Knowledge Networks and Classroom Practice: How students can organize their new knowledge

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Abstract

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1. INTRODUCTION

A well established tenet of cognitive science is that experts organize their knowledge differently from novices. This was demonstrated in the early work of deGroot comparing the ease with which expert chess players could recognize and remember the configuration of pieces in midgame more easily than less experienced players (deGroot, 1965). Subsequent studies of experts in different fields are described in (Bransford, 2000, p 33). In large measure, successful teaching causes a transformation in students from novice to expert. At the beginning of the school year a student enters the classroom as a "novice" 3rd grader and is expected to leave it at the end of the year as an expert 3rd grader prepared to begin the next year as a novice 4th grader. So what is involved in this transformation? Certainly it involves the acquisition of knowledge, but more than that the knowledge must be organized into a conceptual framework that allows it to be easily transferred to new and different situations. We want our rising 4th graders to have a level of expertise that allows them to use their knowledge in situations different from the those in which it was learned.

The U. S. National Academy of Sciences commissioned a survey of recent research on the brain and its operation. The focus of this study was how this new knowledge of the brain's function can be used by educators. A report on the findings of this survey called "How People Learn" was published in 2000 (Bransford, 2000) and it describes an emerging understanding that effective learning requires an individual's introspection – a metacognition. One focus of this metacognition is on the organization of newly acquired knowledge. One of the three principle findings of this report encourages teachers to help their students

> "... (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in a context of a conceptual framework, and (c) organize their knowledge in ways that facilitate retrieval and application"

This implies that each learner must make a conscious effort to organize the information learned so that information becomes flexible enough to use in new or different circumstances. Without this organization, knowledge remains isolated and inert. Absent effort by students to consciously organize the information they are learning it becomes "... episodic rote learning and memorization." (Costa XXXX)

Organization of knowledge beyond the most basic levels is not an innate characteristic of humans; it must be learned. Some students may develop skills at organizing their knowledge in an unsystematic manner but by using our recent understanding of how people learn this process can be more effective and extended to all students. Teachers who can help their students with this organization will increase the efficiency of their learning and thinking.

Teachers have the knowledge they expect to transmit to their students embedded within their own conceptual framework -- their own personal mental construct. They can impart the knowledge they have but they cannot transfer the construct in which that knowledge resides. A mental construct is personal and depends on experience, the state of ones' mind when the knowledge was acquired and each time that knowledge was used. So how can we help our students find a construct? The purpose of this paper is to shed some light on this question by proposing a model for knowledge organization based on recent results in network science. This model will provide a generalized setting within which a mental construct can be discussed.

The major difficulty helping students monitor and evaluate their thinking is that each child's mind is accessible only to that child. Science can study an individual's brain, locating where different mental activities are activated, but science cannot delve into an individual's mind (Damasio 2001). Consequently, we cannot determine how knowledge is stored in someone else's mind. It would help if we had some model of the possible ways that a person could organize knowledge in their mind.

The organization of information is an old question. Diderot and d'Alembert had considered how human knowledge can be organized and how that might reflect on the way knowledge is organized in the human brain (Diderot & d'Alembert 1751). The result was a hierarchical structure called the *"Tree of Knowledge"* which has been added to from time to time. It was, in fact, the first encyclopedia. That early work has been revisited recently because it bears on how one might construct a knowledge network using hypertext in Internet sites like Wikipedia (Rockwell 1999). While it is useful to consider that work as an example of a network structure for knowledge external to a human brain, we are striving to understand the network construct within an individual mind.

In this paper we introduce a simple model of the different ways knowledge can be organized in a human's mind. It will illustrate the transformation from expert to novice we seek to effect in students. The model is based on what we have learned recently about the science of networks. While this model lacks the rigor of a fully developed scientific theory it does provide insight into the possible stages of development of the mind as a storehouse of knowledge and can be used to inform teachers of the organizational processes going on in their student's mind.

2. THE EMERGENCE OF NETWORK SCIENCE

A new area of scientific inquiry blossomed during the last decade of the 20^{th} century. It focused on the study of networks and grew out of our need to understand the many complex networks that are vital to our well being. Operating in the background of our busy, complicated lives there are many complex networks responsible for the delivery of the goods and services we require, networks that provide for our food, water, power, communications and so forth. When these networks fail the consequences can dire, as they were in the spectacular power outages of the 1990's and in catastrophic natural disasters like hurricane Katrina. In addition, have seen new networks emerge with mobile phones and the Internet and we have come to understand old networks much better, for example, the neurological networks in living matter and the human genome. This new science has been applied to understand the behavior of networks for communication, distribution of resources, epidemics, management in organizations and, of course, most famously the Internet. There are two popular books describing network science, written by important contributors to the field (Watts 2003; Barabási 2002) and a there is a comprehensive technical review paper (Albert & Barabási 2001)

One of the most familiar results in the field of social networks comes from the work of psychologist Stanley Milgram who sought to understand the connectivity of human social interactions (Travers & Milgram 1969). He performed several experiments in which individuals in one community (in Kansas) endeavored to make contact with a remote target individual (in Massachusetts) using the social network of their friends and their friends' friends. The resulting notion of "six degrees of separation" implies that an individual in a particular population can contact another individual through a directed chain of, on average, six contacts. This idea, that we live in a "small world", has entered the popular culture through a play by John Guare, "Six Degrees of Separation", in which a principal character, Ouisa Kittredge, speaks the words –

> "I read somewhere that everybody on this planet is separated by only six other people. Six degrees of separation between us and everyone else on this planet."
>
> "Everyone is a new door opening into other worlds. Six degrees of separation between us and everyone else on this planet. But, to find the right six people..."

The play was made into a movie (a good one – 93% on Rotten Tomatoes); there was also a short-lived TV- series by the same name and roughly the same idea.

So what is a network? Here is a simple example. If you have a modern telephone equipped with a directory then you are "connected" to each of your entries; when you push a button on your phone it connects to another phone. Each of those entries has its own directory connecting them to another set of telephones. And so on. So with your phone at the center, there are a series of interconnections that extend far beyond you.

In general, a network is a collection of objects, called nodes, connected in pairs by links. The objects could be anything, telephone numbers as in the example above or neurons, or electrical power stations. The objects are linked by specified connection, being in a directory in the previous example, or by synapses between two neurons or cables between power stations. Figure 1 shows a network; nodes are represented by dots and links by lines connecting the dots. The network grows in complexity from left to right. In some cases nodes stand alone – not connected to any other node. In other cases only two or three nodes are connected. At the extreme right there are a large number of nodes, interconnected in a complex way.

One of the easiest networks to visualize is the social network of your friends. You and each of your friends are nodes connected by links representing your friendship. Your node is connected to the node of each of your friends; the node of each of your friends is connected to their friends, some, but not all, of whom are also your friends. As the network expands to more and more layers of friends it comes to cover the globe. The surprising result of Milgram was that, despite the wide range and apparent complexity of a social network of friends, it is still possible to establish contact between two individuals with relatively few intermediaries (about six).

Despite the wide range of differences among networks and their complexity there are a few characteristic properties which help to describe their general structure. The details of these characteristics are not important here but are discussed in our earlier work (Buoncristiani, 2007). A remarkable result from modern network science is that despite the fact that networks very different they share the same simple organizing principles. Because these organizing principles exist for all networks so far studied, we can conjecture that also exist for a human's network of knowledge.

There are three different kinds of networks each representing a higher degree of sophistication and organization. It is important to recognize these three networks because, as we will show later, they represent different ways that knowledge can be organized in our brain.

The first is a random network and as the name implies the nodes are connected at random. Imagine a collection of nodes represented by dots as in Figure 1. The nodes or dots are not as yet connected. If connections between nodes are made in a haphazard manner the result is a random network. It is a network with no regular structure.

The next kind of network recognizes that real networks are not entirely random but have an element of order. When you think of the collection of your friends, some you have developed because of the structure of you life (where you live, where you work, where you go to church) and some because of individual choices that you make (you play bridge, your hobby is photography and you volunteer at the school library). These two elements of you immediate social network, called structure and agency by sociologists, are responsible for the uniqueness of your friends and ultimately for the global connectivity of our small world. Researchers have developed a mathematical model that allows for the systematic study of networks that have a combination of order and randomness (structure and agency). These so called "small world networks" have a characteristics common to a large number of very different real networks.

The third type of network was discovered by examining the interconnectivity of the Internet. A computer was programmed to explore all of the links associated with a specific web page and then all of the web pages it was linked to and so forth. It mapped the network of pages it traversed as it "crawled" through the Internet. This task was far too tedious for a human, but ideal for a computer. Examining the network obtained in this way showed a preference for a few nodes to have a very large number of links and a preference for new links to be made to these hubs (think of sites like Google, Yahoo or

Wikipedia). This preferential attachment is some times compared to idea that “the rich get richer”; the more money you have the more money you get and so the more links a web page has the more it is likely to get. Figure 2 shows a typical network with preferential attachment. In the figure, the hub nodes are shown as larger. In a network with this sort of “preferential attachment” there are a large number of nodes with a few links and a few nodes with a large number of links.

The technical details of network science are not so important here. What is important is that there is a hierarchy of three increasingly sophisticated networks -- a random network, a small world network and a scale free network – and these can be used to model the increasing sophistication of knowledge networks. We describe this hierarchy in sequel as we develop a model for knowledge organization.

The most impressive result of this new science is that dramatically different types of networks exhibit common properties. It is our premise here that it is reasonable to consider an individual’s mental construct for knowledge to be a network and consequently, that it shares these common properties. This understanding is useful to the extent that it can elucidate the organization of knowledge.

3. A MODEL OF KNOWLEDGE ACQUISITION

We can think of the organization of one’s knowledge as a network. Each bit of knowledge in the brain can be represented as a node in a network and the connection among individual bits of knowledge can be represented by links. The resulting pattern of nodes and links forms a network – the network of an individual’s knowledge, their personal mental construct. The manner in which information is organized in a person’s brain, the structure of their knowledge network, determines the ease of using that information.

Some students treat each learning experience as an isolated event that is disconnected from their other knowledge. They are unable to describe how they learn. They do not question the processes by which they learn. Their learning is episodic, rote memorization. The knowledge they acquire is acquired for a specific purpose, a test, an essay or a project and is not easily transferred to different situations. Consequently, when confronted with situations that confuse them they have no resources to use to resolve the confusion.

One might know, for example, that the Battle of Hastings took place in 1066. A student might know that fact because his teacher told him that dates would be on the test and he dutifully recorded it in his notebook and then reviewed it just before the test. After the final test that information is effectively lost. Another student may be genuinely interested in English history and the succession of British kings. To that student, recalling the date of the battle causes a series of related ideas to flow to his consciousness. Hastings was the last time England was conquered by a foreign power. This insight requires a knowledge of British history subsequent to Hastings. Furthermore, the battle stemmed from disputes over the succession of to the English throne. This understanding requires knowledge of the previous history of Britain. The first student learned an isolated fact while the second student found a context for his knowledge.

The knowledge network of any two individuals can be expected to be as different as their fingerprints. But, just as there are common characteristics for fingerprint features, there should be some set of common organizing principles governing how knowledge networks are formed. If we can understand these principles we may be better able to guide the evolution of the mind's acquisition and organization of new knowledge. Indeed, this is the imperative of the primary findings of "How People Learn".

The following is a hypothetical scenario of such an evolution based on the nascent science of networks. While we may not now be able to prove this hypothesized development, it does provide a tantalizing and plausible story for how knowledge grows within the mind. It illustrates the unsatisfactory nature of the simple episodic organizational schemes and it reinforces the need for personal effort in learning to achieve sophisticated understanding.

When a child first begins to learn he/she is flooded with sense data; each new bit of information appears to be the same as every other bit since there is no basis to discriminate between them. Since there is no discrimination among the bits they are initially linked at random. The organization of early knowledge is a random network. It is featureless, with no structure to the information it contains. Something similar occurs when an adult begins to learn a completely new subject.

As more information becomes lodged in children's minds the network configuration changes and connections between bits of information become recognized and linked purposefully. It is transformed from a random network to a "small world network". Order begins to emerge from randomness. As more connections are discovered between bits of information they begin to cluster. In a small world network there are clusters of knowledge but also a few nodes in each cluster have long range links, a remnant of the random network stage. These long range links provide a connection among clusters.

This small world knowledge network is characteristic of the novice learner. With no effort or guidance to organize new information, learning at this level is episodic rote memorization.

When (if) the learner begins to think about *how* the information she is receiving is organized her knowledge network changes in a more profound way. The attachment of links begins to prefer those nodes which have already established more links. These preferred nodes, called hubs, form the centers about which information is organized. This organization forms a scale free network. The chief characteristic of this stage is the appearance of hubs – centers about which knowledge is arranged without any bounds.

Thus the evolution of the organization of knowledge can be seen to pass through three stages. In early learning, knowledge is organized at random and the landscape is featureless. Later, as connections among the pieces of information are discovered, some bits of information begin to cluster while other bits still retain a random element. Finally, the sophisticated learner begins to organize information around hubs.

There is an technical characteristic of network structure that gives some important insight into the complexity of knowledge acquisition. This characteristic involves knowing how the links are distributed among the nodes. For a random network the degree distribution is a normal distribution – the familiar bell curve. That means that there is a mean number of links attached to nodes and a maximum and minimum number of links. These bounds on the number of links to any one node impose a limit on the complexity of the network. The degree distribution for a small world network is approximately a normal distribution so the same limitations apply. On the other hand, in a scale free network there is no limit to the number of links to nodes. Thus some hubs can have an unlimited number of links and the resulting network has no limit on its complexity imposed by the network structure. There certainly are limits on the complexity of a knowledge network imposed by the brain itself. This justifies thinking of the scale free network as a network of the sophisticated knower.

4. IMPLICATIONS FOR CLASSROOM PRACTICE

We have introduced an idea about how knowledge can be organized in an individual's mind in three stages of increasing complexity. The idea is useful in thinking about how people learn and may be useful for teachers who seek to help their students organize their new knowledge into a conceptual framework. There remains work to be done to validate this idea and to study the process of growth a knowledge network.

The idea that a network structure describes the organization of knowledge in a person's mind allows us to discuss the process of learning for understanding. The language of network science can be used to clarify the process of flexible learning and provide guidance to teachers as they seek to implement the most effective classroom strategies.

This simple view of the evolution of an individual's organization of knowledge suggests a strategy for teachers. In aiding students to transform from the Early to the Middle stage teachers should assist students in recognizing connections among bits of information they are learning. In assisting the transition to Sophisticated Learning teachers need to help students identify hubs of knowledge and fit what they are learning into these hubs. This description of the transition from an early learner to a sophisticated learner in stages could apply when a sophisticated learner takes on a new subject.

The model presented here is consistent with the findings of the report on "How People Learn". That report discourages the teaching disconnected facts because that promotes the organization of knowledge in a random network, the least sophisticated level of knowledge organization. The report also discourages the teaching in separated disciplines. It favors instead the teaching of concepts across disciplines corresponding to the organization of using hubs that extend over fields.

What does this mean for actual classroom practice? It is a common practice among informed teachers to discover what students already know before launching into a new topic in the curriculum. Instructional techniques such as KWL (Ogle 1986*)* provide a structure within which the teacher can survey what students already know (K), set goals based on what they want to know (W) and survey what they have learned (L). This technique was originally devised as a way to introduce students to a new piece of text, by cueing them into the content of the text and giving them a purpose for their reading. A variety of graphic organizers are available and most of them provide a framework within which students create lists. Lists, by their nature are linear and may not be the most useful way to activate prior knowledge and encourage the development of complex knowledge networks. Mind maps, on the other hand, are non linear and encourage students to relate pieces of information and skills to one another. Such a non-linguistic and non-linear graphical organizer can encourage the representation of networks of interrelated knowledge from the earliest point in the curriculum unit. The traditional KWL focuses on the listing of potentially unrelated bits of information. The mind map encourages the recognition and building of complex networks. Both techniques will activate prior knowledge but mind maps will do so in a way that encourages the development of sophisticated learning. Prior knowledge assessment is an means to get students to review their knowledge network so they know what they know and then can properly integrate the new information. The mind maps are a means of externally visualizing a format for their knowledge network. The fact that the mind maps are nonlinear allows the network to be scale free.

4.1 Departmentalism and Curriculum Specialization

The pressures of NCLB legislation has led to a nationwide focus in elementary schools on student achievement as measured by standardized tests in the basic curriculum areas of reading, mathematics and science. Many states also include testing in history, geography and civics. In an effort to ensure that the teachers held responsible for student achievement are as skilled as possible there has been an increasing tendency to departmentalize teaching. In some schools this means that the student will have a different teacher for each subject area, in others subjects are grouped – science and math in one group, the social studies and English in another. In almost all schools art, music and physical education are taught by specialist teachers with specific endorsements in these curriculum areas. The unintended consequence of these practices is the fragmenting of the complex network of knowledge organization that would have been possible with true integration of learning. By limiting the formation of links between areas of the curriculum we are also limiting opportunities to develop the scale free complex networks that characterize the sophisticated learner. Fragmenting of knowledge is at the Random end of the small world network.

The student who is explicitly encouraged by his teacher to create links between his learning about light and color in science, the collection and manipulation of data in mathematics, the effects of climate and light on the settlement and economic development of the USA, the use of color in the visual arts and the concept of color in music will develop a more sophisticated framework for his knowledge through the growth of a scale free network. The organization of curriculum content around 'big questions' that act as hubs results in a knowledge network with no internal limitations on its complexity and our students move closer towards being sophisticated learners.

4.2 Multiple Intelligences

A good football player needs to exercise a number of kinds of intelligences. The use of his interpersonal intelligence enables him to work as a fully functional, responsive team player. Spatial intelligence enables him to predict ball trajectory, player movements and his own responses. His bodily-kinesthetic intelligence is what makes it possible for him to control and direct his movements effectively during the heat of the game. He needs to make use of his linguistic intelligence to understand the guidance and directives of his coach and communicate strategy with his teammates. His understanding of himself, his motivations, his reactions to events are mediated by his intrapersonal intelligence.

Effective learning is a kind of team game between the teacher, the student and the material being learned. A good teacher understands that if a range of intelligences are brought to bear then learning will be more effective and longer lasting. Robert Marzano has explained the value of non linguistic representations as aids to understanding. Students interact with material linguistically but they also bring their non-linguistic intelligence to the task and thereby deepen their understanding. I recall helping my 5th and 6th graders understand the difference between the rotation of the earth on its axis and the rotation of the planets around the sun by actually having them out of their seats and demonstrating the differences with their bodies. With young adults I have used music to enhance their understanding of the poetry of war, comparing, for example, Tchaikovsky's 1812 Overture and its jubilant interpretation of victory with the dark, reflective music of Gorecki's 3rd Symphony. I recall my astonishment at the richness of response to poetry that I saw when I allowed young trainee teachers to communicate these responses to specific poems through visual media. Links need to be made between the ways in which we learn and exercise our various intelligences in order to maximize the complexity of knowledge networks.

4.3 Habits of Mind

Many schools have come to understand that effective life long learning takes place within the context of certain kinds of intelligent behaviors. These have been articulated by Arthur Costa and Bena Kallick as the 16 Habits of Mind of successful people. Teachers who incorporate these habits into their classrooms understand that they do not stand alone as discreet ways of doing things. Instead they interact and link up with one another, forming complex webs of behavior. One of the habits is about taking responsible risks and another involves taking in data with all the senses and another involves the ability to think interdependently. The successful individual will make links between these three before deciding to take a particular course of action. Reading, talking with others, observing the environment all provide data upon which to base the decision to take a responsible risk.(Costa, 2000)

4.4 Bloom's Taxonomy

Benjamin Bloom developed a taxonomy of thinking that has been interpreted as a movement from lower order to higher order thinking and a kind of developmental continuum. This linear view of thinking is also not helpful in ensuring the creation of rich, complex scale-free knowledge networks. Knowledge and comprehension are regarded as the foundational cognitive tasks and analysis, synthesis and evaluation are considered higher order cognitive skills. But how can I comprehend anything if I am not able to analyze and evaluate my experiences and decide what is relevant and what is irrelevant? How does a two year old speak if he hasn't already listened to all the many and varied sounds he hears, discriminated among them and decided which are significant and which are not, analyzed these sounds and synthesized them into words – often original words that we have never heard before! As the child grows in his language experience he is able to compare his words with the adult words around him and adapt and change them until they match more closely – eventually abandoning his baby talk vocabulary. Every time a two year old speaks he is likely to create a new sentence that he has never heard before. He synthesizes the words he has heard and learned and recombines them in novel ways that serve his purposes. The growth of language is wonderful example of the interrelatedness of cognitive tasks and creation of increasingly complex network we call language.

Skilled teachers will recognize the importance of making links between cognitive tasks rather than seeing them as some kind of developmental sequence that children need to be trained to use.

4.5 Curriculum planning

Curriculum that is carefully planned around the concept of Big Questions makes this kind of linked learning possible. The creation of these plans needs to be done with an open mind. Traditional planning proformas simply don't work. Teachers in schools using this approach have frequently chosen to create their weekly or monthly lesson planners on large sheets of paper that can be posted on the classroom wall. The planner may incorporate a Mind Mapping format with the Big Question (McTighe, ref) at its centre and a variety of learning tasks as outliers. As teachers create these planners they are alert to ways they can link different disciplines to deepen student understanding. A tracking chart provides students with different ways of exploring topics and records their choices as well as identifying the kinds of intelligences, Habits of Mind and cognitive tasks that each learning task has potential to activate.

Each curriculum planner also needs to provide a time at the end of that particular topic for students to reflect on their learning – to metacogitate, think about their thinking and learning so that they can evaluate it and adjust their learning as necessary. A student may find, on reflection, that his topic lacked depth because he didn't keep going when the task became difficult. He may identify the fact that he needs to work on the Habit of Mind of Persisting in order to improve the quality of his learning. Another student may discover that by looking at the tracking chart he always tends to avoid using his interpersonal intelligence and so misses out on the opportunity to think interdependently (note the link here between one of the Multiple Intelligences and a Habit of Mind). This can then become a focus for his next learning task.

The work of Canadian educator Lane Clark (http://www.laneclark-ideasys.com) provides teachers with strategies for the design of curriculum that is focused on the creation of linkages rather then the simplistic notion of learning as a linear, step by step process. Additionally, she demonstrates how technology can be seamlessly infused into learning in the classroom. Learning how to design more holistic curriculum is not a simple task, but it is essential if we are going to assist students develop the complex networks that characterize the sophisticated learner.

Skilled teachers understand that learning is not purely linear. Students do not learn how to read fluently, understand history, music or play a particular sport simply by moving one step at a time. Learning is not like building a wall, one brick at a time, one row at a time. Learning is organic and most effective when teachers explicitly seek links and make them apparent to their students.

Figures

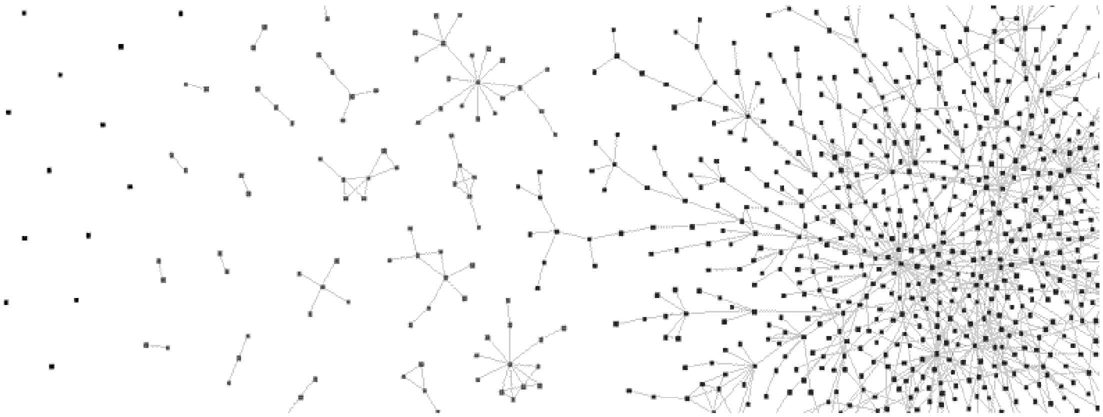

Figure 1. A network is a collection of objects called nodes connected by links. In this diagram each point represents an individual node in the network and each line represents a link. The network shown grows more complex from left to right. The source of this figure was http://www.orgnet.com/prevent.html.

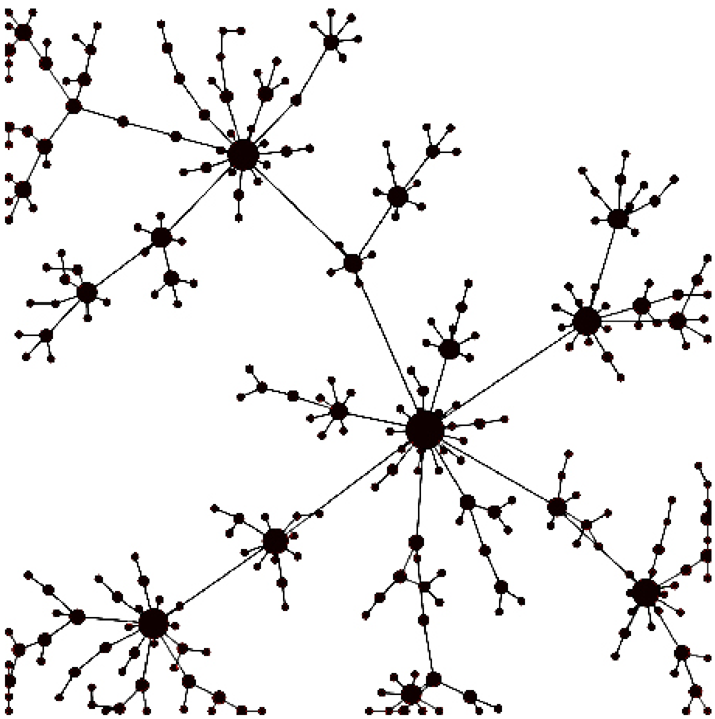

Figure 2. This figure shows a typical network with preferential attachment. In the figure, the hub nodes are shown as larger, their size proportional to the number of links. In a network with this sort of "preferential attachment" there are a large number of nodes with a few links and a few nodes with a large number of links. This figure was generated using software developed by Uri Wilensky of Northwestern University and is incorporated in NetLogo: http://ccl.northwestern.edu/netlogo/models/.

Table 1
Development of the Knowledge Network

Early Learning	Novice Learning	Expert Learning →
Random Network	Small World Network	Scale Free Network
Structureless Bounded range	Clusters Bounded Range	Hubs Unbounded Range

5. BIBLIOGRAPHY

Albert R., Barabási A.L. (2001) *"Statistical Mechanics of Complex Networks"*, Review of Modern Physics, Vol. 74, No. 1. pp. 47-97.

Barabási A.-L. (2002) "Linked: How Everything is Connected to Everything Else and What It Means for Business, Science and Everyday Life", Plume (Penguin Group), New York

Barabási A.-L., Albert R. (1999) "Emergence of Scaling in Random Networks", Science, Vol 286, No. 5439, pp. 509-512.

(Bransford, 2000) Bransford J, Pellegrino J., Donovan S. *How People Learn*, National Academy of Sciences, National Academy Press, Washington, DC.

(Buoncristiani, 2007) A.M. Buoncristiani and P.E. Buoncristiani,

Costa, A, Kallick B (2000) *Habits of Mind:A Developmental Series,* ASCD

Damasio A. R. (2001) *"How the Brain Creates the Mind"*, Scientific American Special Publication on the Brain.

Diderot D., d'Alembert J. *"The Tree of Knowledge"* first appeared in "*Encyclopédie, ou dictionnaire raisonné des sciences, des arts et des métiers"* (Encyclopedia of the sciences, arts and crafts), an early encyclopedia published in France beginning in 1751.

Marzano R, Pickering D, Pollock J (2001) *Classroom Instruction That Works: Research-Based Strategies for Increasing Student Achievement* ASCD

(Mctighe, XXXX)

Ogle, D. S. (1986). *K-W-L group instructional strategy.* In A. S. Palincsar, D. S. Ogle, B. F. Jones, & E. G. Carr (Eds.), *Teaching reading as thinking* (Teleconference Resource Guide, pp. 11-17). Alexandria, VA: Association for Supervision and Curriculum Development.

Rockwell G. (1999) *"Diderot and Hypertext."* unpublished essay presented in January 1999 to the *McMaster Association for Eighteenth-Century Studies.* http://www.geoffreyrockwell.com/publications/Diderot.Hypertext.pdf\ .

Travers J., Milgram S. (1969)"An Experimental Study of the Small World Problem" Sociometry, Vol. 32(4), pp. 425-443.

Watts D. J., Strogatz S. H. (1998) *"Collective Dynamics of 'Small World' Networks"*, Nature, Vol. 393, No. 4, pp 440-442.

Watts D. J. (2003) "*Six Degrees: The Science of a Connected Age*", W. W. Norton & Co. Inc., New York.