography, and these were shared with all members of the class (this might be prohibited today with all the privacy concerns and laws). Several of the assignments early in the semester asked students to work as a team. In general, students responded very positively to this work, and in fact I later learned that several of these "learning partners" got married!

Another assignment I found very helpful was to require students to interview 10 people of their choosing on any topic they chose to use. During the course, I had volunteer students present preliminary findings from their study. Comments on these findings helped both the presenting students and other class members. A final written report on this work was required, including quotations which illustrated concepts and principles presented in the course. This assignment required a substantial time commitment, and therefore was 50% of their course grade.

After we invented the concept mapping tool in the early 1970's (see Chapter 10), I required students to prepare a concept map while planning their interview, and then to prepare a concept map showing the concepts and relationships identified for each interviewee. My colleague, D. Bob Gowin,

invented the Vee heuristic in 1977. This learning tool helps students understand the structure of knowledge and the process of knowledge creation. Equipped with powerful principles from Ausubel's learning theory, the interview worked both to illustrate these principles in operation, and to give the students a deeper understanding of theoretical ideas. In general, the students' response to the course was highly positive.

Most students went on to employ the ideas and tools they had learned in the course in their Masters or PhD research. Some of my colleagues thought the course "indoctrinated" the students in my way of thinking about education, teaching and learning, and they never permitted their students to take a course with me. "Academic politics" was clearly manifest in these actions, and after a time, I just accepted the situation as endemic in academe. The power and universality of the ideas and tools presented in this course was later illustrated in the consulting work I did with corporations and other organizations, described earlier in this book.

As discussed in other sections, (see chapter 11), I had, over the years, numerous visiting professors join my classes and my research group. Many of these went on to publish works that included references to the ideas and tools presented in my "Theory" course.

Learning How to Learn

As we began to apply Ausubelian learning principles and the concept mapping tool in more and more diverse educational situations, it became obvious to me that introducing these tools and ideas to undergraduate students would help them become better learners. I first tried to introduce these ideas to freshman and sophomore students at Cornell University in the summer of 1977.To my surprise, there was little interest in such a course among these students. However, when I offered the course in the spring of 1978, many junior and senior students signed up for the course, and they were enthusiastic.

In subsequent reflection, I saw that differences in student maturity was a factor. I saw that junior and senior students' responses to the course became more positive, and this was more evident as I continued the offering. Cornell students are among the highest achievers in their high schools, and rank very high on SAT scores. Most of these students had become very proficient in memorizing information and doing the typical true-false and multiple choice questions common in high school classes and large freshman and sophomore courses. However, in a great university such as Cornell, most professors expect some "higher level" thinking in junior or senior courses. These formerly

straight A students began receiving C's and D's. These were the students who found my course life altering, and most progressed to high levels of achievement in all of their courses.

At first I was surprised to hear from these students that prior to enrolling in "Learning How to Learn," they never knew there was a better way to learn than just memorizing information. This is a sad but very real situation that is taking place in American schools, and indeed in many schools in most countries. With the advent of extensive testing that became common after the "No Child Left Behind" programs in the 2000's, many thoughtful educators saw the folly in these programs, including Diane Ravitch, who had led that effort under President George W. Bush. See her book: *The Death and Life of the Great American School System: How Testing and Choice Undermine Education* (2010).

Other Courses That I Taught

As a graduate student, I worked as a teaching assistant in general biology, botany, and plant physiology. I also taught evolution, plant anatomy, and general biology at Kansas State Teachers College, Emporia. However, these courses used standard textbooks and varied from similar courses primarily in my efforts always to highlight the key ideas that needed to be understood for any given topic.

Appendix 4

My Students

My first experiences teaching undergraduate students was in the Botany Department at the University of Minnesota in 1952. From the beginning, I enjoyed teaching students about plants and looked for ways to make the subject interesting to my students. I also sought ways to help them understand the key ideas of botany, since I had found this to be important in my own studies.

On the whole, the students were receptive and appreciative of my efforts, more so than the junior high school and high school students I taught the previous year in my intern teaching program. Moreover, I found teaching botany was a great way to enhance my own understanding of the subject. I also observed more carefully the teaching I received in graduate botany courses as I continued graduate studies. I particularly admired the teaching of Professor Ernst Abbe who used Socratic discussions in his teaching rather than ordinary lectures.

Working as a teaching assistant in plant physiology in my second year and beyond, I was impressed with how little knowledge from first year botany students could use to understand plant physiology. These experiences led me to question the effectiveness of traditional laboratory and lecture methods of teaching science, and formed the framework for planning my PhD research, presented earlier. Leading discussion sections in plant physiology was at first challenging, but here again I found that placing emphasis on key concepts was a good way to help students understand the subject.

A few of my students became very motivated to learn more about plants, and I learned later that my teaching was a principal reason they chose to major in botany. I saw that putting extra effort into teaching paid positive dividends both to my students and to me. In my last year of graduate work I was promoted to Instructor in the Botany Department and placed in charge of coordinating all of the first year botany laboratory sections. Since my PhD major was in Science Education, not Botany, I thought this appointment affirmed my qualifications as a botanist!

In my first position at Kansas State Teachers College, I taught general biology, evolution, plant anatomy, and a course called Methods and Materials for Teaching Biology. In the latter course I placed a heavy emphasis on learning how to gather materials from various sources and to fashion instruction

that emphasized hands-on activities appropriate for high school students. The course was well received and became the model for a course for biology teachers when I began work at Purdue University in 1959.

The Biology Department at Purdue University provided all the facilities I needed to teach a course that would mirror the kind of teaching I thought my students should do when they had their own classrooms. I also emphasized building instruction around a few major concepts of biology, such as evolution and the nature of genes and gene action. The latter became easier as the Biology Department revamped its undergraduate curriculum, in which all courses placed emphasis on basic concepts, not the memorization of endless facts. I served as co-chairman of the committee that organized the new Biology Department curriculum. I saw many of the things I was teaching implemented in the practice teaching my students did in their final undergraduate semester.

A major part of my work at Purdue University was to improve the program for prospective biology teachers, including locating better intern teaching experiences with better supervising teachers. Finding really well qualified teachers in the public schools was a great challenge. After two years at Cornell, I introduced a National Science Foundation funded in-service biology training program for teachers at the five University extension campuses. The semester-long courses were offered on Saturday mornings for 3 semester hours of graduate credit in biology. Teachers could apply these courses toward an MS degree in biology at Purdue University. The program not only improved the biological knowledge of teachers in Indiana, but also provided an excellent pool of supervising teachers for our teaching interns. The success of the program was reflected not only in the positive comments from students in the program, but also in the rapidly increasing enrollments in our Biology Teacher Education Program. A few students who prepared for teaching in this program still keep in touch with me.

When I moved to Cornell University in 1967, my primary responsibility was to develop a world class science education research program. Thus most of my work was with graduate students. However, I saw the need to help undergraduate students become better learners. With the new insights we were developing in our research program, it seemed imperative to try implementing some of what we were learning into a course to help undergraduate students become better learners.

I developed a course first called School Learning, and then Learning How to Learn. This course was described in a previous section. A book by this title

came out of my experiences teaching this course in 1984, and I continued teaching this course one semester each year until I retired in 1995. Many of my students were grateful to learn that memorization was not the best way to build an understanding of any subject that meaningful learning was more successful, and transformed the way they viewed their future learning. Many students who took this course spoke about how the course transformed their lives and gave them new confidence in their ability to succeed in any thing they pursued. On three separate occasions my students recommended me for the President's program to recognize faculty who had the most positive influence on their undergraduate education, as presented in Appendix 1.

In all of my work with undergraduate students, I felt I learned much from my students, and with few exceptions, my experiences were both pleasant and rewarding. However, at both Purdue University and Cornell University my primary responsibility was to prepare PhD students who would become tomorrow's leaders in education, so there was always some frustration in trying to find enough time to do everything well.

Work with Graduate Students

When I began work as an Assistant Professor of Biology at Kansas State Teachers College in 1957, a major part of my work was with teachers working toward a master's degree in biology teaching. Most of the people were considerably older than I, and some had 20 or more years experience in high school teaching. We often visited teachers from our summer programs in their home schools during the academic year. This enabled us to see the real world conditions these teachers were dealing with, many of them working in small rural schools with little equipment and few other resources. It was a lesson in what teaching conditions were in most rural Kansas school. I marveled that students from these schools could compete in college. Many of the teachers in our summer programs eventually earned a master's degree in biology teaching. No thesis work was required for this degree.

There were also other students pursuing an MS degree with a thesis in biology or biology teaching. I began counseling these students and supervising their research. In the short 2 years at Emporia, 4 or 5 students completed the MS degree under my supervision. One of these students, Darrel Murray, moved with me to Purdue University in 1959. We had a close relationship, and Darrel often spent time with me in my office during the evenings. He was as interested as I was in finding better theoretical foundations for research in education, and we had a number of conversations about the need for a better theory. We were both delighted in 1963 to discover David Ausubel's

book, *The Psychology of Meaningful Verbal Learning.* As noted earlier, this was a turning point in my research program, and Ausubel's work remains today an important part of my efforts to improve education.

In the 1980's we began to see a shift in educational psychology toward cognitive psychologies and away from behavioral psychologies, but we still see Ausubel's work, especially with the modifications I introduced, as more comprehensive and also more concise. I had several other very good graduate students during my tenure at Purdue University. They were very helpful to me in advancing our research program with better theoretical foundations.

Some of my graduate students, especially Lou Giantris, helped me begin the audio-tutorial elementary science program with area elementary schools. By the end of my tenure at Purdue University, I had supervised a half dozen PhD students and felt that we were beginning to build a really serious research group. This beginning was part of my motivation to leave Purdue University, where I had so many things competing for my time. The move to Cornell University in 1967 gave me the time and support I needed to build a world-class science education research program.

When I began work at Cornell University, there were already several graduate students seeking faculty sponsorship. Almost from day one I was working with a dozen or so MS and PhD students. I was impressed with the abilities of the students at Cornell, both in their classroom studies and in their projects.

Several students began helping with the audio-tutorial elementary science program that was carried over from Purdue University. With excellent support and cooperation from Ithaca Schools, we obtained US Office of Education funding to expand our work to include all 13 elementary schools in Ithaca. Lou Giantris joined the project and continued coordinating some of our work. At this point, about a dozen graduate students were working with me on the Audio-tutorial project, and several others were working on other research projects.

Unfortunately, a junior colleague committed suicide in 1968. Most of his students chose to join my research program. At this point I was supervising the work of 31 graduate students, and there just was not enough time to provide the quality of supervision I wanted. These problems were exacerbated when our research building was taken over by minority students, and we struggled to find adequate work space. The late 1960's were pretty tumultuous at Cornell, more so than on most university campuses. I discussed some of these problems earlier in this book.

Pichas Tamir was one of the first graduate students I worked with at Cornell University. He was working on his PhD thesis under Professor Verne Rockcastle, and found Ausubel's learning theory helpful in explaining his data. We had many interactions over the years.

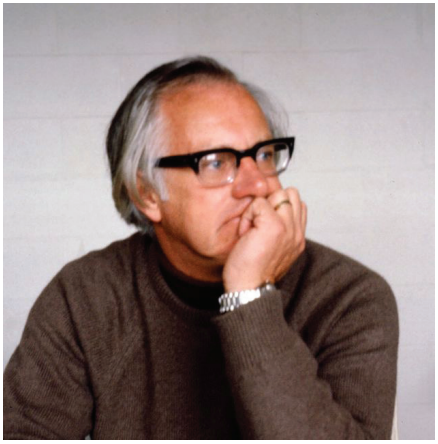
In spite of the turbulence in the late 1960's, our research projects progressed well, and there was excellent *esprit de corps* in our group. This was enhanced by frequent informal "parties," including occasional swim parties and cookouts at our home. We also had several "apple fests" at the home of my students, Marybeth and Michael Hibbard, who had rented a farmhouse with many apple trees. We made applesauce and apple pies and ate these as part of our festivities.

Although research space was always at a premium and I was always looking for better options, we always had our own office space and workspace for most of my students, and work and storage space for projects. This is very rare for graduate students in education. In addition, I always had at least one or two visiting professors from universities in the USA, and from a dozen other countries. Many of these professors were nearly the same age as my graduate students, and many close relationships were formed.

With visiting professors from other countries, both my graduate students and I gained insights into other cultures, as well as into other research programs. Some visitors returned more than once. Leo West and his family spent sabbatical leaves with us three times. Joseph Nussbaum and Marco Moriera returned with their families twice for academic year leaves. Finding housing for visiting professors was always a challenge. For two years I was fortunate to arrange for the use of a large two-story house owned by the University and scheduled for demolition at a later date. This proved to be a great place for three visiting professors one year. Joan and I enjoyed delicious Indian meals prepared by one of these professors, Protima Roy.

Marco Moreira first joined me as a Visiting Professor from Brazil. He and his family came to Cornell on three separate year-long visits. Both Marco and his wife Marli completed PhD studies with me. Here he is introducing me at a conference in Maragogi, Brazil in 2003.

Yossi Nussbaum completed his PhD in 1972, but he, his wife Hanna, and their family returned to Ithaca on two sabbatical leaves. We still exchange correspondence regularly.



Peter Fensham of Monash University in Melbourne, Australia was one of my first visiting professors. Later several of his students and colleagues visited us.

Another visiting professor, James Wandersee, came with his family to spend summers with me at Cornell. I assisted him when he applied for a position at Louisiana State University, where he worked until his death. We subsequently coauthored several books and papers, and I often suggested him when I had a lecture invitation I could not accept. Joan and I were saddened when Jim died of cancer in 2014 at age 67.

Jim Wandersee was a frequent visitor with our program, and an able coauthor for a number of books and papers. He always had a big smile on his face!

Joan with visiting Professors Elizabeth Haggerty from the University of New South Wales, Australia, and Protima Roy from Drury University, St Louis, MO. They shared a rental house near the Cornell University campus.

One of my visiting professors, Vitor Teadoro, Universidade Nova de Lisboa, Portugal, was an Olympic sailor. When we went to Tauganak Park one Sunday, he was disappointed to learn they were not renting Sunfish boats due to high winds. A 15 or 16 year-old boy had beached his Sunfish boat near where we were picnicking. Vitor asked if he could rent it, but the boy refused. He did agree to let Vitor sail if he went along for the ride. And what a ride the boy had! With the high winds the boat was often tilted near capsizing, and whizzed across Cayuga Lake. When they returned, the boy was a bit pale, and commented: WOW, I hope I can sail like that someday!

Prof Vitor Teodoro, outstanding Portuguese educator and world class sailor.

Over the years it has been a pleasure to observe the accomplishments of the more than 350 graduate students and visiting professors who studied with me. Many of these continue to correspond with me. At least once or twice a year I get an e-mail from one of these people, sometimes the first communication in many years.

For example, this past year I was contacted by Nagalingam Ethirveerasingam, a PhD graduate in Agricultural Education, who was in charge of arranging an international conference to guide the revamping of education in Sri Lanka, his home country. Although I had stopped international travel by then, I helped Ethir identify and recruit some outstanding educational leaders who took part in the planning conference. Hopefully the conference will contribute to better education for the people of Sri Lanka, a country of 20 million.

Another student I had lost touch with, Sharon Levy, is now doing private tutoring in Cape Town, South Africa. She contacted me to say she found my latest book helpful. She is applying tools and ideas she learned when studying with me, including more recent materials and tools from our research program discussed in my latest book. Her careful observation on the learning of her tutees is serving as a great testing ground for this work. The above examples and hundreds of others lead me to believe that what I have been trying to do for some 60 years has indeed had a positive impact on the lives of many people.

Appendix 5

Other Honors, Recognitions, and Awards

1955-56 Received my first award as a graduate student at the University of Minnesota. It was a $500 award, the Tozer Foundation Fellow Award. Although this was a small cash award, the money paid for much of the photographic materials I used to prepare the study guide for the experimental group in my PhD research. It also covered some of the costs of duplicating materials needed in my thesis research. More importantly, it recognized the value of the research work I was doing, and this no doubt benefited me for competitive job positions in the future.

1964-68 Secretary, National Association for Research in Science Teaching. Founded in 1934, NARST is the oldest science teaching organization, and also the most important leader in science education research. Due to poor management, NARST had almost no reserve funds when I took over as secretary. I improved communications to members, introduced Associate Member status for anyone interested in science education research, assisted in negotiations with John Wiley Publishers for the new *Journal of Research in Science Teaching,* and helped to quadruple the membership. As the person responsible for planning annual meetings, I helped to shape the future direction of science education research toward greater emphasis on theory-based research and better use of statistics.

1965 Elected President, Association of Midwestern College Biology Teachers. This is an organization that I helped to get started in 1958. I also arranged for an annual meeting to be held at Purdue University in 1964.

1969 Elected President of the National Association for Research in Science Teaching. Program planning and liaison with other organizations. I continued my efforts to encourage the development of better theoretical foundations for science education research.

1980-81 Awarded Fulbright Fellowship to lecture at Monash University and other universities in Australia.

1984-88 Secretary, Section Q (Education), American Association for the Advancement of Science. Responsible for annual meeting program plans, nomination of new officers, and representing Section Q at AAAS Board meetings. Elected as Fellow of AAAS in 1985.

1987 Outstanding Research Report, the highest recognition by the National Association For Research in Science Teaching. Recognized for outstanding research in Science Education.

1987-91 Board of Directors, Biological Sciences Curriculum Studies. Pushed for more use of metacognitive tools in books published by BSCS.

1987-82 Board of Directors, Longitudinal Study of American Youth.

1**989** Elected Chairman of Section Q of AAAS. Responsible for program planning and liaison with AAAS Advisory Board.

1990 Distinguished Contributions to Science Education Though Research Award. This is the highest award given once per year by the National Association for Research in Science Teaching.

1991 Ohaus Award for Outstanding Contribution to High School Science. National Science Teachers Association gives one per year.

1992 Listed in *Who's Who in the World, Who's Who in American Education, Who's Who in Medicine and Health Care, Who's Who in Science and Engineering*. Other listings are provided later in this appendix.

1993 Honorary Recognition dinner and conference. Several of my former graduate students organized an International Conference on Misconceptions and Educational Strategies in Science and Mathematics. This was the fifth such conference held at Cornell University, each drawing some 15 0 to 250 scholars from around the world. Some 150 scholars attended the conference and the dinner was a ceremony honoring my work in Science and Mathematics Education. To my surprise, some $22,00 was contributed in my honor for what became a scholarship fund to help support the research of graduate students and junior faculty working in the field of education. Kathy Edmondson and Robert Abrams, former PhD students, played a major role in organizing the Conference and the Novak Scholarship Fund. Abram's photo was shown on page 121.

Kathy Edmondson

1993-95 National Election Committee, American Association for Advancement of Science. Nominated candidates for officers of AAAS.

1995 Honorary Member, National Association of Biology Teachers. This is the highest award offered by NABT and carries with it lifetime membership in NABT.

1997-98 Distinguished Visiting Faculty Fellow, Schreyer Honors College, Penn State University. Gave lectures and did workshops on improving college teaching.

1998 First award of the Council of Scientific Society Presidents for Outstanding research Contributions to Science Education.

1998 Honorary Citizen of Buenos Aires, March 23. This award was given by City officials in recognition of contributions made to the improvement of science teaching.

1999-2002 National Academy of Sciences Committee for Mathematics and Sciences. Made recommendations for modernizing content and structure of Advance Placement Exams for college credit from high school courses.

2004-2009 Cold Springs Harbor Laboratory Advisory Board. Urged use of concept maps for curriculum design and instruction. See in Appendix 1.

2008- Recognition ceremony at March 27, 2008 National Science Teacher's Association Meetings. Recognized for contributions to Harvard Smithsonian Institute Private Universe Project.

2017- Who's Who – Lifetime Achievement Inductee Representing Outstanding Professional Dedication and Career Longevity

1992-2017 Other listings in Who's Who Publications:

Your biography has been published in the following books.
Who's Who in American Education - 7th Edition, 2005
Who's Who in American Education - 8th Edition, 2007
Who's Who in Medicine and Healthcare - 4th Edition, 2002
Who's Who in Medicine and Healthcare - 6th Edition, 2006
Who's Who in Science and Engineering - 7th Edition, 2003
Who's Who in Science and Engineering - 9th Edition, 2006
Who's Who in Science and Engineering - 10th Edition, 2007
Who's Who in Science and Engineering - 11th Edition, 2010
Who's Who in America - 53rd Edition, 1998
Who's Who in America - 54th Edition, 1999
Who's Who in America - 55th Edition, 2000
Who's Who in America - 56th Edition, 2001
Who's Who in America - 57th Edition, 2002
Who's Who in America - 58th Edition, 2003
Who's Who in America - 59th Edition, 2004
Who's Who in America - 60th Edition, 2005
Who's Who in America - 61st Edition, 2006
Who's Who in America - 62nd Edition, 2007
Who's Who in America - 63rd Edition, 2008
Who's Who in the East - 24th Edition, 1992
Who's Who in the East - 29th Edition, 2001
Who's Who in the East - 30th Edition, 2002
Who's Who in the East - 31st Edition, 2003
Who's Who in the East - 32nd Edition, 2004
Who's Who in the East - 33rd Edition, 2005
Who's Who in the East - 34th Edition, 2006
Who's Who in the East - 35th Edition, 2007
Who's Who in the East - 37th Edition, 2009
Who's Who in the World - 23rd Edition, 2005
Who's Who in the World - 24th Edition, 2006
Who's Who in the World - 25th Edition, 2007

Appendix 6

My Publications

Journal Articles (Chronological order)

l. Novak, Joseph D. 1955. Trends in science courses. Proceedings of the Minnesota Academy of Science 23:88-93.

2. _____. 1958. An experimental comparison of a conventional and a project centered method of teaching a college general botany course. Journal of Experimental Education 26(March): 217-230.

3. _____, & Merle E. Brooks. 1959. College preparation of science teachers. The Science Teacher 26(7):473-477.

4. Breukelman, John, Ted F. Andrews, & Joseph D. Novak. 1959. A study of problems involved in teaching large classes in college general biology. Transactions of the Kansas Academy of Science 62(4):245-251.

5. Novak, Joseph D. 1960. Sultana--an excellent classroom plant. The American Biology Teacher 22(4):204-205.

6. _____. 1961. The use of photomicrographs in teaching college general botany. Science Education 45(2):119-122.

7. _____. 1961. An approach to the interpretation and measurement of problem solving ability. Science Education 45(2):122-131.

8. _____. 1961. Science in the junior high school. School Science and Mathematics 61(9):701-706.

9. _____. 1961. Fundamentals of plant physiology (a critical book review). The American Biology Teacher 23(8):526-527.

10. _____. 1962. Biological education in American secondary schools (a critical book review). The American Biology Teacher 24(1):62.

11. _____. 1963. A preliminary statement on research in science education. Journal of Research in Science Teaching 1(1):3-9.

12. _____. 1963. What should we teach in biology? NABT News and Views 7(2): l, July. Reprinted in Journal of Research in Science Teaching 1(3):241-243.

13. _____. 1964. Importance of conceptual schemes for science teaching. The Science Teacher 31(6):10.

14. _____. 1965. A model for the interpretation and analysis of concept formation. Journal of Research in Science Teaching Vol. 3:72-83.

15. _____. 1965. Secondary school science teacher education at Purdue University. Journal of Research in Science Education Vol. 3:147-152.

16. _____. 1966. The advance of science education. Education 87:223-227, December.

17. Postlethwait, S. N., & Joseph D. Novak. 1967. The use of loop films in individualized instruction. Annals of the New York Academy of Science 142:464-470.

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20. Novak, Joseph D. 1970. Relevant research on audio-tutorial methods. School Science and Mathematics 70(9):777-784.

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23. Novak, Joseph D., Donald G. Ring, & Pinchas Tamir. 1971. Interpretation of research findings in terms of Ausubel's theory and implications for science education. Science Education 55(4):438-526.

24. Ring, Donald G., & Joseph D. Novak. 1971. The effects of cognitive structure variables on achievement in college chemistry. Journal of Research in Science Teaching 8(4):325-333.

25. Kuhn, David J., & Joseph D. Novak. 1971. A study of cognitive subsumption in the life sciences. Science Education 55(3):309-320.

26. Novak, Joseph D. 1972. Facilities for secondary school science teaching. The Science Teacher 39(3):2-13.

27. _____. 1973. Evolving patterns in secondary school science facilities. The American Biology Teacher 35(6):319-321.

28. Gubrud, Allan R., & Joseph D. Novak. 1973. Learning achievement and the efficiency of learning the concept of vector addition at three different grade levels. Science Education 57(2):179-191.

29. Thorsland, Martin N., & Joseph D. Novak. 1974. The identification and significance of intuitive and analytic problem solving approaches among college physics students. Science Education 58(2):245-265.

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

31. Novak, Joseph D. 1976. Understanding the learning process and effectiveness of teaching methods in the classroom, laboratory, and field. Science Education 60(4):493-512. Reprinted in Spanish in Perfiles Educativos, Numero 1, Julio-Agosto-Septiembre, 1978.

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35. _____. 1976. Editorial Comment on A review of Piagetian studies relevant to science instruction at the secondary and college level. Science Education 60(1):251.

36. _____. 1976. Editorial Comment on An analysis of an alternative instructional model for disadvantaged students and an analysis of learner efficiency when individualized and group-instructional formats are utilized with disadvantaged students. Science Education 60(2):235.

37. Nussbaum, Joseph, & Joseph D. Novak. 1976. An assessment of children's concepts of the earth utilizing structured interviews. Science Education 60(4):535-550.

38. Novak, Joseph D. 1977. Epicycles and the homocentric earth: Or what is wrong with stages of cognitive development? Science Education 61(3):393-395.

39. _____. 1977. An alternative to Piagetian psychology for science and mathematics education. Science Education 61(4):453-477.

40. _____. 1978. Editorial Comment on Studies reported in the learning section. Science Education 62(2):267.

41. _____. 1978. Editorial Comment on Teaching about floating and sinking: Further studies toward closing the gap between cognitive psychology and classroom practices. Science Education 62(4):573-574.

42. _____. 1978. A book review of `Schools of Thought'. Journal of Education 160(2):83-85.

43. _____. 1978. Editorial Comment on Implications of Piagetian research for high school science teachings: A review of the literature. Science Education 62(4):591-592.

44. _____. 1979. The reception learning paradigm. Journal of Research in Science Teaching 16(6):481-488.

45. _____. 1979. Applying psychology and philosophy to the improvement of laboratory teaching. The American Biology Teacher 41(8):466-474.

46. _____. 1979. Meaningful reception learning as a basis for rational thinking. In Anton E. Lawson (ed.), The Psychology of Teaching for Thinking and Creativity (pp. 192-225). Columbus: Ohio State University, ERIC Clearinghouse for Science, Mathematics& Environmental Education.

47. _____. 1979. Comment on Graham W. F. Orpwood's review of A Theory of Education. The Review of Education 5(3):267-269.

48. _____. 1979. Editorial Comment on Development of earth and gravity concepts among Nepali children. Science Education 63(5):719-720.

49. _____. 1979. Editorial Comment on Can Ausubel's theory of meaningful learning become an alternative to Piagetian psychology? Science Education 63(2):271-273.

50. _____. 1980. Progress in application of learning theory. Theory Into Practice 19(1):58-65.

51. _____. 1980. Learning theory applied to the biology classroom. American Biology Teacher 42(5):280-285.

52. _____. 1980. Teaching chemistry in the 1980's: Some suggestions from learning theory and epistemology. Swedish National Board of Universities and Colleges and the Coordinating Committee for Training University Teachers Handbook. January.

53. _____. 1981. Applying learning psychology and philosophy of science to biology teaching. The American Biology Teacher 43(1):12-20.

54. _____. 1981. Effective science instruction: The achievement of shared meaning. The Australian Science Teachers Journal 27(1):5-13.

55. _____. 1982. Aplicacao dos recentes avancos na teoria da aprendizagem e na filosofia da ciencia ao ensino da quimica. Textos Blocoensino, boletim Sociedada Portuguesa de Quimica Ano 4-Serie 11(10):3-9.

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