NETWORKS AND THE SPREAD OF IDEAS IN KNOWLEDGE BUILDING ENVIRONMENTS

by

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ABSTRACT

This case study examined the spread of ideas in a Gr. 5/6 classroom in which the teacher was attempting to foster a knowledge building community. The goal of the research was to explore the relationship between the social network of the classroom (in terms of face-to-face and computer-mediated interactions), the teacher’s role, and the spread of ideas. Further, the thesis examined how social network tools may help teachers better understand the pedagogical implications of Scardamalia and Bereiter’s (1991) Teacher A, B, C models.

Analyses of videotaped lessons revealed the teacher used a complex mix of traditional instructional methods and knowledge building strategies while trying to shift the locus of control of learning to students. Critical teacher-driven processes included the class-wide adoption of knowledge building vocabulary and practices, and efforts to foster higher levels of student-student discourse.
Analyses of online interactions provided strong evidence of highly interconnected student-student online networks, with the note reading network being especially dense. Longitudinal studies revealed these network established themselves early in the unit, and persisted during the course of the inquiry. There was evidence that idea improvement was present in addition to idea spread. In face-to-face classroom communication, the teacher’s role was more central, particularly in "Knowledge Building Talk" sessions. However, here too, the teacher made efforts to shift the locus of control.

Overall the analyses suggest that social network tools are potentially useful for helping teachers make the difficult transition from "Teacher A" and "Teacher B" strategies, in which the locus of control is with the teacher, to "Teacher C" strategies, in which strategic cognitive processes are turned over to students. This dissertation proposes that movement toward Teacher C practices may be illustrated, in part, by a shift in classroom network topologies from that of a star-shaped network, centered on the teacher, to a highly interconnected student-student network. Finally, the thesis recounts a number of ways in which the use of social network tools uncovered discourse patterns of which the teacher was unaware, including gender differences in reading, building-on, and contribution patterns.
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When I began the Ph.D. process, I was married and had three children. At the end of the process, I am still married and my wife and three children will still speak to me—a remarkable testament to their patience and understanding, especially when their husband/father went on and on about strange and arcane topics of little interest to them. I owe them a great deal.

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Unfortunately, the teacher and class cannot be identified, but they deserve my thanks for allowing me to work with them, and considerable credit for the way in which they worked.
Thank-you all for your help and encouragement.
Anthropological Space. Anthropological space is a term used by Pierre Lévy to describe what are typically called ages in human history. Instead of being limited by time, as the term ages or eras implies, anthropological spaces are cultural spaces relating to how humans interact with the world and each other. Ages end, but anthropological spaces coexist and interpenetrate, thus affecting one another. An example of this is oil and gas exploration—basically a form of hunting and gathering that has been informed and changed by industrial age processes.

Blog: Blog is an abbreviation commonly used for a WebLog (see below).

Blogspace: Blogspace is the virtual space created by interrelated blogs.

Build-on: A build-on is a response to a posted note in the Knowledge Forum environment. Build-ons are intended to advance the knowledge of the class through the addition of new information or meaningful comment on the previous posting. In some groupware products, build-ons are called replies or responses.

Complex knowledge: Complex knowledge is composed of large numbers highly interactive elements that have not yet been assimilated into schemata in long-term memory (tacit knowledge). The large number of elements puts a strain on working memory, therefore causing an increased cognitive load. Once assimilated into schemata in long-term memory, the strain on working memory is reduced.

Graph Theory: Graph theory is a branch of mathematics that studies the properties of networks. It uses dots (called nodes) to represent agents in the network and lines (called edges or arcs) to represent connections among them in order to create graphical representations of the network. The use of the term graph here should be distinguished from the common usage of graph as a representation using a Cartesian coordinate system—the more common form of graph in science.

Heterogenesis: Borrowed from biology, heterogenesis refers to the spontaneous changes an organism undergoes when introduced into a new environment. As used by Pierre Lévy, it refers to the spontaneous change in a type of event when it moves into virtual spaces. An example would be a virtual visit to a school, which would be changed in many ways from a physical visit to the same school.

Idea-Centered Education: Whereas most forms of education are focused on teacher-created student activities, knowledge building pedagogy uses student ideas as the central focus of knowledge building activity. The focus on student ideas shifts the locus of control from the teacher to the students in terms of the direction and content of the class work.
**Knowledge Forum.** Knowledge Forum™ is a second generation CSILE (computer-supported intentional learning environment) groupware environment having advanced features to support knowledge building.

**Note:** A note is a posting in the Knowledge Forum online learning environment.

**Problems of Understanding:** Knowledge building units typically begin with the teacher posing a problem of understanding. These should be about real-world problems, and be posed in such a way as to generate student ideas about how such a problem could be solved. They are used as a starting point for knowledge building inquiry.

**Rise-Above:** The term rise-above is used for two related concepts: an attempt at the synthesis of ideas leading to a higher level of understanding within the group, and type of note in Knowledge Forum designed to foster such synthesis.

**Scaffolds:** Metacognitive scaffolds are used to assist in reflection about the different kinds of thinking involved in the creation of new knowledge. These are grouped into scaffold sets with attendant supports such as My Theory, I Need to Understand, Putting Our Ideas Together, and so forth. In the Knowledge Forum online learning environment, student postings can be labeled as to the kinds of thinking used.

**Small World Effect:** A concept originally based on an experiment conducted by Stanley Milgram in the 1960s, the small world effect refers to social systems that, through the effect of weak ties, allow information to travel more quickly through the social system than would be possible otherwise. Milgram found that even in a very large social system, a path length of six (six degrees of separation) was about average for the transmission of a message.

**Socio-cognitive Perspective.** Sometimes called augmented intelligence, the socio-cognitive perspective places tools and other persons as central to cognitive processes.

**Tacit Knowledge:** Tacit knowledge is knowledge that is personal and context-bound (Nonaka & Takeuchi, 1995) and is not easily shared. It is often termed the difference between knowing about (explicit or statable knowledge) and knowing how (tacit knowledge). Tacit knowledge is viewed as more complex than explicit knowledge. (See complex knowledge above).

**View:** Knowledge Forum is structurally a database, and as such, database terminology is sometimes used. In a database, all of the data are accessible to the program, but usually cannot be displayed all at once. Therefore, data are displayed in views—meaningful segments of the data. In Knowledge Forum, a view typically is a space devoted to work on a particular topic or unit of study. Views contain supports for collaborative work, and views can be linked to create a set of related collaborative workspaces.

**WebLog:** A WebLog is a kind of evolving journal or diary posted on the internet. WebLogs have recently been used to track the spread of ideas through virtual spaces.
“The network interconnectedness of an individual in a social system is positively related to the individual’s innovativeness.”

(Rogers, 1995, p. 303)

CHAPTER 1: INTRODUCTION AND OVERVIEW

1.0 Introduction

The knowledge building session began with the teacher telling the students to get to work. Then something odd happened: many of the students did very different things. Some went to the library, some got books from the classroom supply, and some went to speak to other students. Many got their laptop computers, and began to read or enter postings into an online learning environment, often in another room, and often in the form of spontaneous *ad hoc* groups that didn’t last very long before the students went on to something else. This is very different from traditional classroom work. Who is in control here, when everyone appears to be doing different things? It doesn’t appear to be the teacher, viewed from the perspective of a traditional classroom. But the students frequently consult the teacher, so it doesn’t appear to be the students either. In fact no one is in control, and everyone is in control. And real work gets done.

In knowledge building classes, the focus is on student ideas about how to solve a real-world problem; student ideas are central to the process; and students work to not just express their ideas, but to change and improve them to better solve the problem under study. However, in order to focus on their own ideas, the students need to be allowed a much greater degree of autonomy (agency) than in traditional classrooms. This autonomy, which is increased when online environments are thrown into the mix, causes problems for teachers accustomed to traditional classroom practice. But what is
happening is that the students are forming a knowledge building community through a network of interactions about their ideas, both in face-to-face interactions, and in online interactions. Control of the process is provided by the networks that form, a kind of control that is only just now coming to be understood. Galloway and Thacker state, "The quandary is this: no one controls networks, but networks are controlled" (2007). An understanding of network behaviour is important to an understanding of knowledge building classes.

It has long been known that ideas spread through networks (Rogers, 1995, see Chapter 8). The central focus of ideas in knowledge building classes makes an understanding of idea spread important in understanding the knowledge building process. However, until recently, the study of such networks has been greatly inhibited by the computational complexity of the analysis. Rogers (1995) notes,

[Network] communication structure is so complex that in any but a very small system even the members of the system do not understand the communication structure of which they are a part…. For instance, in a social system with 100 members, 4950 network links are possible … A computer is necessary to analyze the patterns among these myriad of network links. (p. 308)

The advent of powerful personal computers now allows for such analyses to be done quickly and relatively easily, paving the way for the current study. To date, little has been done on knowledge building networks in schools, Palonen and Hakkarainen (2000), Sha and van Aalst (2004), and Dennen and Paulus (2005) being among the exceptions. We still know very little about the role of networks and the effects of network structure
on the learning process. Thus the centrality of ideas and idea improvement to the knowledge building process, the knowledge that network structure influences this, and the availability of suitable analysis tools suggested this study.

Because a class of students identified by experts as exemplary at knowledge building was available to the researcher, a case study methodology was used to see what could be learned about how ideas spread among this group of students in both the in-class setting, and in the Knowledge Forum online learning environment used by the class.

The principal research question was:

- **What is the relationship between the social network structure and the spread of ideas in this knowledge building environment?**

Sub-questions deriving from this included:

- What is the network structure of ideas in online interactions?
- What is the network structure of ideas in face-to-face interactions?
- Did Knowledge Forum function in the spread of ideas, or was it used to record ideas after they have spread?
- What was the role of Knowledge Forum’s features and functions in the spread of ideas among this class?
- What is the teacher’s role in the KF classroom?
- Was there evidence of idea improvement in addition to idea spread?

The general purpose of the research therefore, was to determine if a social network existed, and if so, to examine the nature of the relationship between the social network structure of the class and its impact upon the distribution of ideas in their discursive computer mediated educational environment.
1.1 Researcher Background

My academic background includes a B.Sc. (basically human biology), an Ars.D. (Artist’s Diploma) in music, a B.Ed., and an M.A. in educational computer applications. Work experiences include fifteen years with the Toronto Board of Education, teaching mostly biology and chemistry, with some work math, computers and music. Prior to that, I was a professional musician in the Toronto area for a number of years, working mostly in classical music with such organizations as CBC radio, the Hamilton Philharmonic, and many more.

The science background prepared me to understand and make effective use of the various data visualization techniques used here, and the music background was beneficial in attending to the qualitative aspects of the study, as much of music performance is dependent on the ability to be aware of the surroundings and subtle nuances of behaviour of others. Additionally, the music background prepared me for an understanding of the innovation process. The Masters degree research was heavily qualitative, and gave me experience in field research in classrooms, interviewing, transcribing, and the subsequent qualitative analysis of the resultant data (Philip, 1999).

Although the present research arose from an observation of the network-like patterns formed by online note contributions, there was considerably more to it than that. Early in my Ph.D. research, I came across references to applications of complexity theory and the principles of self-organization to education (Macpherson, 1995). Reading work by Watts (1999), I realized that the ‘connected caveman’ world structure, in which society was viewed as clumped into closely-interconnected clusters with weaker links
among the clusters, was an apt descriptor of the departmental structure of secondary schools, and that perhaps this could be used to explore how ideas about educational change might spread through a school. Considerable work had been done on this before research by Barabási, Albert, and Jeong (2000) revealed that the *history* of a system had to be taken into account in establishing the pattern of links among group members. At this point, that work had to be abandoned because it was not possible for me to obtain such information.

The legacy of the abandoned research project was an interest in the growing field of network science and its applicability to complex systems, complexity theory, and self-organizing systems. Thus the realization that communications among students in online environments was network-like aligned with the previous research and suggested a way to study idea spread.

Preliminary research into this area revealed an additional gap in our understanding. Although there had been some work done on social networks in schools, (e.g., Hansell (1984)), very little work had been done on hybrid classes—classes in which there was both an online and live-class component. A study of the interplay between ideas in the classroom setting and in the online environment was necessary to understand knowledge building in hybrid classes. These experiences, then, laid the foundations for the current study.
1.2 Organization of the Thesis

Chapter 2 begins the literature review by addressing the issue of changes in education occasioned by the advent of new information technologies and the attendant social effects. Next the socio-cognitive perspective is examined—a perspective that allows us to see the role of tools and social processes in thought, and to see how computers in general, and knowledge building environments in particular, can effectively be used in educational settings. Following this, there is an examination of knowledge building theory and the Knowledge Forum™ knowledge building environment, which was used in this study. This leads into the centrality of ideas to the effective functioning of the knowledge building process, and an analysis of the innovation process, with an emphasis on networks.

Chapter 3 continues the literature review with a focus on networks and social network analysis; how such analyses are presented; measures, limitations and problems; and the relationship of social network analysis to other fields of study.

Chapter 4 outlines the methodology used in the project, which is essentially an in-depth case study of a class in a school that has been identified as exemplary in knowledge building (Bielaczyc & Collins, 2002), and Chapter 5 presents the results. Finally, Chapter 6 draws conclusions from the results, examines them in light of the research questions, attempts to synthesize the results into a coherent whole, and suggests both the limits of, and future directions for, the research.
The future is here. It's just not widely distributed yet.  
William Gibson (nd)

CHAPTER 2: EDUCATION IN THE KNOWLEDGE AGE

In a recent speech to the National Education Summit on High Schools (U.S), Bill Gates, formerly Chair of the Microsoft Corporation said (2005),

When we looked at the millions of students that our high schools are not preparing for higher education – and we looked at the damaging impact that has on their lives – we came to a painful conclusion:

America’s high schools are obsolete. (p. 1, emphasis added)

Through the Bill and Melinda Gates Foundation, he and his wife have invested in excess of one billion dollars in educational research to reach this conclusion. This view is echoed by many others (Bereiter, 2002; diSessa, 2000; Friedman, 2005; Handy, 1995; Sterling, 2002); and often expressed as a concern for 21st century skills (Crane, et al., 2005). Why this is so, and the direction that education should take is the subject of this chapter.

2.0 A Brief History of the World in Broad Strokes

Historians have divided the history of humanity into ages, principally four ages or eras during which changes in the manner in which humanity managed it’s affairs caused revolutionary transformations in the pattern of living. In each case, these changes were so substantial that persons from an earlier age being transplanted into a later one would have major problems adapting. Usually, four such ages are given: the Upper Paleolithic
Age, informally called the stone age (Gailey, 2006); the Agricultural Age ("The Spread of Agriculture, 10000–1000 BCE," 2007); the Industrial Age (Eichengreen, 2006); and currently, the Knowledge Age (Cox, 2000). Lévy (1998) has a rather unique and useful view on this. He views these not as ages, but as anthropological spaces—patterns of human interaction with the world that differ from one another in significant ways. This viewpoint is important because we tend to think of ages as ending, while anthropological spaces can interpenetrate, co-exist, and influence one another.

During the Upper Paleolithic era (starting approximately 40,000 years ago), humans first began to leave behind cultural artifacts, organized themselves into social and governing systems that we still recognize today (families and tribes) (C. Brown, 2007), and began to educate their children in an informal fashion, with children learning from their parents and other members of the tribe. Some native North Americans still follow these practices, as described by Ongtooguk (2002), and most of the very early education of modern children is in the informal mode—they learn from their parents and other relatives.

The Agricultural era, starting about 10,000 years ago (Pearcy & Dickson, 1997), brought tribal peoples into settlements that grew into cities and civilization (civicus being the Latin word for citizen—a member of a city state). In terms of education, the principle form of mass education in the Agricultural era was the apprenticeship, in which a student was formally trained by a master ("History of Apprenticeship," nd).

The Industrial era was heralded by the arrival of the machine, often dated from the invention of the Newcomen steam engine in 1700 AD (Koeller, 1996), about 300 years ago. During this period, there was a huge movement of people from the countryside
to the cities (Eichengreen, 2006), and gradually mass education became more formal, being organized into schools of which the current industrial model schools are the most common form (McCain & Jukes, 2001). (Note that while schools did exist in earlier periods (Whitehouse, 2004), they were not for mass education—a critical difference).

What can we take from this short history as we approach the still-nascent Knowledge Age? First, none of the past forms of education have actually disappeared—there has just been a shift in emphasis and a layering of these. Therefore, we still see families educating their children informally, in conjunction with formal schooling; we still see various forms of apprenticeship (now often layered with formal education in schools ("History of Apprenticeship," nd)); and it follows that formal schools of some sort will still continue to educate children (McCain & Jukes, 2001). We will, however, see new forms of education appear, and these will gradually find their place among, and layering with, the other pre-existing forms. What will these be like?

Lévy (1998) notes that one of the principal characteristics of the Knowledge Age is virtualization, a process in which, “[a]n event is detached from a specific time and place, becomes public, undergoes heterogenesis” (p. 74). He gives the characteristics of virtualization as (p. 75):

- Deterritorialization
- Detachment
- Sharing
- Elevation to a problematic
- Heterogenesis (Lévy, 1998, chapter 2; see also Lévy, 1997, p. 267)

*Deterritorialization* refers to the prying loose of an object or event from a physical
place and moving it to a non-territorial space, to cyberspace. *Detachment* refers to the
praying loose of objects and events from their original context. *Sharing* refers to the
communal nature of virtual spaces, in which large numbers of people from diverse
populations can create communities (see (Turkle, 1995) and, for some odd examples
involving massively multi-player online role-playing game spaces (MMPORPGs), see
public among communities interested in them. *Elevation to a problematic* refers to
arguments (ideas) and the problems that arise from the consideration of the logical
relations among them. Finally, *heterogenesis* is a word borrowed from biology referring
to the spontaneous changes an organism undergoes when it is placed in a new
environment. As used by Lévy (1998) it refers to the spontaneous changes undergone by
anything that is virtualized.

From Lévy’s work, therefore, we can expect that any form of education for
the Knowledge Age will deal largely with virtualized cultural artifacts–closer to reified or
externalized ideas than anything else; ideas that can be virtualized, removed from their
original context, made public, treated as problems, and changed and improved. In the
Knowledge Age, education will increasingly focus on externalized ideas that are
deterritorialized, detached, shared, and elevated to a problematic. One example of this is
in radiology in which magnetic resonance imaging (MRI), computed tomography (CT)
and other scans, all based heavily on theoretical physics, are increasingly being read by
physicians distant from the hospital using virtual private network (VPN) systems–an
example of the virtualization of medical practice (Dr. M. L. Ellins, personal
communication). Other examples include computer-assisted drawing programs used by
engineers to design machine parts, or Wikipedia (www.wikipedia.org), a collaboratively written encyclopedia. The educational system will have to find ways of promoting such forms of education, and to assess outcomes (Andersson, Hellervik, & Lindgren, 2005). The infrastructure that supported industrial model schools for the Industrial Age was a physical infrastructure, and will continue to exist. But the educational infrastructure for the Knowledge Age will be virtual, with all of the attendant social changes that this entails. Mitchell (2003, Chapter 9) gives a good discussion of this using the term post-sedentary space. Using Lévy’s theoretical lens, knowledge building using the online Knowledge Forum knowledge building environment can be viewed as a virtualization of education, making it a good model for education in the Knowledge Age.

One such social change is already evident: businesses have their own views on how knowledge age work should be done. The above analysis was an elaboration based on Lévy’s (1998) work, but a similar analysis can be found in Fisher and Fisher’s (1998) book The Distributed Mind. Written from the business perspective, it notes that the organization descriptor for the agricultural age was patriarchal; for the industrial age, hierarchical; and for the knowledge age, egalitarian. In Chapter 5, they note the organic nature of knowledge work organizations and teams: “These teams are difficult to describe to outsiders because their membership shifts from time to time, forming and reforming like rapidly splitting amoebas" (p. 106). This is an apt description of the flexible work teams that form in knowledge building classrooms.
2.1 The Socio-Cognitive Perspective

In the previous section, we discussed the virtualization of education. However, virtualizing education is a necessary but not sufficient condition—we also need to make use of what is known about learning to create effective virtualizations of education. This section examines how this might be done using a view of learning based on the social cognition perspective.

In recent years, due to advances in cognitive science and educational research, there has been a revolution in how we view the mind, and in our knowledge of how we learn (Bereiter, 2002). Combined, these provide a new perspective on education that is socio-cognitive in nature. In this view, cognition is seen as situated in the physical and social context in which it occurs. Zhang (1997, p. 2) expresses the situated cognition view thus, “The situated cognition approach ... argues that people's actions in concrete situations are guided, constrained, and to some extent, determined by the physical and social context in which they are situated. ... In this view, much of a person's intelligent behaviour results from interactions with external objects and with other people.” In other words, our cognition is affected by our interactions with objects in our environments (particularly tools) and with people (Donald, 1991; Hollan, Hutchins, & Kirsh, 2000). Clark (2003, p. 6) speaks about tools:

It is because our brains, more than those of any other animal on the planet, are primed to seek and consummate such intimate relations with nonbiological resources that we end up as bright and capable of abstract thought as we are. … [It is because we are] forever ready to merge our mental activities with the
operations of pen, paper and electronics, that we are able to understand the world as we do.

Ogle (2007) refers to these interactions (both biological and non-biological) as idea-spaces, noting that communities of practice and the paradigms they support are examples. But such idea-spaces often become invisible in that we are rarely aware of them or just accept that they are part of our normal environment, and as such see any intelligence in them as part of the person, not the system (Pea, 1993, pp. 52-53). This has led to a general lack of awareness of the role of artifacts in cognition. However, as (D. Johnson, 2003) notes,

When someone first begins using computers on a regular basis, he or she often starts to develop clearer and more rigorous habits of thought in other areas of life as well. This is a simple case where not just narrowly intellectual conditions, but also material ones, have proved able to foster certain changes in the workings of people's minds. (p. 85)

The second strand in the socio-cognitive perspective involves our interactions with other people (the biological part of Ogle’s (2007) idea-spaces). In the modern world, these can take place in person, or through the mediation of books, videos, or other media (J. S. Brown & Duguid, 2000), sometimes expressed as interactions with culture (D. Johnson, 2003). Arguably, the most important of our mediating tools are computers, which function as a kind of omnitool because of the diversity of their functions. Thus by functioning both as cognitive artifacts of immense flexibility and power, and as
communication devices that mediate our interactions with others, computers are rapidly becoming central to how we think and learn.

2.1.1 Distributed Cognition

Earlier it was noted that a considerable amount of our intelligent behaviour emerges from our interactions with tools. Wertsch (1991, p. 15) expressed this idea thus: "[E]ven when mental action is carried out by individuals in isolation, it is inherently social in certain respects and it is almost always carried out with the help of tools such as computers, language, or number systems." The theory of distributed cognition does not claim that mental processing always has an external component, but rather that, "... when one takes mediation through artifacts as the central distinctive characteristic of human beings, one is declaring one's adoption of the view that human cognition is distributed" (Cole & Engeström, 1993). In the modern world, this is increasingly important. Both Jonassen (1996) and Donald (1991) note the cultural importance of tools, and Hutchins (1995, p. 95) draws attention to, "... the increasing crystallization of knowledge and practice in the physical structure of artifacts, in addition to in mental structure." So increasingly, we are encoding our knowledge into ever more complex tools that do some of the cognitive work for us. Ogle expresses this concept as, “[The] space of ideas thinks for you” (2007, p. 26, original emphasis). Computers are the main focus of such development at the present time, although these differ from traditional cognitive artifacts since much of the knowledge is virtualized–encoded in software and therefore not physical.

Hutchins (1995) modifies Simon’s parable of the ant in a way that makes this clearer:
Simon (1981) has offered a parable as a way of emphasizing the importance of the environment for cognition. He argued that, as we watch the complicated movements of an ant on a beach, we might be tempted to attribute to the ant some complicated program for constructing the path taken. In fact, Simon says, that trajectory tells us more about the beach than about the ant. I would like to extend the parable to a beach with a community of ants and a history. Rather than watch a single ant for a few minutes, as psychologists are wont to do, let us be anthropologists and move in and watch a community of ants over weeks and months. Let us assume that we arrive just after a storm, when the beach is a *tabula rasa* for the ants. Generations of ants comb the beach. They leave behind them short-lived chemical trails, and where they go they inadvertently move grains of sand as they pass. Over months, paths to likely food sources develop as they are visited again and again by ants following first the short-lived chemical trails of their fellows and later the longer-lived roads produced by a history of heavy ant traffic. After months of watching, we decide to follow a particular ant on an outing. We may be impressed by how cleverly it visits every high-likelihood food location. This ant seems to work so much more efficiently than did its ancestors of weeks ago. Is this a smart ant? Is it perhaps smarter than its ancestors? No, it is just the same dumb sort of ant, reacting to its environment in the same ways its ancestors did. But the environment is not the same. It is a cultural environment. Generations of ants have left their marks on the beach, and now a dumb ant has been made to appear smart through its simple interaction with the residua of the history of its ancestor’s actions. (p. 169)
Thus our interactions with our environment retain traces of the purposes for which we used that environment. Humans intentionally produce external representations and as Hutchins (1995, p. 96) notes, “In an external representation, structure can be built up gradually—a distribution of cognition over time—so that the final product may be something that no individual could represent all at once internally.” This is very relevant to online learning systems: as ideas are introduced into an online environment (an external representation), they influence others, and are increasingly elaborated. The end product is often something that no individual at the beginning of the unit could have produced.

Tools also function metacognitively—they support the task through their design. Well-designed tools contain the knowledge of their creators, often many persons over an extended time period. Such tools are omnipresent. Pea (1993, p. 48) notes, “On close inspection, the environments in which humans live are thick with invented artifacts that are in constant use for structuring activity, for saving mental work, or for avoiding error, and they are adapted creatively almost without notice.” It should be noted that the word tool here is broadly defined. diSessa (2000) gives an idea of what constitutes a tool:

Beyond machines and equipment, it is particularly important … to recognize representational tools such as algebra, calculus, tables, and all the rest. … Arguably … even ‘purely’ intellectual capability—habits of mind tuned to particular services in scientific inquiry—should count as tools. (p. 39)
Therefore, much of education involves learning the proper uses of the tools with which we are routinely provided to accomplish various necessary tasks. Increasingly, the tools we use are software tools resident in small computers that are omnipresent in our environments. Many such tools have been explicitly created to assist cognition. For example Lajoie (1993) notes that *Sherlock I*, an artificial intelligence program, is purposely designed with built-in cognitive supports for memory. Similarly, the *Microsoft Office* suite has many templates, as does the *Inspiration* concept mapping program (www.inspiration.com). The *Knowledge Forum* online learning environment has built-in metacognitive supports (Scardamalia, 2004) in the form of a kind of labeling system for thinking types. Learners can attach these labels (supports) to statements in their postings and clarify for themselves what part of the thinking process they are engaged in. Additionally, *Knowledge Forum* also supports idea synthesis through the use of special forms of postings called *rise-aboves* that are used to bring together different ideas about a problem.

How does this relate to education and the spread of ideas? Computer tools for education should be designed to *extend* human cognition as tools of the past have done (the astrolabe and naval navigation chart being Hutchins’ (1995) examples), to distribute the cognitive load away from the brain and onto the tool: the computer (Jonassen, 1996). And it should be noted that each such tool is an extended and elaborated idea or theory, of how things should be done, often constructed over centuries (Hutchins, 1995). This, of course, requires a radical re-thinking of education, as much of the assessment of learning is based on removing precisely those tools that the students have been taught to use; to remove the essentials from the environment that students need for effective problem
solving. Pea (1993) notes, “Education often results in making far too many people look 'dumb' because they are not allowed to use resources, whereas outside of education we all use resources" (p. 73). Students are already very aware of software tools as a form of distributed cognition. Chen recounts this story (2002, p. xxii, original emphasis):

Recently, I met some middle school students who carry laptops in their backpacks. One boy told me how technology should not be a machine you go to, but a machine that goes with you. He said, somewhat impatiently, ‘It’s part of my brain. Why would I want to leave it behind in a computer lab?’

Much of human cognition therefore can be viewed as a system consisting of the individual, the people to whom they are connected, and the tools that they use. Computer-based tools are powerful cognitive extensions, and as we will see, the people to whom we are connected form a network, and the functioning of such networks can be important in how well the individual functions.

2.2 Innovation and Social Cognition in Organizational Contexts

In this section we examine how innovation functions in organizational contexts. As will be seen, social cognition is a factor, particularly the network to which the individual is connected.

Innovation in organizational contexts has received considerable attention in recent years, partly due to its importance commercially as we move into the changing economy of the knowledge age (Conference Board of Canada, 2007, 2008; UNESCO). Amabile (1996), for example has produced a componential model of creativity in an attempt to understand how creativity works in real-life. Her model has five steps: the identification
of the problem; the preparation phase during which a store of relevant information is either built up or activated from memory; a response generation phase during which the memory and environment guide the response possibilities; the validation of the response(s) against factual knowledge and against (knowledgeable) others; and the outcome, which can be success, failure, or some progress toward the goal. The process works recursively, returning to the appropriate previous stage until success or definitive failure is achieved. Amabile’s model was not intended to be specific to businesses—it is a general model of the creative process.

Amabile (1996, p. 82) notes that although innate talent plays a significant role in creativity, "[F]ormal education seems essential in most outstanding creative achievements (Feldman, 1980)". Amabile also suggests that experience in idea creation is a creativity-relevant skill that needs to be developed (Amabile, 1996, p. 84), and that anyone with normal cognitive skills can produce work that is to some degree creative (p. 82). Thus for a school to foster creative individuals, it must continue to teach a formal body of knowledge, but must also give students experiences in idea generation.

Nonaka and Takeuchi (1995) have examined innovation in corporate settings. They comment that for modern businesses,

[K]nowledge has gone from being an adjunct of money power and muscle power to being their very essence, and that is why the battle for the control of knowledge and the means of communication is heating up all over the world. (p. 7)

Nonaka and Takeuchi have produced a theory of organizational learning (1995). Unlike Amabile’s model, which was concerned with individual cognitive
processes, Nonaka and Takeuchi (1995) focus on the organizational aspects of creativity, particularly in workplace settings. Similar to Amabile’s model, innovation is viewed as proceeding in stages, but the stages differ. Nonaka and Takeuchi (1995) view the process as starting with the sharing of tacit knowledge among team members, moving on to creating concepts, justifying concepts, creating an archetype, and finishing with cross-leveling knowledge among the larger corporate group. Like Amabile’s model, this process also works recursively.

In organizational settings, Nonaka and Takeuchi (1995) argue that the creative process often begins when administrators identify a problem, and assemble a team with the requisite skills to solve it. They provide considerable evidence for this view. However, recent work in companies with considerable horizontal interaction among staff offers evidence of other patterns in which opportunistic collaboration among informal networks is critical to the creative process (R. L. Cross & Parker, 2004; R. L. Cross, Parker, Prusak, & Borgatti, 2003). The latter pattern seems to be a better match for a knowledge building classroom than Nonaka and Takeuchi’s model. However, Nonaka and Takeuchi’s emphasis on the sharing of tacit knowledge resonates with the perspectives of other researchers (e.g., Koschmann, Kelson, Feltovich & Barrows, 1996; Ogle, 2007) who observe that essential knowledge is often embedded in the practices and culture of a community.

2.2.1 Networks and Innovation

Knowledge building deals with the creation of new knowledge among the members of a knowledge building community. It is the purpose of this section to examine
what is known about the creation of new knowledge, innovation, from the perspective of networks.

While most of the models we have examined have discussed stages in the innovation process, some recent work on innovation has shifted the emphasis from the process of innovation (often viewed as linear) to the network(s) in which the innovator is embedded (Tuomi, 2002, p. 105).

Sawyer (2007) suggests that many people believe innovation is the property of solitary genius. However, he considers this a myth and devotes an entire chapter of his book (Chapter 6) to debunking it. He cites numerous examples of collaboration over time among, “… an invisible collaborative web …” of people who assist in the creation of any successful innovation (Sawyer, 2007, p. xi). Likewise, Berkun (2007) devotes a substantial portion of his book to a similar argument. Rogers argues that network interconnectedness is critical to the innovativeness of individuals (1995); Tuomi refers to this network as, “… a field of social interaction” (2002, p. 105). And Ogle (2007, p. 4) comments: "[The] interaction of the idea-spaces of the extended mind can be described equally in network terms. [These networks create] new patterns [of knowledge] as old ones collapse, fragment, connect, merge, and integrate." For Ogle, innovation and the network in which the individual is embedded are essentially the same thing. Lienhard, in (Berkun, 2007) similarly notes, “Rarely if ever are the networks that surround an innovation in its earliest stages given the credit they are due ... “ (p. 114, original emphasis).

This emphasis on the importance of networks on the innovation process has led to an interest in the importance of the network structure in innovation. Taleb (2007)
Borgatti (2005) notes two principle innovation network structures: one in which an individual interacts with others in their network, and then goes off to innovate on their own; and one in which individuals in the process of interacting co-create new knowledge through the integration of new perspectives. In some literature, the structure of the network is referred to as its *structural signature* (Skvoretz & Faust, 2002; Welser, Gleave, Fisher, & Smith, 2007); in other literature, its *topology* (Lewis, 2008).

Examples of the first structure, in which an individual interacts with a network and then innovates on their own, can frequently be found in artistic endeavours. Tchaikovsky’s creation of his first great work, the *Romeo and Juliet* overture (Brown, 2007) illustrates this.

In 1898, composer Mili Balakirev invited the young Tchaikovsky to join the network of composers and music-lovers he had created. Called the *Mighty Handful* after the first five composers to join, it also consisted of musical amateurs and others, who provided, among other things, plot suggestions for operas and program pieces. It was Balakirev who suggested to Tchaikovsky that Shakespeare’s *Romeo and Juliet* would make a good overture subject, and after the overture was presented to the group and with later revisions, it became a triumphal success. The details of this collaborative process in this case have been preserved in a series of letters among the group (Brown, 2007; Grove & Sadie, 1980). As well, the early drafts of the overture have been preserved and recorded, so that the nature of the changes can be studied (Tchaikovsky, 1993, original version, 1869; 2000, third version, 1880).
This process is common in artistic circles: the young newcomer joins a network, becomes encultered into its practices (a community of practice), then goes off and creates on their own. During the creative process however, they often return to their network for comments and suggestions on their work. Blades (1977) recounts how the composer Benjamin Britten presented him passages of his work-in-process of the operas *The Turn of the Screw* and *Albert Herring* to try out, making subsequent modifications in consequence. This author has worked in a similar fashion with Canadian composer Walter Buczynski in the creation of one of his compositions. Thus, although the innovator does work alone, they are in contact with their network and make use of it in refining their ideas. Nonetheless, Borgatti notes that such networks tend to be more sparse and “clumpy” than when groups work more closely to innovate through the integration of different perspectives (2005).

Borgatti (2005) suggests his second kind of network, in which groups innovate through the integration of different perspectives, is common in research settings. Sawyer (2007) states that innovations tend to build incrementally on prior innovations, that the innovation is a combination of many ideas (“sparks” in his terminology), that innovation is often a result of frequent interaction among teams, and that multiple discovery is common. In the latter case, this means that the same innovation may occur to a number of people in the network at about the same time. Incremental innovation of this type is typical of Kuhn’s *normal science*, which seeks to extend and elaborate the current best paradigms (1996). This second kind of innovation network is the kind one would most commonly associate with a knowledge building class.
Regarding any kind of innovation network, there are problems of management so that it produces the desired results (Gloor, 2006). This can be difficult for managers in business settings or teachers in knowledge building classrooms. Gloor, speaking about business contexts has found,

It is difficult for conventional managers to accept the idea that solutions are emergent rather than predefined and pre-programmed. Most managers would rather live with a problem they cannot solve than with a solution they do not fully understand or control. (2006, p. 21)

If we were to replace the term “manager” with “teacher” the quote would arguably still be accurate for modern schools. Galloway and Thacker (2007) suggest that networks cannot be controlled in a hierarchical manner, but need to be controlled in a less-precise, more general manner called protocological control. This notion will be discussed in greater detail in a later section.

2.3 What is Knowledge Building?

The previous section discussed the socio-cognitive perspective, and the role of social networks in innovation. This section examines knowledge building, a model of education that that can be situated among a group of “intellectual community” approaches that emphasize the communal or social nature of knowledge (Scardamalia & Bereiter, 1994). These approaches include communities of practice (Lave & Wenger, 1999; Wenger, McDermott, & Snyder, 2002), communities of learners (A. Brown, et al.,
1993), and problem-based learning (Koschmann, Kelson, Feltovich, & Barrows, 1996; Savery & Duffy, 2001).

While there are many reasons for dissatisfaction with current schooling models, an important one is the emergence of knowledge societies in which the, “… capabilities to identify, produce, process, transform, disseminate and use information …” are critical to human development (UNESCO, 2005). Sterling’s comment sums up the problem: “Today's young students are being civilized for an older civilization than our own” (Sterling, 2002, p. 42).

Scardamalia and Bereiter define knowledge building as follows (2003, p. 1371):

Knowledge building may be defined as the production and continual improvement of ideas of value to a community, through means that increase the likelihood that what the community accomplishes will be greater than the sum of individual contributions and part of broader cultural efforts. Knowledge building, thus, goes on throughout a knowledge society and is not limited to education.

This definition illustrates a key difference between knowledge building and other intellectual community approaches: the production of new knowledge. Learning, in a traditional sense, involves the transferal of knowledge and skills from one generation to the next. Scardamalia and Bereiter (2003) refer to this as the distribution of the cultural capital of society. In contrast, learning in knowledge building communities is indirect—it occurs, “… as a by-product of activity carried out for another purpose …” (Bereiter, 2002, pp. 295-296). The “other purpose” is the productive work of creating new knowledge (2002, p. 295). This notion of a community creating “new knowledge” is
sometimes misunderstood. The knowledge may be new only to the group, as in a class of students, rather than new to the world. This new knowledge typically includes, “… theories, explanations, problem formulations, interpretations …” (Scardamalia & Bereiter, 2000, ¶8). Scardamalia and Bereiter further note (2000, ¶8),

The knowledge that is created may not have much value beyond the local group ... but within that group students are contributors to a common good. Like workers in a modern industry, they are contributing to the knowledge resources of the organization.

Knowledge building communities can take many forms. Academic research teams are often cited as prototypical examples of knowledge building communities (Scardamalia & Bereiter, 1999). In business contexts, some organizations have reinvented themselves as knowledge building organizations. Using research centres as their ideal, management, sales, and secretarial teams have been re-structured as knowledge building communities, as have some manufacturing processes (Scardamalia & Bereiter, 1994, 269). In the arts, we can also find many instances of groups that share the ideals of knowledge building communities. Sawyer (2007) presents analyses of both jazz musicians and improvisational theatre troupes as examples of what he calls group genius–knowledge creating groups. The Russian Mighty Handful and their associated group is another example (previously discussed in the section on innovation). It is because of the multiplicity of knowledge building communities external to schools that the term “knowledge building” was chosen in the first place, providing continuity with these other knowledge building communities (Scardamalia & Bereiter, 1994).
School-based knowledge building communities are hoped to be good preparation for living and working in knowledge societies (Bereiter, 2002, pp. 295-296) in which, “… the values and practices of creativity and innovation will play a major part …” (UNESCO, 2005, p. 19). Like problem-based learning, which seeks to, “[a]nchor all learning activities to [an authentic] larger task or problem …” (Savery & Duffy, 2001, p. 5), knowledge building places an emphasis on real problems that have the potential to, “… [advance] the frontiers of knowledge as these are perceived by the community …” (Scardamalia & Bereiter, 2003). As Scardamalia and Bereiter note (2000, ¶6):

Community knowledge building ... deals with problems that arise within the community–real phenomena that people are puzzled about, real texts in need of interpretation, and so on. ... [T]he focus of knowledge building is on the knowledge itself, its physical representation being secondary.

2.3.1 How do Knowledge Building Community classrooms differ from conventional classrooms?

Early schools for mass education, at least in North America, were patterned as common schools in which students of all ages learned a common curriculum together in a single large room (Urban & Wagoner, 2004). By the early 1900s, this model was breaking down due to the large influx of children from foreign-immigrant families and families moving to the cities from rural areas (Steiny, 2007). Steiny (2007) notes that the model chosen to replace the common schools was the industrial factory. Quoting Ellwood P. Cubberly, an early 20th C historian, these scientific schools were to be, “… factories in which the raw materials [were] to be shaped and fashioned into products to meet the
various demands of life” (2007, ¶6). These raw materials were children, as noted by others as well, e.g., Dr. Franklin P. Bobbitt, a professor to education at the University of Chicago in the early 1900s, who regarded factory model schools as places,

... where the material acted upon by the labor processes passes through a number of progressive stages from the new material to the ultimate product,

definite quantitative and qualitative standards must be determined for the product at each of these stages. (in Button & Provenzo, 1983, p. 218, original emphasis)

Knowledge building community classrooms represent a significant departure from the factory model of schooling. Focused on student ideas about problems of real substance, knowledge building classes emphasize the cyclical nature of the knowledge creation process, with an emphasis on the continual improvement of ideas (Scardamalia & Bereiter, 2006). Students work on a problem, gather information about it, revise their ideas in discourse with others in a continuous flow of inquiry for as long as time permits. The focus is not on memorization of facts, but rather on, “… problems and depth of understanding … decentralized, open knowledge environments for collective understanding … [and] …productive interaction within broadly conceived knowledge-building communities” (Scardamalia & Bereiter, 1994, p. 274).

How does knowledge building differ from other inquiry-based approaches such as communities of practice and problem-based learning? Scardamalia and Bereiter (2006, p. 2) list the following distinctive attributes of knowledge building:

• Knowledge advancement is viewed as a community achievement rather than an individual achievement;
• Knowledge advancement is understood as idea improvement rather than as progress toward true or warranted belief;
• There is a valuing of “knowledge of” rather than “knowledge about”;
• Community discourse takes the form of collaborative problem solving rather than argumentation;
• Authoritative information is used constructively rather than accepted as truth;
• Understanding is viewed as an emergent [property of the process].

Let’s consider these more closely. Knowledge advancement as a community is different from the traditional school practice of valuing individual achievement. Individual effort is rewarded in traditional marking systems; collective effort generally is not. Although no one would suggest that traditional classes do not form communities, the communal production of knowledge is generally not valued, or encouraged in conventional classrooms.

In much of today’s schooling, knowledge is treated as canonical and not to be questioned. In contrast, knowledge building classes encourage knowledge advancement and idea improvement. All knowledge is viewed as improvable (Bielaczyc, 2007; Scardamalia, 2002; Scardamalia & Bereiter, 2006). Knowledge building emphasizes knowledge of rather than knowledge about.

Authoritative sources are not rejected in knowledge classes, but are judged as to their promisingness in solving a problem. Promisingness can be judged by asking if the idea has a direct match to the desired goal (a solution to the problem; if the idea matches the cognitive capabilities of the student; and if the idea points to further possibilities
Finally, understanding is an *emergent* property of the knowledge process. An emergent property is any property of system that arises from self-organization due the horizontal interaction among the agents of the system (J. Cross, 2009; Galloway & Thacker, 2007; Holland, 1998; S. Johnson, 2001; Waldrop, 1992). It is through their work to solve a problem that students interact through knowledge building discourse, and it is these interactions that produce emergent understandings. Hewitt (1996, pp. 28-29) notes that knowledge building involves a sustained study in depth, sometimes a period of months (as in the case study reported here). Such time spans are often a problem for teachers with overloaded curricula. Punja (2007) documents such a case in medical education.

In knowledge building classes, the role of the teacher changes. To highlight the nature of this change, Scardamalia and Bereiter (Scardamalia, 2002; Scardamalia & Bereiter, 1991) offer the following distinction between different types of teachers:

- Teacher A, for whom learning is a by-product of schoolwork and who does all planning and supervision. In Teacher A classes the students do as they are told, and take no agency for their own learning. All of the focus is on tasks and activities;
- Teacher B, for whom learning involves recognizing cognitive objectives and plans these into lessons. Teacher B makes the students aware of cognitive objectives, but does not give the students agency over the learning process and also focuses on tasks and activities; and
• Teacher C, for whom learning involves turning over the higher-level processes that have traditionally remained under the teacher’s control. The principal difference between Teacher B and Teacher C models is that Teacher C allows the students to take over, “… the control structure of activities in the zone of proximal development” (1991, pp. 40-41).

The Teacher A and Teacher B models reflect traditional teaching practice. The Teacher C model is required for knowledge building. For genuine knowledge building to occur, students need to take epistemic agency over their learning (Law & Wong, 2003; Nirula, 2004; Scardamalia, 2002b). This tends not to happen with the Teacher A or B model. Therefore one of the key challenges facing teachers trying to establish knowledge building classes is the difficulty of shifting from the Teacher B model towards the Teacher C model. Scardamalia (2002, pp. 3-4) notes,

For teachers to move from endorsing the Teacher C model to the point where they actually practice it is evidently a significant learning accomplishment in its own right, requiring a good deal of coaching, reflective practice, and mutual support (Anderson & Roit, 1993). It represents overcoming a career-long habituation to being the sole engineer of the learning process, however that is conceived.

Getting teachers to actually use the Teacher C model in practice is made more difficult because many teachers already believe that they are trying make students take agency over their learning. However such agency often devolves into having the
students take agency for the responsible completion of tasks (Scardamalia, 2002), not assuming control of higher-level processes. As well, a particular teacher may at different times move among the Teachers A, B, and C models, at one time being Teacher A, and at others being Teacher B or C. The fact that teachers believe that they are running their classes in a knowledge building manner, while actually using control structures that hinder it, represents a major impediment to establishing knowledge building in the classroom.

For the purposes of this thesis, we will not focus on all aspects of the Teachers A, B and C models. Instead we will focus on the shift on the locus of control necessary to give the students epistemic agency, which is a distinctive and defining characteristic of Teacher C practices.

2.3.2 How can teachers foster a Knowledge Building Community in their classrooms?

Knowledge building can occur in many different settings, from businesses (Nonaka & Takeuchi) to hospitals (Punja, 2007; Russell & Honkela, 2005), to schools (Philip, 2006; Zhang, Scardamalia, & Reeve, 2006). The Institute for Knowledge Innovation and Technology (www.ikit.org) lists active knowledge building research in nineteen different countries at the present time (see http://ikit.org/ksn.html for details). Examples of this work include a project in four British schools (Macdonald & Parry, 2007), work in Hong Kong schools (Law, 2005; Law & Wong, 2003), Canadian schools (Zhang et al., 2006) and U.S. schools (Bielaczy, 2007; Lemke, 1998). It has been found that teachers in different settings have evolved different techniques for creating knowledge building communities. Because many businesses have also been attempting
to make the transition to knowledge building communities, we will first consider business efforts, and then we will turn our attention to school settings.

Because of the transition from an industrial age economy to a knowledge based, knowledge age economy (Trilling, 2005), many businesses have decided that they need to restructure into flexible, less hierarchical organizations. Cross, Prusak, Borgatti, and Parker (2003, p. 261) state that, “A byproduct of these restructuring efforts is that coordination and work increasingly occur through informal networks of relationships rather than through channels tightly prescribed by formal reporting structures or detailed work processes.” Thus, to create a knowledge building community, whether in a business or a classroom, part of the challenge is to change the patterns of discourse from hierarchical, formal structures to more informal networked structures. This means that a large part of the job of managers and teachers in knowledge building communities is to create the structures and protocols that foster collaborative, knowledge building interactions. Such networks are sometimes termed horizontal networks, distinguishing them from vertical hierarchical structures (Stein, 2001, p. 29).

Cross et al. (2003) have identified a number of workplace practices that are consistent with knowledge building. They note that knowledge sharing and idea spread are facilitated by relational qualities (2003). For Cross et al. (2003), relational qualities refer to those qualities of work relationships that allow for the creation of the informal networks that dictate workflow in organizations. In knowledge creating organizations, it is among these informal networks (Gloor’s (2006) collaborative innovation networks) that new knowledge most often is created. Cross et al. (2003) note that relational qualities include protocols to allow individuals to learn what other members of the network know;
protocols to enable individuals to access the information of others; protocols to enable engagement with others, to “… think with the seeker” (2003, p. 211); protocols to ensure that individuals feel secure enough to report that they don’t know or don’t understand something (critical for supporting the knowledge creation process (2003, p. 231)); and protocols ensure public knowledge sharing (2003, p. 210-211, 219). They further note,

By and large, most solutions that companies considered [to improve collaboration] were technical in nature and included such things as e-mail, asynchronous and synchronous collaborative environments, video conferencing, and instant messaging. However, we generally find that organizational design considerations and cultural norms are the more powerful indicators of who is accessible to whom. (2003, pp. 222-223, emphasis added)

Cross et al. (2003) noted the importance of cultural norms in creating knowledge building communities in the workplace. Bielaczyc makes a similar comment regarding the creation of knowledge building communities in the classroom:

We need to go beyond understanding the impact of a given classroom social infrastructure on the integration of a technology-based tool and begin to systematically identify and analyze the aspects of social infrastructure that are amenable to design. (2006, p. 303)

To this end, Bielaczyc has created the Social Infrastructure Framework as a tool for analysis of classroom practices (2006). The framework examines:
• **Cultural beliefs**: These determine what students and teachers need to do to move from a traditional classroom to a technology-based knowledge building environment;

• **Practices**: Students and teachers need to participate in classroom practices that build the skills and knowledge needed to effectively participate in knowledge building classes;

• **Socio-techno-spatial relations**: The ways in which technology is arranged in the classroom is different in different classrooms, and this affects how students and teachers go about their knowledge building interactions; and

• **Interaction with the outside world**: In some cases, knowledge building technologies allow students to interact with the outside world. Both students and mentors need to understand in interaction protocols that facilitate knowledge building.

As Hewitt states, "A key element of any community concerns the accepted *protocols* for interaction" (Hewitt, 2004, p. 30, emphasis added). The Social Infrastructure Framework provides a framework for examining these protocols.

Bielaczyc (2007; Bielaczyc & Collins, 2002) studied Whitman school in the United States and ICS in Canada. The Whitman team consisted of four teachers who shared a common set of beliefs that they frequently articulated during classroom discourse, interviews, etc. (p. 3). These beliefs were used to guide classroom practice (p. 3):

- Learning needs to build from existing knowledge.
- Knowledge differs from information.
- Knowledge is always improvable.
- It is “okay” not to know.
- Knowledge building requires time and reflection.

The Whitman team also developed their own protocols for fostering creativity that included organizing students into teams, the use of outside experts; mini-lessons involving student postings that were presented to the class to facilitate discussion; encouraging students to create “reflection notes” in which the students enter their reflections about their learning; and the use of culminating events to promote reflection and synthesis (Bielaczyc & Collins, 2002).

The Institute of Child Studies (ICS) also has a knowledge building team, and they share some of the same protocols as the Whitman team. However, they also have developed unique protocols of their own. These include varying topics so that students are not all working on the same topic at the same time, using a variant of crosstalk called “knowledge building talk” that allows students to report on their work and discuss it with other students; the creation of glossary notes and teaching notes (written by students to help synthesize and explain their knowledge); and having senior classes teach more junior classes (Bielaczyc & Collins, 2002).

The teachers at both Whitman and ICS used a computer system to create a shared online space for students where they can make their knowledge public. However the presence and use of a computer system, by itself, does not create a knowledge building community (Bielaczyc, 2007). Rather a knowledge building community requires a fundamental shift in the cultural practices of a classroom in favor of student agency and a
shared dedication to the collaborative production and progressive refinement of new knowledge.

The preceding ideas are consistent with the Hewitt’s longitudinal study of a knowledge building classroom (Hewitt, 2004). Over a four-year period, he documented a shift in student and teacher roles. The traditional student role of completing teacher-designed activities was gradually replaced with collaboratively defining research problems, collaborative planning, synthesizing ideas, and collaboratively understanding the problem under study. Goals for the students included both deepening their personal knowledge and advancing the collective knowledge base (p. 5). Teacher roles included functioning as an expert learner, to encourage discourse rather than activities to produce products (p. 5).

Zhang et al. (Zhang, et al., 2006; Zhang, Scardamalia, Reeve, & Messina, 2009), in a three-year longitudinal study of interaction patterns among a knowledge building class in a Toronto school, found three different types of organization created by the teacher. In year 1, the teacher used a fixed small group model; in year 2, an interactive small-groups collaborating model; and in year 3 a fully opportunistic collaboration model, with no groups formally assigned. The latter resulted in, “... small teams forming and disbanding under the volition of community members, based on emergent goals that arose as they addressed their shared, top-level goal of refining their knowledge …” (2006, p. 1).

Bielaczyc (2006) also found that the Whitman teachers experimented with a variety of organization structures for knowledge building. She noted that differing participant structures can be used as long as they are consistent with the principles of the
learning theory being employed (p. 310). The Whitman team was faced with a special challenge in that they had to manage over one hundred students. As a result, they could not use the fully opportunistic collaboration model favoured in Zhang et al. (2006) during year three. Instead, the teachers created small groups in an effort to make communal knowledge building manageable (Bielaczyc, 2007).

It has been proposed that twelve emergent trends in student work tend to support knowledge building, and these have been termed the twelve knowledge building principles (Bereiter, 2002; Nirula, 2004; Scardamalia, 2002) by Scardamalia (2002). The twelve principles are:

- **Real Ideas/Authentic Problems**: Students work with ideas from the real world, ideas that are meaningful to them and their lives.
  - *Technological dynamics*: “Knowledge Forum creates a culture for creative work with ideas. Notes and views serve as direct reflections of the core work of the organization and of the ideas of its creators.” (Scardamalia, 2002)

- **Improvable Ideas**: Ideas are not seen as fixed, but instead are viewed as being capable of improvement. In order for this to happen, an environment in which it is safe to put forward incomplete ideas, notions, and theories must be created.
  - *Technological dynamics*: “Knowledge Forum supports recursion in all aspects of its design—there is always a higher level, there is always opportunity to revise. Background operations reflect change: continual improvement, revision, theory refinement.” (Scardamalia, 2002)
Constructive Use of Authoritative Sources: Students improve their ideas through (among other things) making use of the knowledge found in books and other authoritative sources. Students are also encouraged to take a critical stance towards these sources.

Technological dynamics: “Knowledge Forum encourages participants to use authoritative sources, along with other information sources, as data for their own knowledge building and idea-improving processes. Participants are encouraged to contribute new information to central resources, to reference and build-on authoritative sources; bibliographies are generated automatically from referenced resources.” (Scardamalia, 2002)

Pervasive Knowledge Building: Knowledge building becomes the normal mode of classroom functioning, and tends to carry over into the students’ daily lives.

Technological dynamics: “Knowledge Forum encourages knowledge building as the central and guiding force of the community's mission, not as an add-on. Contributions to collective resources reflect all aspects of knowledge work.” (Scardamalia, 2002)

Symmetric Knowledge Advance: Symmetry in knowledge advancement is the result of knowledge exchange, and is reflected in the flow and reworking of information during the knowledge building process (Scardamalia, 2002).

Technological dynamics: “Knowledge Forum supports virtual visits and the co-construction of views across teams, both within and between communities. Extended communities serve to embed ideas in increasingly broad social contexts. Symmetry in knowledge work is directly reflected
in the flow and reworking of information across views and databases of different teams and communities.” (Scardamalia, 2002)

- **Democratizing Knowledge:** Knowledge is seen not as the property of a more experienced other (teacher or other authority figure), but the property of everyone in the class. Anyone can work with, and improve any knowledge object. This harkens back to Fisher and Fisher (1998), who noted that a key descriptor of knowledge work teams was that they are egalitarian (p. 117), another way of saying that knowledge in such teams should be democratized.

- **Technological dynamics:** “There is a way into the central knowledge space for all participants; analytic tools allow participants to assess evenness of contributions and other indicators of the extent to which all members do their part in a joint enterprise.” (Scardamalia, 2002)

- **Embedded, Concurrent, Transformative Assessment:** In advancing their knowledge, students must take a critical stance to both their own knowledge and their efforts to gain and improve it. They must therefore assess their progress continually. A suite of assessment tools built into Knowledge Forum is a powerful tool to aid in this process.

  - **Technological dynamics:** “Standards and benchmarks are objects of discourse in Knowledge Forum, to be annotated, built on, and risen above. Increases in literacy, twenty-first-century skills, and productivity are by-products of mainline knowledge work, and advance in parallel.” (Scardamalia, 2002)
• **Community Knowledge/Collective Responsibility**: The knowledge building community has a set of top-level goals, real-world problems that guide its path. It is the responsibility of all members to work to advance these goals by advancing ideas of value to the community.

  • **Technological dynamics**: “Knowledge Forum's open, collaborative workspace holds conceptual artifacts that are contributed by community members. Community membership is defined in terms of reading and building-on the notes of others, ensuring that views are informative and helpful for the community, linking views in ways that demonstrate view interrelationships. More generally, effectiveness of the community is gauged by the extent to which all participants share responsibility for the highest levels of the organization's knowledge work.” (Scardamalia, 2002)

• **Epistemic Agency**: In order to improve a body of knowledge, students must take personal responsibility for improving their own knowledge, and the class’s knowledge. In so doing, they must take responsibility for setting personal goals, evaluating their ideas, creating personal motivation, and engaging in long-range planning, tasks usually left to the teacher.

  • **Technological dynamics**: “Knowledge Forum provides support for theory construction and refinement and for viewing ideas in the context of related but different ideas. Scaffolds for high level knowledge processes are reflected in the use and variety of epistemological terms (such as conjecture, wonder, hypothesize, and so forth), and in the corresponding growth in conceptual content.” (Scardamalia, 2002)
• **Knowledge Building Discourse:** Knowledge building discourse is transformative discourse around ideas, and is the process by which ideas are improved by the knowledge building community.

  • **Technological dynamics:** “Knowledge Forum supports rich intertextual and inter-team notes and views and emergent rather than predetermined goals and workspaces. Revision, reference, and annotation further encourage participants to identify shared problems and gaps in understanding and to advance understanding beyond the level of the most knowledgeable individual.” (Scardamalia, 2002)

• **Rise Above:** Attempts are continually made to rise above current understandings through the synthesis of ideas to arrive at improved ideas, higher-level formulations of problems, or more inclusive principles.

  • **Technological dynamics:** “In expert knowledge building teams, as in Knowledge Forum, conditions to which people adapt change as a result of the successes of other people in the environment. Adapting means adapting to a progressive set of conditions that keep raising the bar. Rise-above notes and views support unlimited embedding of ideas in increasingly advanced structures, and support emergent rather than fixed goals.” (Scardamalia, 2002)

• **Idea Diversity:** Idea improvement works best when there is a diversity of ideas to stimulate knowledge building discourse. To this end, students are encouraged to put forward their ideas, and to try and find alternate approaches to problems.
Technological dynamics: “Bulletin boards, discussion forums, and so forth, provide opportunities for diversity of ideas but they only weakly support interaction of ideas. In Knowledge Forum, facilities for linking ideas and for bringing different combinations of ideas together in different notes and views promote the interaction that makes productive use of diversity.” (Scardamalia, 2002)

2.4 Knowledge Forum

In the previous two sections, we discussed knowledge building and innovation. This section will discuss Knowledge Forum, software designed to support knowledge building pedagogy and innovation.

Knowledge Forum is a second generation product of the Computer-Supported Intentional Learning Environment (CSILE) project (Scardamalia, 2004). In common with many current software packages, there is an integration between theory and software, and Knowledge Forum cannot be effectively used without explicit knowledge of knowledge building pedagogy.

2.4.1 The Knowledge Forum Software Package

Knowledge Forum (KF) began as CSILE (computer-supported intentional learning environment) in 1983 at York University (Scardamalia, 2002a), and moved by 1985 to the Ontario Institute for Studies in Education (Bereiter, 2003, p.6). It was first deployed in an elementary school classroom in 1986 (Bereiter, 2003, p. 6). From the beginning, CSILE was conceived of differently from other groupware products in that it is a database rather than an extension and elaboration of e-mail (Bereiter, 2005, p. 5).
This database structure allows for a different and more flexible way of working than more traditional groupware environments.

KF supports the knowledge building process and is designed to allow students to form a knowledge building community resembling a research community (Austin, 2002; Brett, 2002; Hewitt, 1996). It is important to realize that this manner of work is an emergent property of the online environment, Cross’ “… ‘utopian dream’ of e-learning on the way to the future” (J. Cross, 2009).

In terms of function, Knowledge Forum is a database that is organized into views: virtual spaces in which discourse around related ideas is entered as notes and recorded for reading by other students and for later contemplation and reflection. The existence of a permanent form of discourse (KF views and notes) creates a public communal space and this fundamentally changes the nature of the discourse in that it can be reviewed, reflected upon, and improved (Austin, 2002; Hewitt, 1996). In contrast, discourse in the live-class setting is ephemeral and ideas can easily be lost.
2.4.2 Knowledge Forum in Practice

Figure 1: Two Knowledge Forum views showing the various features of Knowledge Forum.

Figure 1 shows two views created by a Gr. 5/6 class using KF. When first presented with a KF database, it is essentially an “empty vessel”–it contains no content,
although the teachers can “seed” it if they wish. The students and teacher provide content in the form of notes containing their ideas or information from authoritative sources. Students can add information to, or discuss another student’s ideas by the process of building-on to the other student’s note. Using the build-on function, the students create a new note that is perceptually linked (via a visible representation—a line) to the original note (see Figure 1). Over time, this creates a network of interactions visible to the students. Students can organize these into meaningful groupings in the manner of a concept map (Jonassen, 1996). Views can have a graphic inserted to serve as a background, and students frequently create these and use them to organize their notes. The term view might be a little unfamiliar, so it might help to think of a view as being a kind of collective workspace.

Notes are similar to postings in other groupware systems, but have certain built-in functions that are designed to support the knowledge building process. Among these are metacognitive scaffold supports that can be used to reify thinking types and focus students on other aspects of their learning tasks; a keywording function that allows students to select what they consider to be important words in their notes and to make them searchable; a referencing function that allows students to reference the notes of other students in the manner of a scholarly reference; and a full search function that allows students to find content in other notes and views. See Scardamalia (2004) for more on these and other functions.
2.4.3 The Analytic Tool-Kit

Records of all online activities are automatically maintained in server logs. These logs are used as a data source by a program call the analytic tool-kit (ATK). The ATK is a suite of tools designed to assist the teacher and students in assessing their performance in the online environment by analyzing the interactions with the environment. By tracking such interactions, it can be determined how many notes a student creates, how many build-ons (responses) they create, who has read the notes of other students, and many other types of information. In other words, the ATK can be used to track how effectively the students are using the various knowledge building affordances offered in the online environment. The ATK allows people to study collaborative learning processes in ways that were not previously possible. Knowledge building researchers are currently experimenting with the ATK in an effort to identify the kinds of reports that teachers and students find most useful. Recent studies have used ATK data to uncover previously undetected learner behaviour (Philip, Burtis, Laferriere, Lamon, & Allaire, 2004; Sha & van Aalst, 2004), and there has been interest in further exploring it to find out what else it can tell us. As well, recent additions to the ATK by the programming team from the Institute for Knowledge Innovation and Technology have provided additional tools to teachers and students: a social network tool, a vocabulary analysis tool, a writing analysis tool, a semantic overlap tool, and others still under development.
2.5 Ideas

In previous sections we discussed concepts of innovation and knowledge building. A key component of the knowledge building process is the spread of ideas among the members of the knowledge building community. This section briefly examines ideas and misconceptions.

As noted earlier, ideas are central to the knowledge building process. However, the word *idea* is somewhat vague. Consider the following definition from the American Heritage Dictionary (Newman, 2000):

NOUN: 1. Something, such as a thought or conception, that potentially or actually exists in the mind as a product of mental activity. 2. An opinion, conviction, or principle: has some strange political ideas. 3. A plan, scheme, or method. 4. The gist of a specific situation; significance: The idea is to finish the project under budget. 5. A notion; a fancy.

Based on this, an idea could be practically any mental event at all. Other definitions are similarly broad, and for the kind of analysis needed for Knowledge Forum notes, not useful. However, one thing that is apparent from such definitions is that our traditional concept of the idea has more than one level: there is the level of the document (i.e., the central idea in a novel); the level of the paragraph; the level of the sentence; and the (essentially atomic) level of the noun. Since this thesis is concerned with the spread of ideas in knowledge building classrooms, a greater level of specificity is required. The Methodology section will discuss this further, and how the level of analysis was chosen.
One concern about idea spread that frequently comes up in discussions about online learning environments is the problem of misconceptions spreading. Do open environments like Knowledge Forum propagate misconceptions among students? Burtis et al. (1993) have analyzed this quantitatively and qualitatively. Overall, only about 2% of the contributions to the online database they studied were misconceptions. Among those, they found that,

When misconceptions did appear as information, they generally went unrecognized. However, when they appeared as hypotheses, progress was often made toward resolving them. The interview data further support the idea that misconceptions were usually conjectures which guided further enquiry. (Burtis, et al., 1993, pp. 2-3)

Therefore, there appear to be self-correcting mechanisms in online learning systems that allow for misconceptions to be identified as such, and to allow better ideas to spread.

2.6 Summary

The Knowledge Age is one of four major cultural shifts that have changed how humans relate to their environment. Many believe that, “… this shift to knowledge-based societies is as historic and as challenging as the shift from the Agricultural Age to the Industrial Age” (Trilling, 2005, p. 1). Being the most recent, the Knowledge Age poses questions for educators and others, as we are less familiar with it. Lévy (1998) has identified virtualization as a key characteristic of the Knowledge Age, and through that lens we have seen that virtualization has the characteristics of deterritorialization (no
specific locus in space), detachment from the original context, sharing among individuals, elevation to a problematic in various ways, and heterogenesis, changing in the process of virtualization. Abrami et al. (2006) recently highlighted the need for education to change (undergo heterogenesis) when moving into the (virtualized) e-learning area. Each previous age had a form of education associated with it, and we can expect that the Knowledge Age will evolve its own form(s) of education. Recent work in cognitive psychology has provided clues as to what form this will take.

The socio-cognitive perspective has shown that it is useful to view human cognitive abilities as situated in a physical and social context. Much of our intelligent behaviour is rooted in our interactions with our tools (cognitive as well as physical) and with other people. The study of such interactions among tools and people has led to theories such as communities of practice (J. S. Brown & Duguid, 1991; Lave & Wenger, 1999; Wenger, et al., 2002) in which individuals are viewed as being situated in a community having a common goal or object to direct their communal work, and who move from the periphery to the centre as their level of expertise increases.

Due to shifts in the economies of many countries, there has been a recent focus on innovation and organizational learning as a path to economic success. In a parallel development, many of the ideas being promulgated in business settings are echoed by educational research leading to a synergy between them. In particular, there are similarities among research into organizational learning in business settings and knowledge building theory (Bereiter, 2004; Scardamalia & Bereiter, 2003). Common among these approaches are communal work and the sharing of knowledge, the externalization of tacit knowledge, the recursive nature of the innovation process, and the
complexity of the knowledge being shared. Recent work highlighting the importance of networks in the innovation process was discussed.

Because of the increased emphasis on the socio-cognitive perspective, and the increasing need for innovation in our society, the knowledge building perspective has become an important model for education in the knowledge age. Classroom practices need to be transformed from a Teacher A or B model into a Teacher C model emphasizing the twelve knowledge building principles as guiding principles in this effort.

Knowledge building, a focus of the present study, has a mediating artifact in the form of the Knowledge Forum (KF) software package. In addition to a flexible discourse space, metacognitive scaffolding tools, search functions, etc., KF also has a suite of analytic tools that can be used to analyze student interactions with the environment and each other, and which were used in the present study.
CHAPTER 3: SOCIAL NETWORK ANALYSIS

3.0 Overview and Introduction

This chapter continues the literature review begun in Chapter 2, but shifts the focus specifically to social network analysis and related items.

“Social network analysis takes as its starting point the premise that social life is created primarily and most importantly by relations and the patterns formed by these relations” (Marin & Wellman, 2009, p. 1). Social network analysis (SNA) has evolved techniques for analyzing interaction patterns among individuals in a social group using mathematics derived from Graph Theory (Watts, 1999). In the past, the mathematics of SNA made the study of larger groups difficult, but the advent of SNA software capable of running on current microcomputers has led to faster and easier analyses than was previously possible, greatly increasing the utility of SNA to researchers (Rogers, 1995, p. 308). SNA is useful to researchers because information and knowledge flow along the communication paths among group members (Rogers, 1995), and SNA makes these paths visible (R. L. Cross, 2006). According to Stein and Stren (2001, p. 3), “The network has become the pervasive organizational image of the new millennium”.

In recent years there has been a great deal of attention paid to the social networks that form during working relationships in various organizational settings such as businesses (Cott, 1997; R. L. Cross, Borgatti, & Parker, 2003; Hakkarainen, Palonen, Paavola, & Lehtinen, 2004; Nardi, Whittaker, & Schwarz, 2000; Palonen, 2003; Palonen, Hakkarainen, Talvitie, & Lehtinen, Submitted for publication), public service (Palonen, Hakkarainen, Akkerman, Lehtinen, & Voeten, 2005), research groups (Stein, 2001; Stren,
2001), and schools (Aviv, Erlich, Ravid, & Geva, 2003; Bearman, Moody, & Stovel, 2004; Grabmeier, 2005; Hakkarainen & Palonen, 2003; Ortiz, Hoyos, & López, 2004; Palonen & Hakkarainen, 2000). However, even with the widespread interest, there remain significant gaps in our understanding of social networks. For example, Kumar et al. (2006) note a lack of work on the evolution of real-world networks. Most current work has focused on networks as they exist, but not how they evolved.

With the aforementioned emphasis on teamwork as a 21st century skill to increase both innovation and competitiveness in business settings (Azzam, 2007; Crane, et al., 2005; The North American Council for Online Learning and the Partnership for 21st Century Skills, 2006; Wallis & Steptoe, 2006), examination of the social networks that form when working with ideas has become increasingly important (Rogers, 1995, p. 303). Since sustained collaborative work with ideas is central to knowledge building, there is a natural fit with SNA and knowledge building classes. In order to understand SNA, it is necessary to describe how the data are presented and how the measures are used to analyze the networks. These will be discussed next.

SNA is a field of study in and of itself, and will be dealt with here in a somewhat cursory fashion. Readers wishing to delve deeper into the field are advised to look at the following books and sources: From simplest to most detailed, these include Social Network Analysis, A Brief Introduction (Krebs, 2006), Networks for Newbies (Wellman, 2003), Social Network Analysis: An Introduction (Marin & Wellman, 2009), Studying Online Networks (Garton, Haythornthwaite, & Wellman, 1997), Social Network Analysis: A Handbook (Scott, 1991), Introducing Social Networks (Degenne & Forsé, 1999), Social Network Analysis (Wasserman & Faust), and Network Science: Theory and Practice.
(Lewis, 2008). Since this is a fast-moving field, other well-written sources could appear at any time.

3.1 Sociograms and Network Measures

Data for SNA are collected in a variety of manners and the specific methods used in the current study are described in Chapter 4. Once the data are collected, they are typically organized into a matrix that can nowadays be imported into a computer program and analyzed there.

3.1.1 Sociograms

The principle method of data presentation in SNA is in the form of a diagram called a graph in Graph Theory and a sociogram in SNA (Watts, 1999). To avoid confusion with the more common usage of the term graph to mean a Cartesian coordinate system, the term sociogram is used throughout this thesis. A sociogram consists of a set of dots representing actors in the network, and connecting lines, called arcs or edges, representing relations among the actors. Sociograms can be of two kinds: directed and undirected (Degenne & Forsé, 1999). In undirected sociograms, interactions are presumed to be reciprocal, so there is no directionality, but in directed sociograms, interaction can proceed in one direction or in both, depending on the data. For certain purposes, directed sociograms are sometimes symmetrized (made undirected) to make analyses easier (Borgatti, Everett, & Freeman, 2002). Figure 2 shows a sociogram and is used to explain some typical features of a social network.
Figure 2. A simple sociogram showing a simulated social network. This sociogram is generated from a random graphing program and does not represent real data. It is used for demonstration purposes only.

Figure 2 shows a social network consisting of ten actors, represented as dots, and the interactions among them represented as lines (edges, with arrowheads). This is a directed sociogram, and the arrows show the direction of interaction. In order to better understand the current study, we will assume that each dot represents a student, and each edge (line) represents one or more communications among them: in this case, opening and reading a Knowledge Forum note.

Looking first at nodes 7 and 8, the arrowhead points to 7, indicating that student 8 has read one or more notes by student 7. In social network terms, this represents an
indegree for student 7 and an outdegree for student 8. Indegrees and outdegrees will be discussed further below, as they are important measures of centrality, again, a concept that will be discussed below.

Looking at students 4 and 5, we can see that the arrowhead goes both ways, indicating reciprocal communication. This means that student 4 has read at least one of student 5’s notes, and student 5 has read at least of student 4’s notes. Reciprocal communication is important in the communication of complex knowledge (Hakkarainen, et al., 2004; Hansen, 1999), and therefore it is important to know about for knowledge building classes (as they frequently deal with complex knowledge). One-way communication is important for overall groups cohesion (Granovetter, 1973) and for the communication of simple information (Hakkarainen, et al., 2004; Hansen, 1999).

Looking again at student 5, we can illustrate another characteristic of social networks. If student 5 were to be removed from the class, students 10 and 2 would no longer be connected to the main group. A node whose removal isolates other nodes from each other is called a cut-point (Degenne & Forsé, 1999) or structural hole (Scott, 1991). Cut-points are important because they can disrupt communications among group members if they are removed. Cut points can also result in informational bottlenecks in which one individual mediates a large part of the communication between networks. Cut point individuals can become overloaded (R. L. Cross, Parker, et al., 2003), slowing idea spread through the network.

Finally, students 1 and 3 are unconnected to the group—they are isolates. Although the term isolate is technically correct, the term non-participant is used in this study, as there are no students who are actually socially isolated in the study class. Instead, there
are some students who do not participate in certain aspects of knowledge building, which is a very different thing.

3.1.2 Network Measures

There are a considerable number of network measures available in the current SNA software packages (Benta, 2002; Borgatti, et al., 2002). The centrality measures discussed here are indegree centrality, outdegree centrality, closeness centrality, and betweenness centrality. As well, there are some basic network measures that can be very revealing, including the number of nodes, the number of edges and the network density. These measures are described below.

3.1.3 Centrality

The concept of centrality is of considerable importance in SNA, and involves measuring the location of actors in the network relative to other actors. Krebs (2006) describes the importance of centrality thus: “[Centrality] measures give us insight into the various roles and groupings in a network–who are the connectors, mavens, leaders, bridges, isolates, where are the clusters and who is in them, who is in the core of the network, and who is on the periphery?” (p. 1). The terms core and periphery (noted earlier) may resonate with educators familiar with the concepts of situated learning, legitimate peripheral participation, and communities of practice (J. S. Brown, Collins, & Duguid, 1989; Lave & Wenger, 1999). Arguably, persons centrally located in a network are more connected to others, and therefore have a better chance of having their ideas spread than persons who are peripheral or isolated. Thus, in understanding idea spread, centrality is key to understanding from which source(s) ideas are most likely to spread.
SNA analysts have devised different kinds of centrality measures for different purposes, and not all are suitable for all purposes.

3.1.4 Indegree and Outdegree Centrality

Among the centrality measures, indegree centrality and outdegree centrality are perhaps the most intuitive, easy to understand, and reliable (Scott, 1991). Formally, the indegree of a node is, “… the total number of other points which have lines directed towards it …” while the outdegree of a node is, “… the total number of other points to which it directs lines” (Scott, 1991) p. 72. Referring back to Figure 2 student 8 has an indegree of zero and an outdegree of three. Student 7 has an indegree of one, and an outdegree of one. Student 7 is more central than student 8 in terms of indegrees, but less central than students 4 and 5 who both have indegrees of two. Outdegree centrality works similarly, but indegree centrality is generally held to be more important because it is typically equated with status and power (Degenne & Forsé, 1999; Wasserman & Faust, 1994). Some, however, have questioned the tightness of the linkage between the two (Mizruchi & Potts, 1998). Lewis (2008) relates these link values to influence as much as power. In knowledge building classes, especially the online portion, it is unlikely that the term power would apply, as it is usually used to mean that the individual can choose to withhold information from the others. However, an online note is available for everyone in the group to read if they so wish, and so is not withheld. Lewis’ (2008) concept of influence, rather than power is probably more appropriate in knowledge building classes.

To review, indegree and outdegree centrality are simple counts of links in or out of a given node. If an arrow points towards a given node, an indegree is counted; if away from a given node, an outdegree is counted.
A problem with simple indegree and outdegree centrality is that, being based on counts, sociograms of different size cannot be compared. For example, in a class of 16 students, a single learner would have a maximum indegree of 15, whereas a similar learner in a class of 31 students would have a maximum indegree of 30. Therefore, one extension of indegree and outdegree centrality that is sometimes used is to calculate the proportional or relative centrality, usually expressed as a percent. Therefore, in a class of 16 students an indegree of 5 would work out to 33%, and for a class of 31 students, an indegree of 5 would work out to 17%. See Scott (1991) for further discussion of this point.

3.1.5 Closeness and Betweenness Centrality

Closeness centrality is the most popular centrality measure in the SNA literature (Poulin, Boily, & Mâsse, 2000), but differs from indegree and outdegree centrality in that it takes into account not only the edges connected to a node, but also the path distance to other nearby nodes. The concept of path distance is relatively simple and can most easily explained with reference to the sociogram in Figure 2.

Looking at node 2, we can see that it is directly connected only to node 10, but that node 10 is connected to both node 2 and to node 5. Node 2 therefore has a path to node 5 through node 10, a distance of two degrees of separation, or a path length of 2. However, to calculate this, we need to disregard the directionality of the arrows and assume that all communication is at least potentially reciprocal. There are times when it is valid to do this and times when it is not, depending on the nature of the social network being studied. It is valid, for example, to assume that all communications among students in a classroom are at least potentially reciprocal, but it might not be valid to assume that
communications from the Director of Education could easily be reciprocated by classroom teachers. By using path distances, closeness centrality includes the concept that information might originate at some distance removed from a particular node, but has a path to travel to it.

Betweenness centrality is similar to closeness, and similarly uses path distances (the mathematical differences are omitted here), but is designed to identify the informational gatekeepers (Scott, 1991, p. 89) or bridges who can control access to knowledge. Looking at Figure 2, node 5 would be such a node, controlling the flow of information between nodes 2 and 10 and the rest of the group. Again, in online environments, the position would not really mean gatekeeper in the same manner as originally intended, as once a note is posted, it is there for everyone to see. However, a gatekeeper node does have the potential to influence the direction of the discourse by selectively including or excluding references to ideas from other nodes.

3.1.6 Basic Network Measures

In contrast to centrality, the basic network measures used in this study are simple to understand. The basic measures used are the number of nodes, the number of edges, and the network density. The first two of these are simple counts. The number of nodes is the number of actors who were active in the network; and the number of edges is the number of communication events among them. Density, however, needs a little explanation.

Network density is a measure of the actual number of communication connections compared to the maximum potential communication connections (Degene & Forsé, 1999; Wasserman & Faust). The formula is simple: the actual number of connections is
divided by the total possible connections. The result always ranges from 0 to 1, and is often expressed as a percent. Therefore, if 8 connections occur out of a possible 10, then the density is 0.80 or 80%. As will be seen, density is an important factor in determining the reliability of the centrality measures. For example, in a large network with a very low density, connections among members might be so sparse that centrality measures might not tell us anything reliable about the group. Network density also has an impact on the influence of initiators and early adopters: if the network structure allows for idea spread, then information cascades can occur; otherwise, they cannot, and density is a factor in this (Watts & Dodds, 2006). In terms of knowledge building communities, Zhang and Scardamalia (2007, p. 4) note, “In a high performing knowledge building community, members should learn about and build onto the inquiries, resulting in dense note reading and note linking networks.”

3.2 The Strength of Social Ties

When individuals communicate they forge social ties. There has been considerable work on the nature of such ties and their effect on the communication of information. Granovetter (1973) did early work on this, and found that weak ties were essential to the overall social cohesion within groups. Hansen (1999) focused on the nature and complexity of the information shared along social ties and found that the sharing of complex knowledge required strong ties between the parties, while weak ties slowed down the sharing of complex knowledge, but sped up the sharing of simple knowledge (basic information or facts). Krackhardt (2003) has indicated that strong ties with an affective component (trust) are important in institutional change.
Complex knowledge is a bit of a vague term, but van Merriënboer and Sweller (2005) attempt to define it more precisely in terms of Sweller’s cognitive load theory. Cognitive load theory relates the difficulty of learning to the amount of load placed by the learning elements on working memory. Working memory is extremely limited when dealing with novel elements from sensory inputs. These limits are much less severe when dealing with elements from long-term memory, as these are organized into schemata that encompass many elements. Since such schemata are dealt with as single elements in working memory, they greatly reduce the cognitive load on working memory. For van Merriënboer and Sweller (2005), complex knowledge is composed of large numbers highly interactive elements that have not yet been assimilated into schemata in long-term memory (tacit knowledge). The large number of elements puts a strain on working memory, therefore causing an increased cognitive load. Once assimilated into schemata in long-term memory, the strain on working memory is reduced. Thus, an individual’s tacit knowledge is not complex in this sense. It is when one individual tries to share that knowledge with a second individual that it becomes complex. The tacit knowledge packaged in schemata (including some physical skills) emerges as a large number of interacting elements for the second person, making the knowledge complex and difficult to share.

One factor in the strength of ties is homophily/heterophily. While the homophily/heterophily factor can occur on any social dimension (Watts, Dodds, & Newman, 2002), gender homophily plays a significant part in interaction networks (Palonen, et al., 2005). For example, Lai and Wong (2002) found that news tended to be shared along strong tie relationships, and that this was related to social position within the
They also found that people spread information to those they thought might find it relevant—probably relating to their better knowledge of the interests of others in strong tie relationships. Further, they found that heterophilous ties (different gender ties) were often involved in information spread between groups, and that homophilous ties (same gender ties) were more important in effective communication (see also (Rogers, 1995)).

Putting this together with Granovetter’s (1973) work, we would therefore predict that weak ties are more likely to be heterophilous and that strong ties more likely to be homophilous, meaning that we would likely see boy-boy and girl-girl strong tie relationships among elementary school children, as found by Palonen and Hakkarainen (2000) and Hallinan (1979). But what exactly are strong and weak ties?

Different researchers use different criteria for determining what is a strong or weak tie (Krackhardt, 2003). Haythornthwaite (2002, p. 386) gives five principal characteristics for assessing the strength of ties:

1. Frequency of contact
2. Duration of the association
3. Intimacy of the tie
4. Provision of reciprocal services
5. Kinship

Some of these would not apply in a typical school class. Kinship, one of the strongest indicators, is not always present in school classes as these tend to be established by age and grade and most family members are not in the same grade at the same time (although exceptions do occur). Likewise, the duration of the association is often set by
the school year, and students can be in a class together one year, but not in others (the size of the school having much to do with this). Part of the problem here is that much of the work in this area in schools has been done on friendship ties (Hallinan, 1979; Louch, 2000), or on corporate networks that are much larger than a school class (Hakkarainen, et al., 2004; Palonen, et al., 2005; Palonen, et al., Submitted for publication; Ruef, 2002). Among these different analyses, two characteristics of ties stand out: reciprocity, and frequency of interaction (Hakkarainen & Palonen, 2003; Hakkarainen, et al., 2004). These are the two characteristics that are used in this study to establish the strength of ties.

3.3 The Non-Homogeneous Nature of Social Groups (Clustering)

The movie, *Mean Girls* (Waters, 2004) nicely illustrates the non-homogeneous nature of social groups. In the movie, a home-schooled girl has trouble adjusting to the social world of high school. Upon arrival at the school, the heroine becomes aware of the various social cliques within the school, among which are The Plastics (the mean girls of the title), Art Freaks, Burn Outs, Freshmen, Mathletes, Desperate Wannabes, and others. All of these groups are clusters more tightly connected to each other than to the school population at large. They have strong interactions among themselves and relatively weak interactions with others. Most populations have a clique structure if the sample is large enough, and most educators have seen such cliques emerge in their schools.

Studies of business networks have revealed the importance of clustering in the innovation process. Cowan et al. (2007) found that there was a strong correlation between a high degree of clustering and knowledge performance. This was particularly true when the innovative task was moderately decomposable—capable of being broken into sub-
tasks. Schilling and Phelps (2007) noted the importance of cohesion and connectivity (both aspects of clustering) in the circulation of creative materials (ideas) that could be recombined into new creative products.

While the term *clique* is in use in ordinary English, it is only one of several words used in SNA to describe non-homogeneous clustering within social groups. These all have precise definitions, and include *k*-cores, *m*-cores, *n*-cliques, clans, clusters and more (Scott, 1991; Wasserman & Faust, 1994). Of these, the *k*-core is the closest the folk understanding of a clique and is used in this study.

3.4 *k*-cores

Where a *component* is a maximally connected sub-graph, a *k*-core is a component on a sociogram in which all nodes have a degree greater than or equal to *k* (Scott, 1991). Thus, a *k*-core of one would be a 1-core and would include all component members having a degree of one or greater; a *k*-core of two would be a 2-core and would include all component members having a degree of two or greater; and so forth.

The *k*-core concept is useful in showing how the clustering of a sociogram increasingly fragments as one increases the value of *k* in what is termed a *core collapse sequence*. Using this technique, *k* is used as a *threshold* (Gloor, 2006), sometimes called a *slice* (Scott, 1991) and increased in increments until there are no longer any connected components on the graph. This technique allows the researcher to determine the most strongly connected sub-graphs, and therefore the most strongly tied sub-components of the larger group.
3.4 Clustering and Spring Algorithms

An alternate way of finding the clustering is the use of spring algorithms to create the sociogram. Spring algorithms originally derive from physics (the study of springs) and were used to determine the positions in space of particles that attracted or repelled each other. They were applied to physical networks and have moved from there into the social sphere. In some sources, spring algorithms are called force-based algorithms (Steinbach, 2002). Although there are a number of different spring algorithms, the basic idea is simple: nodes (actors) in the network are assigned attractive or repulsive forces based upon the frequency of interactions among them. The model is then allowed to ‘run’—work out all of the various interaction possibilities (typically using about one hundred iterations of the model) and then the position of the nodes in space is plotted on the sociogram. Links among them are shown in the normal manner. Using this technique, both clustering and centrality can be shown. Spring algorithms provide a meaningful and visually appealing way of showing social network data (Steinbach, 2002).

3.5 Issues Surrounding Network Measures

As with any measure, centrality measures cannot be used without a consideration of the issues surrounding their reliability and validity. Social networks are vulnerable to measurement errors or omissions, as when students decline to participate in a study (Kossinets, 2006). Missing data create structural holes that can give the impression that the network is more fragmented (less centralized) than it actually is. In some cases, if the student is peripheral to the network, or a non-participant, this is trivial, but in others, for example if an extremely central student’s data cannot be used, it can cripple a study. In recent years, this has been the subject of scrutiny by researchers (Kossinets, 2006).
Network density is of considerable importance in evaluating the reliability of network measures. Zemljic and Hlebec (2005) and Butts (2006) note that denser networks are more stable in terms of centrality. For sociograms of the size used in this study (N=20), density decreases linearly from 0.10 (10%) to densities of zero (Butts, 2006). While such networks can have densities much higher than 10%, there is therefore no sudden crash as density decreases—the decay is not Gaussian. Small networks (N=5 to 10) have the largest reliability problems. Zemljic and Hlebec (2005) also note that it is unknown if reductions in reliability increase with network size.

Constenbader and Valente (2003) found that reliability closely corresponds to the percentage sample size obtained. When the sample size was large (≥ 80%), indegree, outdegree, betweenness and closeness are all closely correlated, but that the two degree measures correlated overall better than the others. They also note that the centrality measures are relatively stable provided that the network boundary can be specified. In the case of this study, the specification of the network boundary was fairly simple, as the school class is a recognized boundary for social network analysts (Laumann, Marsden, & Prensky, 1989).

Borgatti et al. (2006), studying the effect of measurement error (missing, inaccurate, or unavailable data) on network accuracy, found that the centrality measures of indegree, outdegree, closeness and betweenness, “… behave virtually identically in the face of measurement error” (p. 128). He found that the variance between true centrality and observed can be approximated simply using the formula $Centrality\ Variance = 100\%-Error$, where Error is the percentage of persons in the network who did not participate in the study. Thus assuming a network with 20% error, the accuracy would be
100%-20%, or 80% (concurring with Costenbader and Valente, 2003). Borgatti (2006) also found that the centrality measures were, “… surprisingly similar with respect to pattern and level of robustness …” and in terms of the pattern of robustness, “… the measures are essentially identical” (p. 128). Overall Borgatti (2006) found that, “By social science research standards, the observed [centrality] score is clearly a superb proxy for the true score” (p. 134).

3.6 The Status of Network Research and Network Science

Partly because the availability of software that allows for powerful network analyses, there has been growing interest in research into networks of all kinds in recent years. As mentioned above, SNA derives its mathematical foundations from Graph Theory, but social scientists are not the only ones who have made use of network research. Scientists in physics, chemistry, biology, ecology, and more have all established their own methods and practices in the study of networks, usually without reference to the other fields of study (Buchanan, 2002). Research into networks has proceeded in silos that firmly protect their territory (Committee for Network Science for Future Army Applications, 2005). This has presented some problems, as there have been rediscoveries of the same basic fundamentals in different fields, leading to an emphasis on the uniqueness of phenomena rather than on the underlying commonalities (Committee for Network Science for Future Army Applications, 2005). There are, for example, many different terms for various network properties in use, but describing the same phenomenon. Yet an emphasis on the commonalities is essential. Not only is it wasteful to duplicate results over and over again; not only does it disregard that fact that networks are built on other networks on which they depend (as when an online learning
environment is built to make use of the internet) (Galloway & Thacker, 2007); it slows down progress. And progress is essential, as we live in an increasingly interconnected world in which networks play a critical role.

In a recent major study for the U.S. army (which is moving to a concept they call network centric warfare), the Committee for Network Science for Future Army Applications (2005) has described the current status of network science:

The current state of knowledge about network design and characterization is roughly analogous to the state of knowledge about metallurgy in Europe in the 16th century. The empirical steel-forming technology of the day was sufficiently advanced to enable Europe to conquer most of the world but provided only a pale indication of the materials designs that would become possible in the 20th century based on the science of metallurgy (Diamond, 1999, p. 14).

It is obvious that substantial progress can be made, but it will not occur unless the silos are broken down. The Committee has therefore called on the U.S. government to fund an extraordinary research effort into the basic nature of networks to create a discipline called network science, which they define as, “…the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena” (p. 28). In their survey of approximately 1,200 network researchers in 29 different countries and in a variety of disciplines, they found that 70 percent agreed that a discipline of network science could be created, with the majority of the remaining 30 percent agreeing that it could exist, but that practical difficulties might prevent it. The Committee has called on the U.S. government to fund basic research into
network science in the amount of a minimum of U.S.$10 million per year up to a maximum of a research commitment similar in scope to the Manhattan Project. One of the first fruits of this report was the creation of the Network Science Center at the United States Military Academy (West Point – http://www.netscience.usma.edu/default.htm). This center is already actively involved in research and teaching programs.

Recently, Lewis (2008) published what is probably the first textbook on network science. In it, he provides a succinct eight-point summary of what is known about networks at the present time (2008, pp. 19-21, original emphases):

1. **Structure.** Networks have structure—they are not random collections of nodes and links. For example, the structures of electrical power grids, online social networks, and the nervous system of the C. elegans nematodes are not random, but instead have a distinct format or topology. This suggests that function follows form—many real-world phenomena behave the way they do because of their network structure.

2. **Emergence.** A network property is emergent if it changes by a factor of 10 as a consequence of a dynamic network achieving stability. In other words, emergence is a network synchronization issue—stable networks transition from one state to another until they reach a fixed point, and stay there. The fixed point is a new configuration for the network with corresponding order-of-magnitude change in a certain property. For example, on the Internet, a group of teenagers will form a social clique 10 times larger than expected from purely random behavior, because the clique is formed by preferential attachment; the top 1% of Americans make 10 times more money than the average American; the popularity of a few movie stars is 10 times greater than the popularity of the average movie star; and the largest cities in the world are relatively rare and are ten times larger than the average city. In each of these
examples, the "hub property" or concentration is a consequence of some instability working its way through the network as the network achieves a new fixed point. This is the impetus behind online social networks that begin with nothing, and end up with millions of subscribers. However, it is not clear what ingredients go into online social networking to cause explosive growth. Likewise, it is not always obvious what motivation causes an order-of-magnitude change in a network's property.

3. Dynamism. Network science is concerned with both structure and dynamic behavior of networks. Dynamic behavior is often the result of emergence or a series of small evolutionary steps leading to a fixed-point final state of the system. The Internet, many biological systems, some physical systems, and most social systems are growing and changing networks. One must understand their dynamic properties in order to fully understand these systems. Analysis of only their static structure, such as degree sequence, is not sufficient to understand the network. For example, network synchronization, such as in the case of chirping crickets, is a consequence of the dynamism of each cricket, as well as the structure (triangular subgraphs) of the social network of crickets.

4. Autonomy. A network forms by the autonomous and spontaneous action of independent nodes that "volunteer" to come together (link), rather than through central control or central planning. Structure and function arise out of chaos, more as a result of serendipity than determinism. Examples are formation of large conglomerates from the merger of small companies; emergence of large cities from small communities; and formation of global telecommunication systems from linking of many smaller, local, independent operators. The initial configuration of a network may be premeditated, but over time, the network either "decays" with the onset of some form of
entropy, or adapts and changes via the absorption of energy. For example, a highway system will either decay and fall into disrepair, or improve and grow through the expenditure of effort to repair, extend, increase its capacity, and so forth.

5. Bottom-Up Evolution. Networks grow from the bottom or local level up to the top or global level. They are not designed and implemented from the top down. This can be regarded as a form of distributed control where network evolution is a consequence of local rules being applied locally without any centralized control. Even if the initial structure of a network is the result of a premeditated design, networks evolve and change as a consequence of their dynamism. Examples of "unplanned systems" are formation of the Internet from local networks, formation of the electrical power grid from local utilities, and formation of highway systems from local roads and animal trails.

6. Topology. The architecture or topology of a network is a property that emerges over time as a consequence of distributed—and often subtle—forces or autonomous behaviors of its nodes. A network is dynamic if its topology or other properties change as a function of time. Thus, topology (structure) is a consequence of Darwinian forces that shape the network. For example, scale-free networks (networks with dominant hubs) emerge from the force of "preferential attachment" (economics), unintended consequences (regulatory law), such as the vulnerability of electrical power grids as a consequence of government deregulation, or "hidden order" of decentralized infrastructures emerging from complex adaptive systems such as the rise of the Internet, formation of metropolitan civilizations, or creation of monopolies like the Microsoft Corporation.

7. Power. The power of a node is proportional to its degree (number of links connecting it to the network) influence (link values); and betweenness or
closeness; the power of a network is proportional to the number and strength of its nodes and links. For example, Metcalfe's law states that the power of a network is proportional to the square of the number of nodes it contains [e.g., the maximum number of links that a network with n nodes can contain is n(n-1)/2, which is approximately n²]. The influence a person exerts on a group is proportional to the position, number, and power of colleagues the person has within the group, such as the person's connectivity. The power of a corporation, within an industry or market, is proportional to the number of customers (links) that it has, or its intermediary position within the industry. Power is a subtle but important organizing principle in most networks, but it is often called something else, such as influence, signal strength, or infection rate.

8. Stability. A dynamic network is stable if the rate of change in the state of its nodes/links or its topology either diminishes as time passes or is bounded by dampened oscillations within finite limits. For example, the regular and rhythmic beating of an animal's heart is controlled by a stable network of nerves that regulate the pacemaker, the loss of a power plant in the electrical power grid stabilizes quickly by switching from one source to another without disruption in supply, or the loss of a coworker causes short-term reallocation of responsibility without organizational failure.

The importance of the move to a network science perspective for the present work cannot be understated. A major, well-funded research effort into network science could rapidly produce new techniques, procedures, and measures, rendering the old ones, including those used in this study, obsolete. This is already a fast-moving field and a research effort of this scope could increase the speed exponentially. A move from the
empirical description of networks (the current situation) to predictive models of networks would represent a major advance in our understanding.

3.7 General Problems in the Study of Social Networks

There are, as alluded to earlier, problems inherent in any form of social network analysis. These can be inherent limits on the nature of social network analysis, or they can be problems unique to social networks: reporting bias, deliberate falsification of network ties (for example to increase social status), deliberate non-reporting of network ties (discussed below), and so forth. One of the most critical to understanding the current work is that SNA is useful in analyzing the patterns of communication, but does not analyze the content of the communications. Therefore, unless a qualitative analysis is done on the communication content is messages, it is not possible to say if the communication is of any significance or not.

The other problems with SNA can be illustrated by reference to a study by Bearman et al. (2004; Grabmeier, 2005) that examined the sexual networks among adolescents in a secondary school. The researchers interviewed 832 of the approximately 1,000 students at the school, and they were asked to identify their sexual partners in the past eighteen months—the first time such a study had been done and the social network mapped. More than half reported sexual contact, according well with the U.S. national average. The largest connected component on the sociogram was 288 students, a broad, cyclic component with numerous branches as offshoots from it. There were also a two star clusters, some linear chains, dyads and triads, and so forth, unconnected to the main component. What is problematic about this?
Networks of sexual contact among adults, as reported by Gladwell (2000) for the AIDS epidemic, tend to be hub-dominated—having individuals who are much more sexually active than normal and who, if infected, spread disease more frequently than others. However we do not see this in the high-school network. This either means that the pattern of sexual contact among adolescents differs from that of adults in critical ways, or that the network structure mapped by the researchers is incorrect. The former is possible because the spread of disease can be affected by a large variety of factors (Buchanan, 2002). However, it is the latter that concerns us here, as it illustrates some special problems of social network analysis.

Typically, in such a study, students are asked to name their sexual contacts, and are given a roster of names to jog their memories. However, because this is a very large group (N≈1000), the question could be asked if the students really read the full roster, or just glanced at it. Memory is a factor. A student might have forgotten an incident, particularly if they were very sexually active, or drunk. Then there are issues of status. What if a student had sexual contact with someone that they didn’t want to admit to? In such a case, they might underreport their contacts, and vital links might be lost. As well, sexual contact is a delicate subject, and it is possible that some students would not trust the researchers not to report contacts to parents or teachers. Again, in such a case, the number of sexual contacts would be underreported.

Therefore, in almost any study of social networks that relies on self-report by students, issues of social status, social approval or disapproval, and recall are (among others) possible problems in the research, usually resulting in an underreporting of the
network, and sometimes indicating that the network is more fragmented than it actually is.

This problem can be alleviated in two ways: the researcher can include all reported contacts, even if they are not reciprocated, in which case the social network will be larger, but the data less reliable, or they can choose to include only the reciprocal reports, in which case the network will be smaller and more fragmented, but more reliable, as the students are acting as a check on each other. In the case of the Bearman et al. (2004) study, they chose to report only reciprocal contacts, probably reducing their network, but making their data more reliable.

In the case of students engaged in knowledge building however, some of these problems are minimal compared to other types of networks. Knowledge building status is difficult to ascertain. Does it mean the student who contributed the most notes? The student who read the most notes? The student with the highest indegree centrality? The student with the highest outdegree centrality? Since all of these (and others) are factors in knowledge building, and usually different students are involved in each, issues of status don’t really arise, at least not to the same extent. Thus it would be expected that knowledge building networks would tend to be more correctly reported than socially delicate ones.

More general comments on the drawbacks of current network research are made by Galloway and Thacker, who, observe that network analyses are heavily dependent on their roots in graph theory, and state (2007),

While graph theory provides us with a set of useful principles for analyzing networks … graph theory also obfuscates some core characteristics of networks: dynamic temporality, the lack of fixed node/edge divisions, and the
existence of multiple topologies in a single network. (p. 57)

Certainly, static sociograms cannot accurately portray the development of a network over time, nor can they demonstrate how the network flexibly changes moment by moment (the lack of fixed edge/node divisions). As will be seen in Chapter 5, multiple topologies for a single network will be demonstrated in the examination of the note reading versus responding (building-on) networks. The single network, of course, is the entire complex network of students’ interactions, and the multiple topologies are readily evident.

3.8 Complexity Theory and Social Networks

In recent years there has been an intersection between complexity theory and network science. Complexity theory is the study of complex dynamic systems in which hidden order has been found. The rise of complexity/chaos theory is detailed in Gleick (1987), and a good introduction to it can be found in Kauffman (1993) or, for organizational settings, Axelrod and Cohen (2000). It is an evolving field, and growing very quickly. It takes a systems approach, and notes that when there is a system of independent agents (such as students in a school), interacting in a manner constrained by physical or social rules, the system will self-organize, revealing emergent properties (recurring patterns) that cannot be deduced from a study of the individual agents in isolation (Holland, 1998; Yoon, 2005). This is similar to the network definition of emergence from Lewis (2008) given in a previous section. White (2003) notes the intersection of social network analysis and complexity: "Understanding complexity and broad systems-level frameworks in the life, physical, and social sciences has turned, in
recent decades, to issues of network dynamics” (p. 14). Put simply, it is the dynamics of
the social networks in play that determine the degree and form of self-organization in
social systems. This has implications for the study of social networks, and it should be
noted that complexity theory has been used in the study of science and technology classes
(Yoon, 2005).

The importance of networks in understanding complex systems has been noted by
Galloway and Thacker (2007) who note that there is a new alliance between the concepts
of control (in the traditional sense) and emergence (in the complex systems sense).

Ball (2004, p. 397) notes that traditional statistics may not always be valid in
studying social networks: "It seems that once people begin to interact and establish
connections, the ubiquitous Gaussian distribution that so dazzled early social statisticians
vanishes, and the scale-free distribution emerges in its place" (see also (Galloway &
Thacker, 2007) and (Shirky, 2003)). Power-law relations characterize scale-free
distributions, and for these, traditional statistical measures of central tendency (such as
mean, median, or mode) are invalid (Buchanan, 2001). This implies that we need to
understand the structure of the network being studied before choosing the analytical
techniques needed to study it. Another implication is that just because a social network
software package can calculate a measure, it doesn’t mean that the measure applies to
that particular network without doing further study to ensure that the distribution of the
measure is indeed valid for that population.

For example, Amaral et al. (2000) studied network effects in different social
networks, among which are 417 Junior High students, 43 Mormons, and others. They
examined the small-world effect, in which the number of degrees of separation (path
lengths) are surprisingly small even in very large networks (Milgram, 1967; Watts,
1999), and found it applied to smaller networks as well. They identified three classes of small-world networks among their study populations: 

"... (a) scale-free networks, characterized by a connectivity distribution with a tail that decays as a power law ... (b) broad-scale or truncated scale-free networks, characterized by a connectivity distribution that has a power law regime followed by a sharp cutoff, like an exponential or Gaussian decay of the tail ... and (c) single-scale networks, characterized by a connectivity distribution with a fast decaying tail such as exponential or Gaussian ...") (pp. 11150-11151). Thus, even though most of the work on small-world networks has been done in silico and on very large networks, the effects found apply to much smaller social networks as well (Albert & Barabási, 2001; Barabási, 2002; Barabási, et al., 2000; Barabási, Ravasz, & Vicsek, 2001; Watts, 1999). As Ball (2004) notes, "Scale-free networks are now starting to look like such a fundamental aspect of human culture that eyebrows are raised and questions asked when they do not appear" (p. 396).

The two implications of the above for the current study are: first, that even though the size of the study class (N=20) is too small to definitively state that small-world or scale-free effects are at play, there are strong reasons to suspect that they could be, and therefore care has to be taken with the analysis and the application of statistics. Second, the concept of control needs to be reconsidered for complex networked systems.

Galloway and Thacker (2007) use the term ‘protocol’ in relation to the constraints on network behaviour. They note:

*Derived from the discourses of both the life sciences and computer science, the concept of 'protocol' refers to all the technoscientific rules and standards that govern relationships within networks. Protocols abound in*
technoculture. They are rooted in the laws of nature, yet they sculpt the spheres of the social and the cultural. They are principles of networked interrelationality ...

(p. 28, original emphasis).

They further elaborate on the concept of protocol, noting the existence of protocological organizations that are as real as hierarchical organizations, but for which the control structures are emergent. It should be emphasized that this usage of the term ‘protocol’ differs from the normal usage of the term. Galloway and Thacker are introducing a special technical usage of the term as it applies to their theory of networks. This usage replaces the clumsier concept of physical and social constraints on the system, embodying both concepts in a single term that acknowledges that both the physical and social always operate on social systems.

A critical role of the teacher in knowledge building classes is to put in place the constraints, the protocols, for the class so that knowledge building can occur; so that a knowledge building community (network) is in place. One aspect of these protocols is the use of appropriate software, for as Lessig (1999) notes, for software, the computer code that runs it has the force of physical (natural) law: one cannot do what the software does not allow, just as one cannot suddenly invalidate gravity in physical systems. If the software somehow prohibits knowledge building (for example by not allowing students to communicate), knowledge building will not occur. However, even with appropriate software, there are social protocols, appropriate ways to work that are in the teacher’s purview and these have to be arranged so as to allow for a knowledge building community to develop.
3.9 Networks and 21st Century Skills

The current educational system was designed to shift the educational system from the common schools of the 19th C to the assembly line popular in early 20th C workplaces (McCain & Jukes, 2001; Urban & Wagoner, 2004), and the principal function of the schools was for, “… the socialization of the students into the authoritarian order they would encounter in the workplace” (Urban & Wagoner, 2004, p. 177). As noted in Chapter 2, the student was viewed as a kind of raw material, and the function of the different grades in the schools was likened to a station on the assembly line where value was added at each station, dehumanizing, all in an effort to make the educational system more efficient (Button & Provenzo, 1983). Because of the aforementioned changes in how businesses are being run, especially the learning organizations, and the influence business is likely to have on educational reform, one of the elements currently coming to the fore in educational reform is a concern for 21st century skills. What skills do modern-day students need to compete in a global work market?

Arguably the most complete work on this to date is the work done by the Partnership for 21st Century Skills (2005) in which they give the following set of ‘new basics’ for 21st century students (p. 11):

*Information and Communication Skills*

- Information and media literacy skills: Analyzing, accessing, managing, integrating, evaluating and creating information in a variety of forms and media. ...
- Communication Skills: Understanding, managing and creating effective oral, written and multimedia communication in a variety of forms and contexts.
Thinking and Problem-Solving Skills

• Critical thinking and systems thinking: Exercising sound reasoning in understanding and making complex choices, understanding the interconnections among systems.

• Problem identification, formulation and solution: Ability to frame, analyze and solve problems.

• Creativity and intellectual curiosity: Developing, implementing and communicating new ideas to others, staying open and responsive to new and diverse perspectives.

Interpersonal and self-directional skills

• Interpersonal and collaborative skills: Demonstrating teamwork and leadership; adapting to varied roles and responsibilities; working productively with others; exercising empathy; respecting diverse perspectives.

• Self-direction: Monitoring one's own understanding and learning needs, locating appropriate resources, transferring learning from one domain to another.

• Accountability and adaptability: Exercising personal responsibility and flexibility in personal, workplace and community contexts; setting and meeting high standards and goals for one's self and others; tolerating ambiguity.

• Social responsibility: Acting responsibly with the interest of the larger community in mind; demonstrating ethical behavior in the workplace and community contexts.

Among these are, under interpersonal and self-directional skills, teamwork, leadership, adapting to varied roles, and working productivity with others. Further (p. 12) they note that 21st century techniques should be used to assess 21st century skills. Some authors (Jermann, Soller, & Muehlenbrock, 2001; Palonen, et al., 2005; Palonen, et al., Submitted for publication) have noted the potential for the use of SNA in assessing teamwork and leadership in classrooms.
Both teamwork and leadership are nebulous and slippery to define, as they can mean different things in different settings. van Aalst (2003) emphasizes a goal focus, a climate of trust, willingness to be vulnerable when putting forward ideas, and accountability. Seibold (2007) discusses peer and leader bonding and social cohesion within the team. Tasa et al. (2007) note that teamwork is an emergent process, and further notes that what is true of the individual tends to be true also of the team (a fractal dimension common to emergent systems). Tambe (1997) includes coordination of action, common goals, cooperation among team members, monitoring performance, and meeting emergent needs by reallocation of resources among his characteristics of teams. Sage Publications (2007) note the disparate nature of teams, that the size can vary from 4-20 individuals, and that team interactions may occur through computers or other communication devices. They further note (p. 5, Table 1.1) that teams have the characteristics of goal orientation, interpersonal interaction, perception of membership, and mutual influence. Bell (2002) notes that team members may hold multiple roles (such as leader in one context, but not in another).

SNA cannot measure all of these parameters, nor should it try. However, it can measure some. By measuring reciprocity and frequency of communication, emergent teams can be identified, the climate of trust evaluated (frequency of reciprocal communication), and peer-and-leadership bonding can be measured. While this is empirical at present, it is possible that firmer measures of teamwork can be established in the future. At present, these give us enough to make a start.

Leadership is similarly poorly defined, again because of the varied circumstances in which the term could be applied. In organizational settings in which an authority assigns a leader to a project, the leader is whoever is assigned. Hopefully, they have the requisite skills to manage the team, but sometimes (continuously emphasized in the Dilbert cartoon strips, http://www.dilbert.com/), they do not. However, for emergent teams, Katz (1955) notes that the administration must realize that it is dealing with
informally organized groups and that there will be emergent leadership patterns (p. 121). This latter is important in that it emphasizes patterns, not individuals, something SNA is well-placed to evaluate through examination of sociograms and centrality measures.

A word here is in order based on the work of David (1990). In his seminal study of the transition from steam power to electricity in the factories of the mid-1800s (the second industrial revolution), David noted a number of factors that relate to the adoption of computer technology in schools and businesses. Two are pertinent here: the unmeasured quality changes that came about when the new technology (electricity) was adopted, and the production of things that had previously been too marginal to be measured before. Relating these to 21st century skills, we can note that online courses are still too new to have been evaluated on their own terms rather than as compared to existing courses and pedagogies, and there are likely qualitative changes in online work that are currently going unmeasured. As well, the production of new ideas and the emergence of leadership and community (teams) are two factors that were previously marginal, and have increased importance in education for innovation. These are factors not currently being taken into account in the assessment of online work.

Thus it can be seen that some of the 21st C skills of teamwork and leadership can be evaluated using SNA, although this is still nascent and further work needs to be done. These skills are currently unmeasured in most contexts, and this needs to change.

3.10 Summary

This chapter has examined the concept of social network analysis as a means of analyzing the communication patterns among the students in a knowledge building class. The concept of a sociogram as a way of graphically analyzing the network was introduced and the measures of network centrality, in particular indegree and outdegree centrality have been discussed.
Inherent problems with social network analysis, include missing data, incomplete reporting, and inaccurate reporting of contacts. Nonetheless it was noted that with large participation rates (>80%), such data have been demonstrated to be reliable and good compared to other social data.

Social network analysis was situated in the discipline of network science, and the current move to note commonalities among different kinds of networks (physical, biological, and social). As well, connections were drawn with complexity theory and the recent work on small-world and scale-free networks, which can affect the analysis of social networks.

The concept of protocological control as a means to control networks was introduced and discussed. While the teacher generally cannot affect the physical factors in which they find themselves, there are social protocols that are within their purview and these need to be adjusted to foster knowledge building.

Finally, the current concern with 21st C skills was examined, and SNA proposed as a way to measure teamwork and leadership among the emergent groups that form in the classroom.
CHAPTER 4: METHODOLOGY

4.0 Overview

Case studies are research efforts that aim to study an issue through one or more cases in a bounded system (Creswell, 2007, p. 73). In this study, the case is the class, and the boundaries are discussed in detail below, but essentially are the class of twenty participating students and their teacher. There are three types of case study:

- Single instrument case studies that examine a single issue using a case chosen by the researcher;
- Collective case studies that use a single issue, but illustrate it with multiple cases; and
- Intrinsic case studies in which the researcher focuses on the case itself because elements of the case make it of intrinsic interest.

(Creswell, 2007, p. 74).

The current study is a single instrument case study, with the issue being idea spread and the case being a single class in an elementary school.

Creswell gives four forms of data analysis for case studies:

- Categorical aggregation, in which the researcher seeks a collection of instances from the data from which relevant meanings will emerge;
- Direct interpretation, in which the researcher looks at a single instance and draws meaning from that;
- Pattern finding, in which the researcher attempts to establish any patterns that emerge; and
• *Naturalistic generalizations*, in which the researcher develops generalizations that people can learn from themselves or apply to a population of cases. (2007, p. 163)

Because case studies typically use multiple data sources, including qualitative data and quantitative data such as descriptive statistics that triangulate it (Creswell, 2007, pp. 131-132; Kitchenham, Pickard, & Pfleeger, 1995), a number of different types of analysis are possible. In this context, sociograms hold a somewhat unique place. Although generated through mathematical means (matrices), they function very much as qualitative artifacts, and often are used in business settings to start discourse around behaviours (Viegas, 2007). Sawyer notes the observational nature of sociograms when he comments that such visualizations allow everyone to see what is happening in a collaborative system (2007, p. 177). Sociograms are also important in pattern finding in social network data (above).

This is a case study comprised of three sections: an analysis of student work in the live-class setting; an analysis of the teacher’s role in the classroom; and an analysis of student work in the archived database. Both qualitative and quantitative methods were used in the analysis. The live-class analysis was restricted to an eight-week period, during which time there were two weeks that were essentially unusable due to technical problems (Jan. 17-28), making the effective observational time about six weeks. During the internet outage, the class usually engaged in other work unrelated to Ancient Civilizations. The researcher was present generally three times per week during the study period. However, the unit that the class was studying lasted roughly four months, and the archived data allow for the capture of the interactions in the database during this period.
As well, the data set has been supplemented with archived video data from an earlier class and teacher interviews.

Observational and interview data and transcripts were analyzed using the NUD*IST qualitative analysis software package; video data were analyzed using the Transana video analysis package.

The live-class portion of the study attempted to discover the knowledge building interaction patterns among the students that could not be captured electronically. To that end two techniques were used. The students were surveyed via questionnaire as to any non-database interactions they had about certain ideas under study to provide social network data; and the students were also queried as to the original sources of some of the ideas under study.

As well, the students were interviewed as a group about why they chose to use certain features and functions in the Knowledge Forum software. The results of this interview were used to prepare a questionnaire that yielded data about why they chose to use the features and functions they did.

During the live-class portion the researcher also made a set of observations that were used to triangulate the information gleaned from the questionnaires and interviews where possible. The live-class study is described in greater detail later on in this chapter.

Analyses of the archived database material employed the Analytic Toolkit (ATK), which, as noted earlier, records server log data about the student’s interactions with the Knowledge Forum environment. The data obtained from the ATK were imported into the Ucinet social network analysis software for some analyses, into the Agna software for others, and into the Excel spreadsheet for non-network numerical analyses. These
analyses included looking at the frequency of use of many of the Knowledge Forum functions, the social network data of interactions among the students for a number of different functions, and longitudinal data about how the database developed during the course of the study.

4.1 Research Questions

The objective of this study was to examine the spread of ideas in a knowledge building classroom from the perspective of network sciences, analyzing both the in-class interactions and the notes in Knowledge Forum views. The principal research question was:

- What is the relationship between the social network structure and the spread of ideas in this knowledge building environment?

  o It is already known, as noted in the literature review, that information spreads along social networks in a variety of situations. This is something that intuits well, as communication channels have to be open for information to spread. However, these channels tend to be invisible, as noted by Cross and Parker (2004). It was a goal of this research to make the channels that were present in this class more visible.

Sub-questions included:

- What is the network structure of ideas in the database view?

  o A Knowledge Forum database contains ideas that are being discussed, considered, and improved. These ideas should beget related ideas or at
least create a network of ideas. It should be possible to determine what the structure of this network looked like for this class.

• **Does KF function to spread the ideas, or is it used to record ideas after they have spread?**
  
o As Knowledge Forum is supposed to function, ideas spread through the use of the online database. But in the hybrid class setting, where students also have the option to talk to one another about the ideas, it is possible that other means may be used.

• **What is the role of KF features and functions in the spread of ideas among this class?**
  
o As noted earlier, there has been considerable work done on information spread among acquaintance networks, but little done on idea spread in knowledge building classrooms. In particular, it is possible that the students in this class chose to read and respond (build-onto) notes along friendship lines, and that this might affect knowledge building. By examining the use of KF features and functions among experienced knowledge building students, it should be possible to see both how the students used these tools, and whether or not acquaintanceship networks played a significant role.

• **What is the teacher’s role in the KF classroom?**
  
o As noted earlier, for knowledge building to proceed effectively, the students must take on epistemic agency for their learning. The teacher’s
role therefore changes. This analysis looks at how knowledge building proceeded, the balance between direct control and allowing the students agency, and what feelings the teacher had about his role and practices.

• **Is there evidence of idea improvement in addition to idea spread?**
  
  o For true knowledge building to occur there must be idea improvement, and the mere repetition of an idea by a number of people does not constitute improvement. Therefore, it is important to see if ideas were considered, accepted, rejected, improved, and so forth to see if knowledge building was actually occurring.

4.1.0 Research Plan

There were three main parts to the study: a study of *live-class interactions* in a knowledge building classroom; a study of the teacher’s role in the classroom; and a study of the *database view* created for the topic under study during the observation period. Following Creswell (2007), who recommends collecting data from multiple sources, the data sources used in this study included:

• Observations in the live-class setting, recorded with pen and paper while the class worked;

• a set of interviews with the teacher about how he and his intern work to foster knowledge building, and a separate post-observation period interview in which the teacher was asked to reflect on the research questions, and on the analyses;
• archived video transcripts and video data;
• idea spread questionnaire data;
• interview/questionnaire data about the use of Knowledge Forum features and functions;
• archived data about student interactions with each other through Knowledge Forum, retrieved using the ATK.

The research had both qualitative and quantitative aspects. One of the intriguing aspects of social network analysis is that, although heavily mathematical, one of the principal analysis tools is data visualization in the form of a sociogram that reveals much about the *qualities* of the network.

4.1.1 The Live-Class Study

Four types of data were collected from the live-class study: student questionnaires about ideas that were being studied; student interviews and a questionnaire about idea spread and the use of Knowledge Forum functions; observational data that was primarily used to clarify and validate the results of the questionnaires; and interviews with the teacher and intern about how they go about knowledge building and how they view idea spread in the class.

One problem facing such a study is that of boundary specification. Since this study looked at the spread of ideas in knowledge building class, where should the boundary be drawn? This is a common problem in social network studies, where for example, social interactions among people in a village might be studied. But how far around the village should the line be drawn to limit the study? How many outlying farms
should be included? Laumann et al. (1989) give a thorough discussion of this and conclude, "The most commonly used definitional tactic is that of using a restriction based on some attribute or characteristic of the actors or nodes in the network" (p. 67). One of the specific examples they give is that of the school class–restricting the social group under study can be done based on membership in a group. Therefore, it was decided to restrict the analysis to the class itself (students and teachers) and exclude family members and friends outside of the class, etc. In the end, this turned out to exclude few reported contacts.

4.1.2 The Class

The class studied was a Grade 5/6 class of 22 students (20 participants and two non-participants), at the Institute of Child Studies (ICS), a Toronto lab school recognized by Bielaczyc (2006) for its innovative capacity. The class was chosen as an exemplar of a well-functioning knowledge building class. Typical of Toronto schools, the class is mixed in gender and is multi-ethnic. As Figure 3 shows, it was informally organized, and consists of two rooms with a work area between. This allowed the students to move between rooms to form informal work groups as needed. Students were all provided with laptop computers.
Figure 3. Layout of the classroom used in this study.

The teacher organized the workday into a routine that allowed an extended period of time (90 minutes) for deep inquiry three days a week, adding up to about four and a half hours per week\(^1\). During this time, the students engaged in work with the KF software, but also conversed among themselves, usually about the ideas under study. In the case of this study, the students were using the extended inquiry periods to investigate ancient civilizations.

\(^1\) This might seem like a considerable amount of time, but it should be noted that knowledge-creating companies like Google, which allots about 30 percent of its employees time (twelve hours out of a forty hour work week) to new learning and knowledge creation (Ignatius, 2006), consider this essential.
In addition to their work with KF, the students also participated in semi-regular knowledge building talk sessions in which the ideas under study were discussed. In these, the students sat together as a large group and discussed their ideas about ancient civilizations under the guidance of the teacher.

The observer was present for approximately six weeks during which the class was observed approximately three times per week. Observations were concluded when the class had nearly finished the topic and were beginning to move on to another area of study.

4.2 Analysis 1: In-Class Observations

During the class, for most of the time, the researcher sat quietly as indicated in Figure 3—at the rear of the class in a corner. A notebook and pen were used to record observations about the activities of the class. From a seated position, it was not possible to hear all interactions, and so the observations focused on the manner in which the students worked: the formation and breakup of working groups, on- and off-topic interactions, and the general functioning of the class. Principally, these data were used to provide a general idea of how the classroom functioned.

4.3 Analysis 2: The Idea Spread Questionnaire

This analysis related to the network structure of idea spread, and whether KF was used to spread ideas or used to record them after they had been discussed in the live-class setting. Data were collected using the idea spread questionnaire.
The idea spread questionnaire was a simple document that asked students about an idea that was under study in the class. The questionnaire recorded the student’s name, the idea being tracked, and asked the following questions:

1. How did you first learn about this idea? Please include as much detail as you need to fully answer the question.

2. Did you create a build-on to a note containing this idea? (Yes or No)

3. Did you communicate about this idea with anyone in the class by any means other than through Knowledge Forum? (Yes or No)

4. If the answer to the above question was “Yes”, with whom did you communicate? Please put each name on a separate line.

5. If you communicated with someone about this idea, how did you communicate (e-mail, telephone, personal conversation, etc.)?

6. If you have any further comments you feel would be of use, please put them in the data field.

The full questionnaire as given to the students is displayed in Appendix A. Data fields were provided for the students to write their answers, and the teacher reviewed all of the questions with the students before the questionnaire was administered to ensure they understood what was being asked. The questionnaires (three in total) were given at the end of each of first three weeks in January.

As to the reliability of the network established by this technique, research has shown that people tend to underreport the networks established by recall techniques, sometimes by as much as 20% (Brewer & Webster, 1999). This would lead to the
network reported being smaller and less connected than the actual network. This problem is common to almost all social network research.

Often, these kind of questionnaires are accompanied by a class roster to jog student memories (see Wasserman & Faust (1994, p. 45 et seq.) for a discussion of this), but for small groups, roster and free-recall techniques have been found to yield equally reliable data (Ferligoj & Hlebec, 1999).

The idea being tracked was chosen by the researcher in consultation with the teacher. Each idea was one that had been discussed either online or in class (often both) during the preceding week and was one that was identified as being of importance to the class by the researcher and teacher. In all, three such questionnaires were administered.

4.4 Analysis 3: The Idea Sources Questionnaire

The purpose of this analysis was to determine where people first encountered a particular idea. This analysis used data included in the Idea Spread Questionnaires and was therefore administered at the same time (the first three weeks in January).

The first question on the questionnaire was aimed at finding out what the sources of student ideas were. These data were analyzed separately from the Idea Spread data, and allowed the researcher to identify the sources of the specific ideas under study–essential to answering the question about whether KF is used to spread ideas, or merely to record ideas generated elsewhere. Counts were made of the student responses, and the results were analyzed graphically.
4.5 Analysis 4: The Group Interview and Questionnaire about Knowledge Building Behaviours

The purpose of the group interview was to ask the entire class at the same time why they chose to use Knowledge Forum functions such as notes and build-ons when, in a live-class setting, they could just speak directly to each other. This addresses the research questions about how student interactions affect idea spread, and how KF usage patterns relate to idea spread. A series of questions about KF function use were designed in consultation with the teacher, but these were just used as a guide, and there was room in the interview process for the students to add their own questions and responses. The basic question framework is given below:

- What make an idea interesting?
- What are the sources for your ideas?
- What prompts you to create a new note?
- Why do you build on to a note?
- Why do you create a rise-above?
- Why do I use any of the KF features? (Why do I revise a note, etc.?)
- How do you choose when or when not to read a note?

The initial design of this analysis involved individual interviews. However, after consulting with the teacher, it was realized that interviewing the students individually or in small groups might be disruptive for other class members. It was decided instead to interview the class as a whole with the teacher present to clarify (and to add some questions of his own). The researcher took notes during the interview process to capture
the student responses. This interview structure proved to be fortuitous, as it was possible to see during the interview that there were varying levels of agreement among the students. As a result, and after consulting with the teacher about available time, the researcher created an additional questionnaire that took the most frequent student responses about KF use, phrased them as statements, and allowed for a yes or no response to each statement. The interview was conducted in the second week in February; the questionnaire administered the week following. Table 1 below shows a few of the statements and the general layout for the questionnaire. The full questionnaire is presented in Appendix B.

*Table 1. Excerpt from the interview questionnaire about why Knowledge Forum functions are used.*

<table>
<thead>
<tr>
<th>Q</th>
<th>Statement about what makes an idea interesting:</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>If there are lots of ideas in a note, it is more interesting.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>An idea is more interesting if it’s surprising.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>An idea is more interesting if I disagree with it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>An idea is more interesting if there is an argument about it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>An idea is more interesting if you talk about it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>A note looks more interesting if there are a lot of build-ons to it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>An idea is more interesting if we think of it and question ourselves about it.</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

In all, the questionnaire contained sixty-two questions about what makes an idea interesting, idea sources, why new notes (postings) are created, why build-ons (responses) are created, why rise-above notes are created, the use of other KF features, note reading, and other items of interest.

Before the questionnaire was administered, the teacher reviewed it with the students. Both the teacher and researcher were present to answer any questions. One flaw in the questionnaire rapidly became apparent when the students asked what they should
do if they didn’t know how to answer. They were told to circle both yes and no for this, and this seemed to address their concern. The students were able to finish the questionnaire quickly (in less than fifteen minutes), so that administering it did not use up too much of the class time. The interview process occurred.

The use of the interview to create a follow-up questionnaire allowed for numerical analysis of the responses, and made the interpretation of the responses clearer.

4.6 Analysis 5: Analysis of the Archived Database Material

During the period of the study, the students worked in their own private database views, and in the *Ancient Civilizations* database view. The private views were unavailable to the researcher, unless the students included notes from private views in rise-aboves in the *Ancient Civilizations* view. (Rise-above notes are designed to help foster ideas synthesis by collecting related notes in the same space). The public *Ancient Civilizations* view, consisting of 108 notes plus additional notes in the rise-aboves, was available to the researcher for analysis.

Data were collected using the Analytic Toolkit (ATK). This provided the raw data for further analyses. Once compiled, data were imported into the Excel spreadsheet program, and the results were analyzed and graphed.

Network analyses using the ATK data were performed on the networks of build-ons, and note-reading, but due to the restrictions about the students’ private views, only included the notes in the public view. Other network-related measures were run on these and other knowledge building behaviours.
For the network analyses, the *Ucinet* program (Borgatti, et al., 2002) was used as the primary source for the sociograms, the *Agna* program (Benta, 2002) was used for the relative indegree and outdegree centrality and other measures.

4.6.0 Analysis 6: Analysis of Student Interactions in the Knowledge Forum Database

This analysis addressed the question about the social network structure through which ideas could spread in the database, and used the ATK data to examine the building-on and note reading networks. These networks were analyzed to determine the number of nodes and edges, the number of non-participants, and the network density. Sociograms were created to examine the overall network structure, to examine the strong-tie/weak-tie relationships, any tendencies towards gender preferences in communication patterns, and the development of the networks. As well, the average number of words per note was analyzed by gender.

4.6.1 Analysis 7: Longitudinal Analysis of Student Interactions

This analysis responds to the research question about the relationship between social networks and the spread of ideas over time. The longitudinal analysis of student interactions encompassed both the build-on and note reading networks. Time slices were taken at the end of the first week, and monthly thereafter until the end of the study period. The results were displayed as sociograms to show the changes in the networks over time, and are presented in the results section.
4.6.2 Analysis 8: k-Core Collapse for Building-on and Note Reading

This analysis addresses the nature of the network through which ideas could spread among the students. As noted previously, k-core collapses are used to deconstruct the network through progressive deletion of edges based on the frequency of interaction. The network was first established using the minimum connection frequency of $k = 1$, meaning that one interaction among the pair of students was sufficient to include them in the network. Raising the communication threshold to $k = 2$ resulted in the deletion of single-interaction connections. Thereafter, the connection threshold was raised incrementally until only two connections remained. This allowed the researcher to find the persistent connections among the students.

Since building-on was less frequent than note reading, the threshold increments used for edge deletion was one. For note reading, threshold increments of five were used. The results of these analyses are presented in the Results section as a series of sociograms, each showing the progressive collapse of the network and the most persistent connections.

4.6.3 Analysis 9: Analysis of the Network of Ideas in the Database

This analysis addressed both the questions about the network structure and the spread of ideas and the network of ideas present in the database.

A second type of analysis run on the Ancient Civilizations view involved tracking a particular idea through the view to see who created build-ons to this idea, in how many note clusters the idea appeared, and how its spread in the database related to knowledge building talks and other live-class interactions. Again, this analysis provided the
necessary data to show the network structure of ideas as sociograms—essential to answering the related research questions.

The analysis involved the identification of two ideas that were of importance to the classroom work. These ideas, which were first introduced to the children during their introduction to the Ancient Civilizations unit at the Royal Ontario Museum (ROM) visit, were (a) that an organized religion was necessary for a society to be judged to be a civilization; and (b) that a written language was necessary for a society to be judged a civilization. These ideas were chosen because they were important to the students, and therefore useful to show idea spread.

The data for this latter analysis are of the type that falls under the purview of content analysis. Therefore, data validation proceeded as outlined in Krippendorff (1980) and Neuendorf (2002). Two coders were used: the researcher and a second coder familiar with Knowledge Forum and knowledge building. Both the researcher and the second coder separately analyzed the database notes for the presence of the ideas being tracked, and recorded their findings in a database created for this purpose. There were three iterations of the coding process, to ensure good results. Appendix C shows a screenshot from this database, showing the data fields used. Appendix D shows the code book used to code the data.

The boundary specification problem was touched on earlier, but needs to be briefly revisited here. The research area was confined to the Ancient Civilizations view in the database, but there were two problems. First, the students, by means of rise-aboves, brought notes from other views into this view, and it was decided to include these in the analysis as these notes were public to this view. Second, two persons external to the
defined group of the class plus the teacher posted a small number of notes in the database view. These were excluded from the analysis.

Therefore, for each note in the defined boundary group, an analysis determined whether or not it contained the ideas of organized religion and written language as important to defining a civilization. Any build-ons to these were identified, as were rise-aboves and references, and used to establish the network of ideas as expressed in the Ancient Civilizations view.

In addition to the boundary specification problem, another problem was to decide whether to treat the ideas in notes as belonging to the individual student, or to treat the idea in the notes as being independent of the individual once contributed to the database. Ultimately, it was decided that notes in the database were objects in their own right and were treated as such.

Within this framework, two forms of analysis were run: the network of identified ideas was established as closely as possible using network analysis techniques; and a temporal analysis was run to show when the activity about these ideas occurred and how they might relate to other classroom activities.

4.6.4 Analysis 10: Analysis of Idea Improvement

One of the research sub-questions asked whether or not ideas enter KF and spread without alteration, or if there are attempts by students to improve the ideas as KB theory predicts. In order to answer this question, a second qualitative analysis was performed. Notes from the Ancient Civilizations database view were analyzed according to the following criteria:

1. Does the note indicate that there are flaws in an idea from an authoritative source?
2. Is there a suggestion that the idea needed to be changed?

3. Is there a suggestion as to how the idea should be changed?

Criteria 1 and 2 would be sufficient to show knowledge that an idea should be improved, while criterion 3 would show a definite attempt at idea improvement.

In this case, the source of an original idea from an authoritative source was easy to find. The students had started their unit with a visit to the *Royal Ontario Museum* (ROM) and had been given a definition of what distinguished a society from a civilization. These characteristics are given below, modified from a student’s note in Knowledge Forum:

- Architecture and engineering: A civilization has to create buildings from durable materials.

- Language: A civilization has to have both an oral and written language, including written literature and mythologies.

- Political system: A civilization has to have a government, class structure, and laws.

- Art and Music: A civilization needs to have its own unique forms of entertainment.

- Religion: A civilization must have an organized religion.

- Science and perception of the universe: A civilization needs to have its own views of science and the nature of the universe.

The students returned frequently to the question of what constituted a civilization, and there were a number of notes to choose from, making the analysis easier.
4.6.5 Analysis 11: Analysis of the Teacher’s Role in the Classroom

The teacher’s role in the classroom was analyzed using observational data, video transcripts, and transcripts of two interviews: one with the teacher and one with the teacher and an intern. These data were analyzed qualitatively and thematically coded using NUD*IST for text-based material, and Transana for video data.

4.7 Validation of the Data Analysis

To validate the data collection and data analysis process, and external auditor was recruited to review all aspects of the research. The auditor was a doctoral student who was not associated with the researcher of the case study classroom in any way, and who was familiar with qualitative and quantitative forms of inquiry. As recommended by Creswell (2007), the auditor was provided with full access to the raw data, the codes and categories generated, and a description of the research process. The auditor’s report—the Attestation—is attached in Appendix E.
CHAPTER 5: RESULTS

This chapter presents the results of the analyses described in Chapter 4. The chapter is constructed so that we will first consider the networks that formed outside of regular class time; we will consider the teacher’s role, including knowledge building talk sessions; we will consider analyses of the ATK server log data from Knowledge Forum as well as observational and questionnaire data about how the live-class setting interacted with Knowledge Forum; and finally we will consider the spread of ideas in Knowledge Forum and the relationship between the live-class setting and the online discourse. Figure 4 shows how the various sections of Chapter 5 relate to the research questions. The purpose of this organization scheme is to address key research questions by looking at both the properties of the networks themselves, and at the factors that affected the development of those networks (i.e., external factors such as student interactions in and out of class, and the role of the teacher in providing an environment that allowed the networks for form as they did).
Chapter 5

5.0 Networks Outside the Class

In setting up the study originally, we considered the possibility that the students might communicate about ideas about Ancient Civilizations outside of the class by

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Figure 4. Map showing how the various sections in Chapter 5 relate to the research questions.

5.0 Networks Outside the Class

In setting up the study originally, we considered the possibility that the students might communicate about ideas about Ancient Civilizations outside of the class by
various means such as phone calls, instant messaging, conversations, and so forth. To find out, a survey was administered to the students that asked about an idea the teacher and researcher considered prominent that particular week at the end of each of three weeks. The survey asked to whom in the class the students might have communicated the idea and through what means. The results of this were used to construct sociograms showing the networks of these interactions during a three week period.

The sociograms presented in this section will all follow similar conventions: Circles represent girls, squares represent boys; node size indicates degree centrality—the larger the node, the greater the number of degrees attaching to a particular node; arrows indicate the direction of the interaction, with an arrowhead pointing to a node indicating an indegree for that node; line thickness for the connections among nodes indicates the frequency of interaction between node pairs; and double-headed arrows indicate reciprocal communications (stronger ties). A triangular node indicates the teacher. This survey did not ask about the frequency of interaction, and therefore all line thicknesses are equal in this set of sociograms.

As noted in the previous paragraph, the students were asked to describe by what means they communicated about the idea under consideration. With the exception of one telephone call, all reported interactions were verbal. There were no instant messages, e-mails, or other forms of communication. These results were consistent for all three weeks—the students reported only conversing and other than the one exception, didn’t use other means to communicate. As well, the boundary specified in the Methodology section holds for this analysis: only interactions among students and the teacher were considered as the boundary was restricted to the class. One student did report talking to her father
and brother, but no other students reported conversations about the ideas in questions with anyone outside of the class.

Figure 5: Sociogram showing the network of interactions outside of the class for the first of the three weekly questionnaires.

Considering Figure 5, we can see that seven of the twenty of the students did not report discussing the idea being tracked outside of class at all. Of the remaining thirteen students, we see a dyad between students 18 and 7, a triad involving students 14, 3, and the teacher, and a larger cluster of nine students who consist of five boys and four girls. This represents a network that is fragmented into clusters without ties between them, and over a third of the class (35%) did not report participation.

Student 5 appears more central than he actually is in this sociogram. If the sociogram were in three dimensions, he would appear on the z-axis at right angles above students 9 and 10–on the periphery. However in the two-dimensional representation,
given that a triad formed, closer to the centre was the only place the algorithm could place him.

*Figure 6.* Sociogram of the second week's questionnaire results about idea communication outside of class.

Figure 6 shows that eight students (40%) did not report communication about the idea being tracked outside of class during the second week. Again we see a triad involving the teacher, but the majority of students formed a larger cluster of nine students: five boys and four girls. We therefore have three clusters here: non-participants, a triad, and a cluster of nine students. The cluster of nine students is not the same as the previous nine-student cluster, although there is some overlap.
Figure 7. Sociogram of the third week’s questionnaire about discussion of ideas outside of the class.

In Figure 7, we can see that the number of reported non-participants is now ten students (50%) of the class for the third week’s questionnaire. The other students are in three groups, two triads (one including the teacher), and a tetrad.

Summary:

Overall, the reported outside-of-class network was generally sparse, ranging from 65% participation to 50% participation, and tending to be in unconnected clusters instead of connected clusters. The sparseness and fragmentation of the networks indicate that communication about Ancient Civilizations ideas was not particularly frequent, which prevents a more-detailed sociometric analysis. Most of the sociometric measures such as degree centrality, closeness, and betweenness are sensitive to sparseness and fragmentation and are therefore unreliable in cases such as this. The best we can say is what we observe on the sociograms: ideas communication outside of class appears to be
sparse, infrequent, and fragmented. Marin and Wellman (2009, p. 11) note that when community networks, “… are internally disconnected, information cannot diffuse fully through the network …”

5.1 The Teacher’s Role

This section is concerned with the teacher’s role in the classroom. How did he attempt to nurture a knowledge building community? How did he perceive his role, and what was the relationship between the day-to-day activities of the teacher and the communication networks of the class? The analysis is divided into two sections. The first section examines videotaped footage of his interactions with students during knowledge building sessions. The second section examines the teacher’s personal perceptions of his role as a knowledge building teacher.

5.1.1 Data Sources

Video data of classroom activity during the Ancient Civilizations unit was generally unavailable, so the data collected from that unit was limited to the following:

- researcher notes recorded during sixteen classroom sessions;
- one video of a knowledge building talk session; and
- a post-session interview with the teacher.

In an effort to more deeply investigate the teacher’s instructional practices, the researcher conducted an extensive analysis of videotape footage from another knowledge building unit taught by the same teacher. The data sources consist of fourteen videos of
classroom knowledge building sessions filmed during a unit on “Mars” and transcripts of a one-hour interview with the teacher and an assistant teacher. In fourteen classroom videos, the teacher wore a wireless microphone so that his interactions with students (both at the front of the classroom and in individual one-on-one exchanges) could be recorded. The videotape was transcribed and then hand-coded. The themes that emerged from this analysis are presented in the following sections.

It is important to emphasize that the differences in content between the Mars and Ancient Civilization units make it difficult to make definitive claims about the instructor’s knowledge building practices. Although both units employed Knowledge Forum, and both were considered knowledge building units, it is possible that the instructional strategies captured on film during the Mars unit were different, in some respects, than the ones practiced during Ancient Civilizations unit. Nevertheless, it was felt that it was important to take a closer look at how the teacher supports knowledge building in his classroom and the Mars videos offered a useful case study of the instructor’s in-class strategies.

5.1.2 What Did the Teacher Do in Knowledge Building Classes?

An analysis of the classroom transcripts from Mars unit suggests that the instructor employed a surprisingly complex variety of pedagogical strategies and styles during knowingly building sessions. Some of the strategies might be considered knowledge building approaches while others more closely resemble traditional teaching. The analysis of the video transcripts yielded the following themes:
Theme - Giving students direction: Like teachers in traditional classrooms, the instructor often directed students to engage in certain kinds of activities. For example, in the following video transcript passage, the teacher directs the class to investigate the use of touch sensors on the Martian probes they are designing:

Teacher: "so all of us are going to be working on adding touch sensors and while you're doing that at you tables, maybe one group at a time can come and try out their probe on the slope here.

Sometimes, the teacher gave students specific directives about how to work in Knowledge Forum and the notes that they should write:

Teacher: “This note is in the view: Banks and Slopes. I want you, in the pair that you were working with to open it up and do a build on. Say what you understood and what you still don’t understand from this note.”

Interestingly, although the teacher frequently gave direction to students, he reports that he is not comfortable with this style of teaching, and tries to avoid it, concerned that it runs counter to the spirit of knowledge building. However, he also justified his actions by explaining that time pressures sometimes necessitate a direct approach:

Teacher: My ideal is to make [the class] as democratic as possible but if I look at the video [of the session we are discussing] I will cringe because I know that I find I'm much more teacher-centered than I'm comfortable with due to time.
The teacher also explained that, in his opinion, not all concepts could be learned through discovery learning approaches. On occasion, he felt that he had to give students specific direction to meet curricular expectations:

*Teacher:* *[You] can say these are the two expectations I want to cover well.*  
*Then you can plan everything around that, but even in terms of gravity,*  
*the rest of the teacher directedness, it's not just discovery learning,*  
*where we're just sitting back there and at some point they're going to pick up what gravity means, it's not that either. So we want to help them make the connections as quickly as possible, but in a meaningful way too.*  
*But there is also [unclear] there's too much, it's too big.*

**Theme – Engaging in IRE teaching:** A variant of IRE teaching (initiation, response, evaluation) was another pedagogical strategy that the teacher commonly employed during the knowledge building unit, most often during Knowledge Building talks. Instead of the traditional evaluation follow-up however, the teacher often used this to probe deeper into the student’s level of understanding and to clarify concepts. In the follow excerpt from the video transcripts, the teacher prompts a student to clarify what is meant by the concept “inclined plane”:

*Teacher: “You know how that crater...they've made it a little easier for us to get out of it. What have they added to the crater that if it wasn't there we'd have to really think about the re-design of our probes?”* What does the 2nd paragraph
talk about ramps? Does anyone remember how they describe ramps. They use the word ramps but they also talk about something like a plane or something.

Student: "Inclined plane."

Teacher: "What does that mean?" Like's what's plane?"

Student: "A plane's like that" (showing with his hands).

Student: "slip" 

Teacher: (brings out a board) "Can you make that an inclined plane. If we want to get the probe to go from this to onto [location] and there wasn't that inclined plane, what kind of job would that be?" And think about what does an inclined plane do?"

Student: "it helps you go up"

Here is a similar episode in which the concept of “traction” is explored:

Teacher: What were some of the key words in the reading?

Student 1: Traction

Teacher: What does that word mean “traction”?

Student 1: It’s when something is secure.

Teacher: What do you mean?

Student 2: It won’t move- it’s secure

Teacher: It’s secure; it’s a grip (uses gestures with hands to demonstrate this). So do you want traction or you don’t want traction?

Student 3: Sometimes you don’t, sometimes you do.
Teacher: When would you want traction?

Student 1: When you don’t want something to slip or move.

Teacher: Why?

Student 4: You might be on a hill or something.

Teacher: How do we make more traction happen?

Student 1: Make more friction.

Teacher: I don’t understand, make more friction? How do we make more friction? R said we want more traction, because he said that from the reading he learnt traction was like a grip. We liked that, it made more sense. How do we give the probe more traction?

Student 5: It has like a speed. It depends on traction.

Teacher: So what’s your theory? What kind of speed?

Student 1: Not a low speed or a very high speed

Teacher: O.K and why?

IRE teaching is typically associated with conventional instruction, although it may have a useful role to play in knowledge building classrooms as well. Most of the teacher’s IRE exchanges appear to focus on exploring particular concepts (e.g., “traction”, “inclined plane”). The purpose of these dialogues appears to be, in part, to push students to deepen their understanding of key concepts. However, the dialogue may also play a secondary role. One could interpret the exchange as the teacher’s effort “…to serve as a model for the sorts of conversations students might initiate on their own”
It is evident from the transcripts that the teacher is often engaging in productive knowledge-building behaviours, such as identifying what one doesn’t understand, asking questions, developing theories, and so on. Thus, the dialogues appear to serve two purposes: to model key knowledge building processes and deepen the class discourse.

**Theme - Describing the class as research team / knowledge building community:** While teaching, the instructor would often refer his class, collectively, as a research team engaged in experiments or as knowledge building community involved in knowledge work.

*Teacher (addressing the class):* “We could have in the back of our minds an idea of the type of probe we are thinking about. But we don’t worry about that now. We are experimenting.”

*Teacher (addressing the class):* “These are amazing experiments they need to stay the way they are so that you can continue working on them again.”

*Teacher (addressing the class):* “The probes are going to change over time as we come up with new theories over the next few weeks.”
In one instance, the teacher read aloud a short story about the painter Picasso and then used the story to make a point about the importance of progressively improving one’s ideas:

Teacher: “Picasso needed a better theory and it ended up being very different and much better. He brought his knowledge to the painting and he created something much better….And today we are going to be doing something very similar. We have our probes. We have done a lot of research and our information together. We have read stuff, we’ve experimented and now we are going to experiment on the crater. Can our probes get out of that crater? When you test it out then you might realize that, like Picasso, even though the rest of us think it’s so nice, you might need to make some changes to your probe and that’s perfect.”

Through these sorts of comments, the teacher was constantly reminding students that they should view themselves as a knowledge building community, and moreover, that participation in such a community entailed a commitment to experimentation, theory development, and the progressive improvement of ideas. Such comments appear to be an important part of the teacher’s efforts to foster a classroom culture of knowledge building.

**Theme – Infusing Knowledge Building Terminology in Classroom Conversation:**

Consistent with the previous theme, the teacher frequently used knowledge building
terms, such as “build on”, “big ideas”, “problems of understanding”, “knowledge advances”, and “theory” when addressing the class or talking to individual students. Here are some examples:

*Teacher (during KB Talk):* "Ok can someone build on that".

*Teacher (addressing the class):* What were some of the big ideas in here that we need to share?"

*Teacher (addressing the class):* “Picasso needed a better theory and it ended up being very different and much better.”

*Teacher (during KB Talk):* So what’s your theory?

*Teacher (during KB Talk):* This is our first KB talk, I think of the year so far, so can someone just remind us of how, what’s the best way we’ve found to be able to talk about our problems of understanding, or some of our knowledge advances.

Throughout the video transcripts, there was considerable evidence of the teacher trying to use a consistent knowledge building vocabulary when talking to students. The teacher’s modeling of this vocabulary appears to be a central part of his efforts to nurture a Knowledge Building Community in his classroom. The transcripts reveal many instances of students also using this vocabulary in their classroom conversation, suggesting that the teacher’s modeling was effective and that the language of knowledge building had been widely taken up in his classroom.

*Theme - Connecting students to each other:* The teacher regularly made efforts to create communication links among students. Some of these links occurred during Knowledge Building Talks, as the following example illustrates:
Teacher: So slipping can be reduced?

Student 1: Slipping can be reduced by reducing time and speed.

[The Teacher asks another student to elaborate on this theory. The student elaborates on the previous theory using an analogy. The teacher helps the student further articulate her theory by asking questions]

Student 2: Like when a two-wheel drive got stuck in the snow. If you press on the accelerator a lot the wheels would go round and round and round without anybody pushing.

Teacher: So what do you need to do? [Teacher makes gestures with his hands and uses facial expressions to show he is thinking and very interested in what the student is saying.]

Student 1: So if you press on the accelerator a little by little you may be able to edge forward a little by little.

[Rather than responding to the student, the teacher passes on to another student to encourage student-to-student discourse].

S3: We were trying to get out of school and we couldn’t get out of the place where we were parking, because of all the snow. And my dad was pressing on the accelerator. The wheels kept turning, but we didn’t go anywhere because the surface was too slippery

In other cases, the teacher made class-wide appeals for students to share their ideas with one another:

Teacher: “I heard J say that she was addressing a problem - which was how to make an arm for the probe, and she said we can use this idea. Does any one have
an idea that they can share? Think back to the toys that were brought in from the ISK classroom and some of the ones I brought in. Think of and idea that we can use to address the problem that J has reminded us of - because we have all had this problem.”

In still other cases, the teacher encouraged students to respond to each other’s ideas in Knowledge Forum. Repeatedly, the teacher would try to get students communicating with each other. Sometimes he would try to step back and remove himself from the classroom discourse in an effort to foster greater exchanges among students.

Theme - Encouraging students to take chances and make their ideas public: The analysis identified a number of occasions when the teacher took encouraged students to share initial, undeveloped ideas with one another. For example, he explained the purpose of KB Talk to students in the following fashion:

Teacher (addressing the class): “I often describe Knowledge Building talk as rolling a ball of clay. These theories are going to get squashed and molded and that creates a safe place. Once you have stated your theory, it’s gone, it’s not yours anymore. It lives…. This lives apart from you, because someone else is going to tweak it or criticize it or offer new information. And that has to be okay with you. Everyone has to realize that it is for the benefit of getting this knowledge, not about being right.”
When asked about this practice during an interview, the teacher acknowledged that it was one of his goals to view ideas as “objects” that people work on and improve over time. He remarked:

“And that’s huge… and to get students to a place where they realize that it is not about getting the right answer it’s about getting your ideas out their where they can be created and added to and molded. That’s huge for one child to know, this information isn’t right but I want it to be there.”

Summary

In summary, the teacher appeared to draw from a wide repertoire of instructional strategies during the Mars knowledge building unit. Sometimes he took control; at other times he deliberately relinquished control in an effort to foster student-to-student interaction. At times he could be teacher-centered in the manner of a conventional classroom teacher. He often used IRE dialogue, especially during knowledge building talks, to push the discourse deeper and to model important Knowledge Building processes. He tried to connect students to one another and attempted to foster a knowledge building community by repeatedly describing the class as a research team and infusing the language of knowledge building in classroom talk. Thus the teacher’s role in the classroom was complex and nuanced, involving the strategic application of a wide range of pedagogies, both traditional and progressive in nature. His choice of strategies, in any particular situation, appears to be influenced by a variety of factors such as time pressures, curricular expectations, the nature of the content, knowledge building objectives, and perceptions of student needs.
5.1.3 What were the Teacher’s Perceptions of his Role?

The teacher was interviewed on three separate occasions in an attempt to better understand the teacher’s perceptions and personal insights regarding his role in a knowledge building classroom. The interviews were transcribed, coded, and then organized into themes. Three themes were identified: feelings of uncertainty, comfort as a co-learner, and ambivalence.

Theme - Feelings of Uncertainty: Zhang et al. (2009), who also interviewed this teacher, noted that he was, “… dedicated to developing a ‘feeling of empowerment’ among his students …” (p. 46). However, when asked about his feelings about releasing agency to the students, the teacher commented,

Well, I have to say it's scary for many reasons. We're comfortable with feeling that much is happening at the same time [and] you can't limit the children's understanding based on your own understanding. Because students become quite specialized, they're going to go very deeply. It means that your role is different, you're a facilitator. You don't need to be up on absolutely everything that's happening … you can't compete … you're doing all those things so that changes your role … But the other scary thing [is] that when you've got many things like this happening at the same time is that there is the possibility that nothing is happening, and so I'm always trying to get a sense of what's happening over here, are they really contributing there. I've been wrestling with this now for five years, where it's trust in them. [Once when] they were laughing around a video they had found on the web, my initial reaction was that we have to go along
with [this], maybe they are really getting something out of that experience and you could see that somebody at our table talk was able to say, no there was a whole process that got the probe onto Mars. So it is about letting go and letting them really explore things, but you never, it's tough when things start clean

In the Mars unit video transcripts, the teacher also revealed that sometimes he is more teacher directed than he is comfortable with:

I sort of go through cycles [with teacher directedness], but maybe it’s also a state of my comfort with it. I’m still in the factory model where I want to be on control of everything, and so I’m facilitating a meeting a lot more than I’d like to …

The teacher here is again wrestling with issues of releasing agency to the students and still maintaining some form of control. He tends to default to the factory model (hierarchical) model of control sometimes, but does not feel comfortable about it when he realizes it is happening.

Although the teacher is dedicated to giving the students agency, he still finds himself uncertain about it, and struggles with the fear that students may not be learning. If he teaches in a teacher-centered fashion, he is aware that his own knowledge may circumscribe what the children learn. However, if he releases too much agency, there is a chance that students will flounder or waste time. Nevertheless, he feels it’s important to err on the side of “letting go”, even though this is often difficult for him.
Theme - Comfort as a Co-Learner: Another theme that emerged from a reading of the interview transcripts concerned the teacher’s perspectives on his own knowledge. He noted that he had become comfortable with the realization that he has misconceptions about certain topics.

\[I \text{ am very comfortable that my misconceptions may not be right. There are moments when I’m the co-learner in this classroom. Children will not let you ignore questions just because we [teachers] don’t have the correct answer. You have to let go, the feeling of being on top if it.}\]

While the teacher has learned to be comfortable with his misconceptions, he has to view himself as a co-learner, and again, let go of the temptation to control the students’ research agenda. As noted in the previous section, this creates some uncertainty.

Theme - Ambivalence: The third emotional sub-theme is that of ambivalence, and again it relates to the problem of giving agency to the students. In this interview transcript, the teacher comments on the ambivalence that arises when he has expectations that he feels that he has to cover, and letting the students take collective cognitive responsibility (agency) over their own learning:

\[You \text{ can say these are the two expectations I want to cover well. Then you can plan everything around that. But in terms of teacher directedness, it’s not just discovery learning, where we sit back, and at some point [the students] are going to pick up what [a concept means]. We want to help them make the connections}\]
Among ideas as quickly as possible, but in a meaningful way. But there are also problems when the topic is too big.

Again, we see the teacher wrestling with the problem of control (teacher directedness) and agency. He wants the students to be able to make connections among ideas quickly, but wants it also to be meaningful. And the problem is exacerbated when the topic has many elements. He is ambivalent, wanting both to control and let go at the same time. Indeed, this theme is consistent with the analysis of the classroom video, where the teacher was observed using a teacher-centered approach on some occasions, IRE methods on other occasions, and knowledge building pedagogies on yet other occasions.

Summary

While the teacher was comfortable with his role as co-learner, he expressed uncertainty and ambivalence in moving between the teacher-centered model and the knowledge building model. Time pressure and the desire to make connections among ideas were strong temptations to revert to a Teacher A model.

5.2 Online Networks

In this section, and the section that follows (5.3), we consider two networks: the reading network that formed when the students read each other’s notes, and the build-on network that formed as students responded to notes. Both of these are sub-graphs of the larger set of all interactions, and are reported separately to make the data more clear. Data sources for this section were extracted from the Analytic Toolkit, downloaded in raw
form and imported into either Excel or the UCINET social network analysis tool for analysis.

The first analysis starts with the notes contributed by each student.

![Bar chart showing the number of notes created by each student during the course of the Ancient Civilizations Unit.](image)

**Figure 8.** Graph showing the number of notes created by each student during the course of the Ancient Civilizations Unit.

Figure 8 shows the number of notes created by each student. The data have been sorted from highest to lowest prior to graphing.

We can see from Figure 8 that the largest number of notes contributed by a single student was 16, and the smallest was 2. Most students contributed between four and eight notes during the course of the unit.
Figure 9. Figure 9a shows the note contributions for the girls; 9b, for the boys.

Figures 9a & 9b show respectively the note contributions for the girls (upper) and boys (lower). This is exactly the same data set as in Figure 8, and sorted the same way, but separated by gender. As can be seen, the girls contributed, overall, about double the number of notes that the boys did. The girls’ total note contributions were 93, and the boys’ total was 48. A t-test score of $p = 0.0185$ reveals this to be statistically significant. It is unclear why this was so. The analysis of the average number of words per note showed the girls wrote an average of 71 words per note, and the boys wrote an average of 48 words per note. However a t-test score of $p = 0.095$ revealed this to be not statistically significant.
The interview transcript in which the teacher was shown the results indicates that he was unaware of these gender differences:

*Teacher: You know, this almost looks like you made it up. [laughs]*

*Researcher: I promise I didn't.*

*Teacher: It's half, I mean, even the dip is exactly [half]. It's really fascinating.*

*We've been doing a lot of talk about boys and girls and our policy is that we teach to the individual. But clearly this is telling us that there's a difference between the genders. … [The] girls are writing twice as many notes, and yet the boys are reading just as much … The boys were really invested … I'm remembering two or three of the boys. In the classroom it felt equal, but we might find that if we were to graph the oral participation, there might be some gender differences there as well.*

As the interview transcript shows, the teacher was surprised to find gender differences among the student’s note contributions. In the classroom, the participation felt equal, but was unequal. At present, there is no explanation for this finding. This could be typical, or it could be an isolated incident. Looking at the use of the keyword function, the boys added about twice as many keywords to their notes as the girls did, but again, there is no clear explanation for this. The best that can be said is that gender differences in note contributions were found in this particular unit.

Results from the questionnaire give us some idea of why students contribute notes. The results for the question about why students choose to contribute notes are given in Figure 10. The students were interviewed as a group and their interview
responses used to produce the statements to which the students responded. The statements for this part of the interview/questionnaire process were:

- S1: If the KB talk is going too fast, I sometimes create a new note to explain.
- S2: I create a new note to make something more interesting.
- S3: I create a new note rather than go around and tell everyone the same thing.
- S4: I create a new note if there’s a lot of information—too much to tell.
- S5: I create a new note if an idea is very interesting so everyone can see it.

![Figure 10](image)

**Figure 10.** Results of the interview/questionnaire process for why students choose to create notes.

In Figure 10, we can see that the most strongly supported statements are statements 3, 4, and 5: students create notes so as to not have to tell everyone things individually, if they have a lot of information to present, or if they have an interesting idea to share. Statement 1, about KB talk going to fast was not supported. Half of the
students, however, agreed with statement 2 that something can be made more interesting by creating a note for it.

Summary:

In terms of note contributions, we are struck most by the differences present: differences among the students in the overall number of notes contributed, and statistically significant differences between contributions of boys and girls. Further, the differences present overall were also present when separated by gender, with the differences among girls’ contributions being the most pronounced. Students reported during the interview/questionnaire process that they created notes so as not to have to tell people things individually, if they had an interesting idea to share, or to make an idea interesting, but this does not explain why there are gender differences.

5.2.1 The Reading Network

The reading network was ascertained through the use of server log data harvested by the ATK. This was downloaded, cleaned, anonymized, and imported into Excel for further processing. The actual analyses of the network were done using the UCINET program. The same conventions used earlier are used here: squares are boys, circles are girls, thicker lines indicate more frequent interaction, faint lines are less frequent interactions, and arrows indicate indegrees for the node to which the arrow points.
Figure 11. Sociogram showing the end state of the reading network formed during the Ancient Civilizations unit.

Figure 11 shows the network that had formed by the end of the last month of the Ancient Civilizations unit. Node size here indicates that the majority of the students both read, and were read frequently. Line thicknesses and double-headed arrows indicate that the majority of students engaged in reciprocal (strong tie) interactions with many of the other students. Student 5 (lower left corner) was not read by anyone because he contributed no notes during the Ancient Civilizations unit. On bringing this to the teacher’s attention, the teacher noted that this child had special needs and this related to his not contributing notes.
During the entire period of the Ancient Civilizations unit, the teacher only contributed two notes, and he was not included in this analysis for that reason. The network we see here is a network of horizontal interactions. The twenty students in this unit produced 348 edges (reading links), and had a reading density of 92% of the theoretical maximum with no evidence of gender homophily in reading. A hierarchical network would have had fewer edges among the students, and a lower density of reading among the students. The sociogram would have been more of a star pattern centering on the teacher, with some clustering among the students—more similar to an organizational chart (see R. L. Cross, Borgatti, et al., 2003, for an example).

Summary:

In examining the reading network sociogram, we saw that the majority of students read and were read frequently, as indicated by node size and line thickness. Faint lines indicate less active nodes, as in the case of student 5; darker lines the frequent, persistent interactions. Thus we can see both the strong tie and weak tie systems within the same sociogram. The high reading density (92%) and large number of edges (348) is consistent with a high-functioning knowledge building class (Zhang & Scardamalia, 2004). Barabási (2002) notes that one definition of community is the emergence of a “giant cluster” of connected nodes, and we can see this here—by this definition, a community of note reading students has formed. As well, the teacher, by virtue of his low number of posted notes, was not central to this community. This would be consistent with Scardamalia’s (2002) Teacher C model.
5.2.2 The Development of the Reading Network

The preceding section dealt with the end state of the reading network. This section, using the same data sources and conventions as regards sociograms, examines the developmental pattern of the reading network. Samples were taken at the end of the first week, and the end of the first month, and at the end of each month thereafter.
Figure 12. Sociograms a-e show the development of the reading network over the period of the Ancient Civilizations unit.

As can be seen, Figure 12a shows that within the first week, an inclusive network had already formed, probably a result of the class being experienced with both knowledge building and Knowledge Forum. For the remainder of the time, we see that a pattern has emerged that changes little subsequently, although some students change position within the network, an indication of dynamism. Figure 12e is unchanged from Figure 12d, indicating that there was little note reading activity during this period. Figure 12a demonstrates particularly well the differences between the strong tie (dark line) interactions and weak tie (fainter lines) interactions. As the time progresses, we can see that while initially, the weak tie network shows quite prominently, the strong tie network comes to predominate and absorbs most of the former weak tie group.

What is unclear here is whether a class of inexperienced knowledge builders would achieve a similar network in a similar time frame.

Summary:

An inclusive reading network formed quickly, and became more dense and rich in strong tie relationships (important in conveying complex information) over time, until the strong tie network had absorbed almost the entire weak tie network. Once established, the overall network structure changed little, although some students changed position within the network, a dynamic quality indicating the note reading network was still active. However Figures 12d and 12e show no such dynamic quality, indicating that by the time of Figure 11e, the end of the unit, there had been little change—that the reading was largely inactive for the final month. This was in part due to a disruption in internet connectivity.
5.2.3 The k-Core Collapse

A $k$-core collapse, as noted in the chapter on networks, is a form of network analysis in which the threshold for what is accepted as a link is raised. This helps to find persistent patterns. In the previous analyses, a single communication was accepted as a link, but in this section, we will gradually raise the threshold to see what this tells us about persistent patterns in the network. In these sociograms, the node size has not been changed to indicate interaction frequency because the $k$-core collapse would make that meaningless.

![Diagram](image)
b. $k=5$

c. $k=10$
Figure 13. Sociograms a-d show the \( k \)-core collapse for the reading network.

Figure 13a shows the reading network \( k = 1 \), meaning the a single interaction sufficed to allow the link to be included in the network.

Figure 13b shows the network with \( k = 5 \), meaning that five links were necessary for the link to be included in the network. As can be seen, 13b is not so very different from 13a.

Figure 13c shows the network with \( k = 10 \), and we see a noticeable difference. The network has centered on two girls, students 7 and 8. While there is still some reading of student 4 at this level, students 7 and 8 dominate. The fact that two girls dominate the reading at this level is probably the result of the girls having contributed more notes than the boys.

Finally, Figure 13d shows the network at \( k = 15 \). At this point the network has fragmented into a single pair of interacting students. Given that the student (girl) who contributed the most notes wrote 16 notes, it isn’t surprising that the network has
fragmented at this point. Typically the students would read a note only once, although there are exceptions.

Figure 13 shows that the overall structure of the network, its general topology, persisted up to at least the five interaction level. However at the ten interaction threshold, as 13c shows, the network has re-structured into an entirely different topology, so much so that it wouldn’t readily be identified as the same group of students on the basis of its topology. Still, at the 10 interaction threshold, the network is cohesive, with only three students unconnected to the network. At the 15 interaction threshold, the network has completely fragmented, as a dyad wouldn’t really be considered a network.

We can therefore say that the $k$-core collapse reveals that for this class, reading interactions up to the five interaction level were common, that they diminished after that to the ten threshold level, and subsequent to that, the network began to fragment completely. This pattern may be typical, but absent of other samples, it is impossible to say. This is an area that requires further research. Combining these data with the reading network data, we can see that the students engaged in reciprocal interactions, and as the $k$-core collapse data from the $k = 5$ threshold level indicate, they frequently read each other’s work.

Summary:

$k$-Core collapse sequences are designed to show the persistent clusters in the network as the interaction frequency threshold is raised. Here, we can see that the overall shape of the network is robust to at least the five interaction level, indicating that most students had reading interactions at least five times during the course of the unit. By the ten interaction threshold however, the network had changed considerably, revealing that
two students were responsible for most of the reading interactions at that level. Still, much of the network remained connected. By the fifteen interaction level, the network had almost completely fragmented.

5.2.4 Indegree Centrality, Power, and Influence

Indegree centrality is calculated in two ways: a simple count of the indegrees to a node, and a weighted indegree centrality that is the counted centrality divided by the maximum centrality and expressed as a decimal or percent (Degenne & Forsé, 1999). A weighted centrality allows for better comparison among networks of different sizes. Here, weighted indegree centrality has been used.

In the social network analysis literature, indegree centrality is considered an important measure related to power, but with regard to a note reading network, it is difficult to see what power means. Lewis clarifies this, equating power to influence in social networks (Lewis, 2008, p. 21): “The influence a person exerts on a group is proportional to the position, number, and power of colleagues the person has within the group, such as the person's connectivity.” Thus, the indegree of an individual in a network is an indicator of the influence they have on the group, in this case through the number of ideas they spread through being read by other students. A very uneven pattern, with one individual having a very high indegree, and others a very low indegree, would indicate that the first individual could have had a disproportionate influence on the class—they would dominate the discourse. Figure 14 shows the indegree values for the students.
Figure 14. Graph of indegree centrality values for the reading network.

Figure 14 shows that the reading network demonstrates considerably evenness in indegree centrality values. Thirteen of the students received the same value, and the other students are lower, but not dramatically so. Student 5, of course, is an exception because he contributed no notes. Based on this analysis, the students in the class were quite equal in influence, with no one individual dominating the interactions. Zhang et al. (2009, p. 64) indicate that centrality measures indicate variance among the students. High variance would indicate a high degree of centralization in the network. In this case, the centralization of the network is low, as no one individual has a centrality value very much higher than the others. This would not be true in highly centralized networks. This would
be consistent with students taking collective cognitive responsibility for the advancement of community knowledge (Scardamalia, 2002).

Summary

Indegree centrality values show low variance, indicating evenness of participation in note reading. In the reading network, no single individual dominated the network.

5.3 The Building-On Network

The building-on network is the network of responses (i.e., who responded to whom online) during the course of the Ancient Civilizations unit. The sociograms presented here follow the same conventions as in the previous sections.

The sociometrics for building-on are different from those for the reading network. Recall that the reading network had 348 edges and a reading density of 92% of theoretical maximum. We would expect that the building-on network would have a smaller number of edges and a lower density because responding would be less frequent than reading. For building-on, the number of edges was 64, and the density was 15% of theoretical maximum—both numbers considerably lower than for reading. The teacher was asked during an interview if he felt this level of building-on was low. He replied,

In terms of build-ons, if this were information from a [class in progress], I would go and look and see are people not building-on for a good reason. Is it because of the type of questions we are asking, is it just not asking people to build-on, or is it because we haven't had time, or are we addressing these in a face-to-face environment? … And it might be perfect just the way it is.
The teacher here identifies a few reasons why building-on might be infrequent. It might be the type of questions being asked in the notes, it might be because the students had not been reminded to build on recently, or it might be because of face-to-face interactions in the class. In any event, the teacher was reluctant to characterize this level of building-on as bad, because, “… it might be perfect just the way it is.”

Figure 15. Sociogram showing the building-on network.

Figure 15 shows the end state of the building-on network. Compared to the reading network, there are many fewer reciprocal interactions, indicating that this is a weaker-tie network. Because building-on was much less frequent than note reading, the node size is unaltered in this sociogram because it would give the impression that some
students were more dominant than they were at this level of interaction. As with the note reading network, we do not see gender homophily here—both boys and girls interacted freely.

Summary:

The building-on network was overall sparser than the reading network, having fewer edges (64) and a lower density (15%). However, the building-on network was inclusive, with all but one of the students contributing. Although not as strong as in the reading network, by Barabási’s definition (2002), a building-on community had emerged among the students.

5.3.1 Build-On Contribution Patterns

![Figure 16](image)

*Figure 16.* The pattern of build-on contributions for the whole class.

Figure 16 shows the pattern of contributions for the entire class. We can see that same kind of pattern that we found in the analysis of note contributions—some students
contributed disproportionately more than others. In this case, the highest-contributing student contributed 12 build-ons, and the lowest-contributing students contributed 1 build-on. In both note contribution and building-on, student 8, a girl, was the most frequent contributor. Half the students (10) contributed 2 or fewer build-ons, while one student, student 5, contributed none (consistent with his performance in note contribution). Four students (students 8, 3, 4, and 7, all girls) contributed over half (51%) of all build-ons. This could indicate that they could have had a larger influence on the class than their classmates. These students are also centrally clustered in Figure 16.
Figure 17 shows the same data as Figure 16, but separated by gender. We can see a similar pattern to that found for note reading: the girls contributed about twice as many build-ons as the boys did. A t-test value of $p = 0.0432$ indicates that this result is statistically significant. It is perhaps not surprising that these results are similar to those
of section 5.3, since there is likely a tight relationship between the number of notes written and the number build-ons written.

When the build-ons and new notes (not build-ons) were separated from the total note contributions we found that the variance among new note contributions was not statistically significant between boys and girls, indicating that most of the variation in note contributions is due to the build-on notes created by the girls.

**Summary:**

Analysis of the build-on contributions for this class reveal greater differences in participation levels than seen in the reading network, enough so that it could be said that in terms of building-on, some students were more influential than others. This could not be said of the reading network. As in note writing, statistically significant differences in levels of contribution were present between boys and girls, with the girls again contributing more. Combining these two results, the girls were more influential than the boys as revealed by their creation of build-on notes.

**5.3.2 Development of the Build-On Network**

As with the reading network, the development of the building-on network can examined by means of a longitudinal study. Samples were taken at the end of the first week, and at the end of each subsequent month. In this case the last month was omitted as the network had not changed from the previous month.
a.

b.
Figure 18. The development of the build-on network.

Figure 18 illustrates that the building-on network developed more slowly than the reading network. 18a shows that relatively few of the students (9) participated in building-on during the first week, whereas all twenty students had participated in note-
reading during that time period. As well, we do not see the degree of interconnectedness that we saw in the note reading network.

By 18b, however, the network was better-developed and eighteen of the twenty students participated. Student 5 (special needs) did not participate in building-on, and student 14, who eventually did, was also peripheral in the note-reading network for a long time.

In 18c and 18d there is no change whatsoever between the two graphs, indicating that building-on had virtually stopped. While the note-reading network showed some changes for most of the unit, the building-on network does not show the dynamism that would indicate network activity toward the end of the unit.

It should be pointed out that, mathematically, one would expect a build-on network to develop more slowly than a reading network. For example, if there are twenty students in a class, and if students make an effort to read all of the messages that are posted online, each student must read, on average, approximately 20 notes for every single note they write. The potential for interconnectivity is much higher in the reading network and the network forms more rapidly.

Figure 19 shows the daily contributions (notes and build-on notes) during the study period, and can help to clarify the growth of the build-on network.
Figure 19. Graph showing the number of notes and build-ons contributed each day during the study period.

Figure 19 shows that contributions (notes and build-ons) were most frequent in the early stages of the inquiry, and decreased in frequency thereafter. The contributions appeared in bursts. As well, there were long periods of dormancy when there were no contributions.

The bursts of activity are consistent with patterns found in other human systems. Barabási notes (2005, p. 209), “… as long as individuals balance at least two tasks, a bursty, heavy-tailed interevent dynamics will emerge” (2005, p. 210). This implies that as long as the students have multiple tasks, a pattern of contributions in bursts will occur. The hypothesis is that “…humans execute their tasks based on some perceived priority, setting up queues that generate very uneven waiting time distributions for different tasks” (2005, p. 211). However, the exact mechanism for this remains unknown at this time (2005, p. 209).
The periods of inactivity are easier to explain. Knowledge building sessions on Ancient Civilizations occurred three times per week. The other days, and on weekends, the students did not have the opportunity to contribute. The Christmas break intervened starting about 49 days into the study and ending about 69 days into the study, and there was a period of time (days 81-89 on Figure 19) when the connection to the internet was unavailable to the class and students were unable to work with Knowledge Forum. Towards the end of the unit (around day 100), the students began to be more focused on presentations than on knowledge building work, and as a result, did less work on Knowledge Forum.

Summary:

The longitudinal analysis of the development of the building-on network demonstrated that it developed more slowly than the reading network, and that it was not as consistent in topology as the reading network. The weak tie network is more prominent here even by Figure 18d, which was near the end of the unit. Similar to the reading network, Figures 18c and 18d reveal no change, indicating that the building-on network was not dynamic at this point–little or no building-on was occurring, not enough to change the network topology. However, the network was inclusive, with only one non-participating student.

All note and build-on contributions occurred in bursts, a pattern typical of students having multiple tasks that prevented them from contributing. Some bursts were larger than others, and it is not clear why. Large bursts were more prominent at the beginning of the unit, and absent during the later period of the unit. This, however, may be unique to this class.
5.3.3 The $k$-Core Collapse of the Build-On Network

As with the reading network, a $k$-core collapse sequence analysis was done on the building-on network. Because the building-on network was sparser than the reading network, thresholds of 1, 2, and 3 were used for this. The same conventions for the sociograms were used here as before, and again, node size was not changed to reflect frequency as this is not meaningful for the $k$-core collapse.

\[ a. \quad k=1 \]
Figure 20. The $k$-core collapse sequence of the building-on network.

The $k$-core collapse sequence for the building-on network shows it to be more fragile than the reading network. At a threshold of $k = 1$ (Figure 20a), the network is a highly connected cluster with one non-participant. However raising the threshold to $k = 2$ fragments the network into twelve unconnected individuals and a connected cluster of only eight students (Figure 20b). By $k = 3$ (Figure 20c), the network is down to a dyad, and by $k = 4$ (not shown), it is completely fragmented, with no build-on connections. In
contrast, the reading network was robust to $k = 5$. It is not known at this time whether this represents a normal pattern. We would not expect that building-on would happen as frequently as note reading, but it might be hypothesized that more frequent building-on would enhance knowledge building. This is an area that requires more research.

**Summary:**

The $k$-core collapse sequence of the building-on network was revealed to more fragile the reading network. Whereas the reading network was robust in topology to the threshold level of five interactions, the building-on network showed considerably fragmentation by the threshold level of two interactions, and by three interactions, was completely fragmented. It could be viewed therefore, that the building-on community was more fragile than the reading community, using Barabási’s definition of community as a connected cluster (2002). However, it should be noted that it is not really known what level of building-on activity is optimal for knowledge building, only that higher densities are associated with high functioning knowledge building communities (Zhang & Scardamalia, 2007).

5.3.4 Centrality, Power, and Influence in the Building-On Network

Indegree centrality is calculated here as it was for the reading network: weighted indegrees calculated by taking the indegree count, dividing it by the maximum and expressed as a percent.
**Figure 21.** Graph showing the indegree centrality values for the building-on (response) network.

Indegree centrality for building-on indicates who has been built-onto the most, not who has created the most build-ons, and therefore indicates whose notes have been influential enough to cause others to respond.

Again following Lewis (2008), who views centrality measures more as measures of influence than of power, we can see that there is a large difference in the indegree centrality measures among this group.

In examining the reading network indegree centrality, we remarked on the degree of evenness among the results. Of the twenty students, thirteen had the same high value, and there was no large difference among the students. However in building-on indegree centrality values, we see a larger difference. These results imply that as far as actual
responses, some students in this class are more influential than others. This might be partially explained by the fact that some students contribute a larger number of notes than others. However, this could only partially explain the results, because the highest note-contributing student was student 20, and the highest students for build-on indegrees were students 2 and 15, who in comparison contributed nine and thirteen notes respectively. Student 20 was fifth in build-on indegree values. A social network analysis reading of this phenomenon is that students 2 and 15 were more influential among this class than the other students.

A gender analysis of indegree centrality for building-on was performed, but although there were differences, a t-test p value of $p = 0.13$ reveals these to not be statistically significant.

Overall, indegree centrality values for building-on are lower than for reading, but this is explained by the fact that building-on is a less frequent event than note reading. Both the building-on network, and the $k$-core collapse of the network (which decomposed completely at a threshold of three) support this.

**Summary:**

Indegree centrality among this group showed large differences between highest and lowest students. Four students, all girls, showed a centrality of zero. This contrasts to the evenness shown in the reading network. While no individual could be said to predominate in influence in reading, we can identify more influential students in the building-on network. Gender differences were present, but not statistically significant. Perhaps this is because building-on was sparser than note reading.
5.3.5 Summary of Findings

This section revealed differences between the reading and building-on networks. The building-on network was not as richly interconnected as the reading network, and that while there was evenness of influence in the reading network, the building-on network showed that some students may have been more influential than others.

The rich interconnections revealed by the reading network provide pathways through which students can become aware of the ideas of other students. The building-on network allows students to elaborate on each other’s ideas, but each student only interacted with a handful of other students during the Ancient Civilizations unit.

The $k$-core collapse of the reading network showed it to be quite robust, showing sustained interactions among pairs of students, whereas the $k$-core collapse of the building-on network showed few sustained interactions between pairs of students.

Collectively, these types of analysis are potentially useful for identifying the breadth of the discourse network through the level of student interactivity; for identifying who among the students are peripheral to the group, and who are central (influential) to the group; and for demonstrating whether there exist sustained, reciprocal interactions among pairs of students.

5.4 Idea Spread in Knowledge Forum

In this section, we report on the spread of ideas through the Knowledge Forum database. As noted in the Methodology section, two ideas were chosen for close study: the idea that having a written language was important in judging if a society was a civilization, and the idea that having an organized religion was important in judging if a society was a civilization. Both ideas were introduced early on in the unit (during the visit
to the Royal Ontario Museum that introduced the unit), and were referred to frequently in student notes.

The analysis was in the form of a content analysis as per Krippendorff (1980) and Neuendorf (2002) (see Appendix D for the code book). The researcher and a second coder each read all notes in the Ancient Civilizations view, eliminated any notes that were not within the boundary specifications (class and teacher), and coded them separately. For both ideas being tracked, there was high inter-coder agreement (≥95%), probably because keyword coding simplified the process considerably.

5.4.1 The Network of Ideas about Religion

Figure 22 shows the network of notes that formed around the idea that an organized religion is essential for a society to be identified as a civilization. Figure 22 is a spring algorithm sociogram with note names removed so as to make the pattern of connections clearer. Notes are present in the analysis if they contain a reference to religion being important to the identification of civilizations; links among the notes indicate build-ons, annotations, or other links that also contain references to the idea. “Other links” here refers to any form of reference to another note, either formal (KF referencing function) or informal (such as a passing reference in the text of the note).
Figure 22. Sociogram showing the build-on or other connections among notes containing references to religion being important in identifying a society as a civilization.

In Figure 22, it can be seen that not all notes containing the idea are linked, but many are. This analysis proved sensitive to non-participants and the degree of linkage would have been greater if the non-participants had been included in the analysis.

It can be seen that a cluster of sorts has formed around note 14, entitled “How is religion a part of an ancient civilization?”. This note can be seen to be central to the largest cluster of notes (11 in total), and it can be seen that there are connections among the build-ons as well. Such patterns are often called star pattern clusters. We also have a triad of notes and two dyads.

This note was unusual in that it had four co-authors. (Co-authoring was sufficiently rare that it was not possible to identify any co-authoring networks that formed). The note contained a series of questions, all about religion (as opposed to a note
that may contain multiple questions, but about different things), and importantly, was a rise-above note—an attempt at synthesis in which the co-authors gathered relevant notes about the questions they were posing. This cluster was therefore intentionally created to focus on religion.

Figure 23 shows the idea spread network for the idea that having a written language was important in determining if a society was a civilization.

*Figure 23.* Sociogram of the idea spread network for the idea that written language was important in identifying civilizations.

Figure 23 shows a higher connectivity than Figure 22. Eight of the twenty-five notes identified are unconnected, and we have two clusters: a linear cluster of six notes with no real central focus, and a star pattern cluster of eleven notes centering on note 9, entitled “Language of all the civilizations”. The same *caveat* applies here as with the
previous analysis: the level of connectivity would be higher than shown because of the effect of non-participants.

Note 9 discussed the importance of the alphabet, Norse runes, and the quipus (knotted rope documents) of the Maya, Inca, and Olmecs. Unlike the previous analysis, this note had a single author. As in the previous analysis, the note was tightly focused on the nature of written language, and whether or not the quipu could be considered to be “written”. Again, as with the previous analysis, this was a rise-above note created as an attempt at synthesis of ideas.

Idea synthesis is important to knowledge building, and so the appearance of such a rise-above cluster is an indicator of such synthesis.

Summary:

Figure 22 shows that a rise-above star pattern cluster was the largest connected group in the idea network about the role of religion in civilizations. Overall, this network was fragmented, and therefore it is impossible to meaningfully calculate indegree centrality. The rise-above note was focused on a single idea, and asked specific questions about religion’s role in civilizations, and had four co-authors.

Figure 23 shows another rise-above star pattern as the largest cluster (11 notes), although there was a linear cluster as well. The rise-above note asked focused questions and but unlike the other rise-above, had a single author of record.

It is notable that both of these notes appeared after the students had done enough research to identify multiple issues regarding the idea. This implies that a period of time is need to generate notes that contain information, and that in order to generate a cluster, there has to be some form of synthesis of that information, in this case in the form of a
rise-above note. This may relate to what causes an idea to become a Big Idea for the class. These attempts at synthesis serve as indicators of knowledge building.

5.4.2 A Temporal Analysis of Idea Spread

In this section, we examine the patterns of idea spread over time. Earlier in the chapter, data were introduced showing that contribution levels (notes and build-ons) were not steady, but occurred in bursts. Here, we examine the two ideas (religion and written language), and when notes about them were contributed, how many, and what relation they had to classroom activities.

Figure 24. Graph showing the weekly contributions of notes or build-ons relating to the ideas about religion and written language.

Figure 24 shows for each week from early November to early February the note and build-on contributions that contained ideas about the importance of religion and
written language in determining if a society was a civilization. We can see that the contributions did occur in bursts, (the big gap for the Christmas break has been left out here), as was previously noted.

Early on, there was a large burst of contributions relating to the religion idea, and on two subsequent occasions, there were other bursts. When shown these data, the teacher commented about the religion idea:

> We try to create as many opportunities for students to become interested, we try to have as many questions on the database as possible, but we can't really determine what's going to engage all of the students. What this is showing us is that there was a lot of interest early on about religion. I remember those discussions, and I think that that would be something that the children, because it's a non-denominational school, would, in their diversity in the classroom [be interested in]. That makes a lot of sense.

The teacher here believed that the cultural diversity of the class caused the religion idea to pique the interest of the students who were aware of the diversity of religions in the class. As well, there were classroom discussions about religion that may have contributed to note contribution.

In addition to any classroom discussions, the visit to the Royal Ontario Museum (ROM) raised some questions about religion that might have spurred interest among the students. For example, this is a note by one of the girls:

> At the ROM I had one question. How did constellations start and who come up with constellations? I haven’t shared these yet with anyone one. And I
had a question about the Afterlife in ancient Egypt. The question I had is did what the Egyptians believed happen in the Afterlife actually happen? I also haven’t shared that question yet.

The ROM teachers gave the students a description of the Egyptian version of the afterlife, and a student was understandably curious as to whether the described events could occur. The religions of some Ancient Civilizations differ considerably from those of the modern religions with which the students would be more familiar, and would be new and odd to the students. Since the ROM visit was early in the unit, this might account for the early spike (first week) in notes about religion.

The written language idea also appeared in bursts, but the contribution levels were lower for the most part, without a single large burst, as can be seen for religion. Again, the teacher commented about this:

*The writing is something that I think would take a little bit longer for them to appreciate. Why is that? Why do they agree or disagree with what the people from the [Royal Ontario Museum] said? Maybe that was because they did more writing, had a deeper understanding of what a civilization was, so that may have grown. I think it does show you that it's hard to predict, and that's why we need to leave as much open as possible for them to decide.*

Here, then, the teacher believed that the importance of written language was not as immediately apparent to the students as the importance of an organized religion. As well, arguing against the importance of written language (as some students did) in
judging a society to be a civilization required the students to recognize that there were societies that might be a civilization, but didn’t have a written language, as discussion of the Mayan quipu (knotted rope records) indicated.

One question that arose in designing this study was whether the KB talks influenced note posting. To examine this question, a timeline was created showing the postings about religion, written language and the relations with knowledge building talks and classroom observations.

Figure 25. Timeline of postings about religion and language, and KB talk and classroom observations.

Figure 25 shows the timeline from the beginning of the unit until the effective end of the unit (when students began to work on presentations rather than knowledge building). The purpose of this was to see if KB talk, or other classroom discussions, had an effect on postings about organized religion or written language. The data as to the number of postings here are the same as in the previous figure.

During Nov. 15-19, there was a KB talk, but neither religion nor language was discussed. Religion was posted about once; written language twice. During Jan. 10-14, a KB talk discussed religion, and a classroom discussion about written language was
observed. Religion was posted about once; written language twice. However during the periods when there were no KB talks or observed discussions about religion or written language, we see instances of many more postings, as during Dec. 6-10 and Dec. 13-17. In fact, during weeks when there were KB talks, there were no instances of larger numbers of postings about religion or written language. During Jan. 17-28 there was an internet outage during which the class did other work.

The flurry of postings about religion before the Christmas break might be explained by the proximity to Christmas, a religious holiday not shared by some students. However, the burst of notes about written language cannot be similarly explained.

These data show no indication of connections between KB talks and postings in the database. However, because of the limits to the observations (including students being present in another room), it is not possible to say that no such connections existed.

We can therefore say that although postings about certain ideas appear in busts, the stimulus for this is not obvious from these data. However, the teacher, in interview data had some ideas about this. When asked about how he would manage his class without Knowledge Forum, he replied:

"Teacher: That's a question I'm [often] asked, how would you do this without KF? I say, well, it would be very difficult. On one level, it would be easy in the sense that that's how we would start, but what KF allows us to do is, as the graphs show [referring to the graphs showing contributions in bursts], it allows us to have a period where we're interested in something else, where we haven't resolved that idea or that question, and then we can come back to it. Maybe something that we've been researching in the meantime is connected to [it], and the children
realize that all these connections, that something we’ve abandoned, we can go back and search for become interested again because we had new information.

Researcher: So you're saying the ideas are less ephemeral and don't get lost.

Teacher: Yes, that's it. They don't get lost [pause] and they're easy to access too, so it's not only don't we forget about them, but it's easy to bring them back as well.

This is an appealing and intuitive answer to the question of bursts in contributions, but it would take further research to establish this firmly.

Summary:

Notes about religion and written language were contributed in a fashion that showed a different pattern. Notes with ideas about religion appeared in bursts—a number of notes appearing in the same week—and three of these bursts were larger than the largest burst of notes about written language.

Notes about written language also appeared in bursts but these tended to be smaller than bursts about religion, although there were exceptions to this. Once, towards the end of the unit, there was a large burst of six notes about written language.

The teacher felt that ideas about religion and different civilizations might already be more familiar to the students and this might account for the larger bursts of notes about it. The association of written language with civilizations, on the other hand, was a less-familiar idea and the teacher felt that this might be slower to develop.
5.5 Idea Improvement

The notes from the Ancient Civilizations database view were analyzed for evidence of improvement of ideas according to the following criteria:

- Does the note indicate that there are flaws in an idea from an authoritative source?
- Is there a suggestion that the idea needed to be changed?
- Is there a suggestion as to how the idea should be changed?

The results of the analysis indicate that the students do actively try to improve ideas.

Take the following examples:

Example 1:

*At the ROM we heard from our tour guide that a group of people is not considered a civilization unless their material (buildings, statues, houses) lasted. Native Canadian Tribes are not considered civilizations to some researchers.*

*This theory cannot explain [Scaffold support] What if the artifacts that aren't made of preservable materials do last? For example the totem poles we saw in the ROM? It shouldn't matter what the building material was, but rather what was being built. For example if a temple is built out of wood then that showed they prayed. It all depends where the group of people lived and what resources they had access to. The group was not interested about being considered a civilization but rather using the material to survive.*

Analysis

- In this example, the student explicitly referred to the set of characteristics given at the ROM.
• The student stated that the theory from the ROM cannot explain something. This is important for two reasons: first, the student recognized that what they were given at the ROM had the status of theory and is improvable, not immutable; and secondly, the student pointed to a perceived flaw in the theory.

• According to the ROM, one of the characteristics of civilizations is that they build in durable materials, and they did not consider wood to be a durable material. The student noted that sometimes wood does survive for long periods (implying that it is durable), and that the choice of building materials had more to do with what was available rather than what would be the most durable. Moreover, the function of the building is arguably a better indicator of civilization than the materials it was built from.

This would therefore be considered idea improvement because the student identifies an idea, finds an identifiable flaw, and proposes an alternate idea to solve the identified problem, satisfying all three criteria.

Example 2:

*I need to understand [Scaffold support] Are cavemen considered a civilization?*

*My theory In order to answer this question, we need to know the definition of a civilization. Do we agree or disagree with the definition we got at the ROM? I think we should develop our own definition.*

Analysis

• The student explicitly referred to the ROM definition of a civilization.
• The student posed a question about whether or not caveman societies could be considered a civilization.

• The student asked if the ROM definition should be accepted, and expresses the idea that the class should develop their own definition.

Although this note does not propose a specific alteration in the ROM definition, it does pose a problem that the student feels the ROM definition cannot satisfactorily handle, and suggests that the ROM definition is not definitive and is improvable, satisfying criteria 1 and 2.

Example 3:

New information [Scaffold support] In the Webster New Dictionary and Thesaurus I looked up the word civilization. The actual word was not in it but one two of its root words civil and civilize were. Civilize means to be proper, polite and well mannered, to surpass the low level of barbarianism and to be artistic and refined. (civilization) (civilized). Civil is to be part of a community or a citizen and follow the rules and laws of it. To have the same qualities of other city-bred people: politeness, refinement and a ordinary life style.

So if civilization is to be ordinary and kind then why is one of the main characteristics of most civilizations war and barbarism?

Analysis:
Although the student did not explicitly mention the ROM characteristics, he/she indicates dissatisfaction with them by going to a dictionary and looking to see if there was an alternate definition.

Finding no definition, the student synthesized one from the root words *civil* and *civilize*, indicating an alternate theory.

The student then pointed to an implied flaw in the ROM characteristics: that one of the main characteristics of civilizations identified in the literature (again implied) is war and barbarism. The student felt that his/her criteria were an improvement on the ROM theory.

This therefore satisfies all three criteria: it identifies an (implied) flaw in an idea from an authoritative source, suggesting a need for change, and suggests an alternate idea.

Although not exhaustive, these three taken together demonstrate that the students actively try to improve ideas. The summary for this section is combined with that of the following section.

5.5.1 Teacher Comments

During the post-study interview, the teacher was asked if he had seen evidence of idea improvement in his classes, and if so, what did it look like. He responded,

*Absolutely … there are many examples. I remember one year in Gr. 4 where a student had written something about light. … I think it was about lenses and somebody else said no but this can't be, and you could just see the conversation [develop] … [T]his is between two children who wouldn't normally engage in a class discussion, but because it was very safe in the sense that they*
could approach those problems on their own terms, in their own time, and own comfort, we could see idea improvement, that they were talking in a way that … emotions were removed from it. It was strictly about improving our understanding …

We also have video footage of … children trying to solve [problems about ideas] … where there's contrasting theories, and how do you bring these together, and … it's not so much that they're contrasting theories [but] that there are facts that support this and facts that support that. And so if … we have one theory for one and one theory for the other … we realize that the theories aren't good enough, we need to improve our ideas or theories in order to encompass even what seems like apparently contradictory facts. Light travels in a straight line or it travels in a, in waves. And so we can't, our theory of now light travels needs to rise above that and incorporate all these apparent contradictions and then maybe we realize they're not contradictions. So I think [is] some evidence of idea improvement.

Thus the teacher’s evidence supports the analysis above. He too notes the students finding flaws in authoritative sources (light as particles, light as waves), suggesting that the contradictory theories need to be changed, and suggesting improvements to them (rising above).
Summary:

The idea improvement analysis was not intended to be exhaustive, and was to serve as an indicator that students did indeed work to improve ideas. The analysis revealed that this was so. At least some students identified flaws in ideas from authoritative sources, and suggested improvements to them.

Data from an interview with the teacher supported this. He noted that video data show students trying to solve problems where there are contrasting theories with attempts at synthesis. He stated that students realize that facts may support some theories better than others, and that they needed to rise above their current theories to resolve these contradictions. He considered this to be evidence of idea improvement.

5.6 Teacher Comments Additional to the Original Research Questions

As is standard in qualitative research, the teacher was asked questions that were quite open-ended, and the researcher encouraged him to talk as much as he wanted to about any of the topics covered. As a final question, the researcher asked the teacher if there were any questions that had not been asked that should have been. There were two areas of comment relevant to this analysis.

The first area relates to the use of Knowledge Forum. The teacher supported the use of Knowledge Forum as a channel for idea spread, noting,

Absolutely [Knowledge Forum is] an advantage because it archives the idea; and it also reminds us of the origin of the idea, and the development of that idea. And so, some people have that skill, that incredible memory, where they're able to say, “Actually no, this is what we thought originally”, but the software ensures that we know where the idea came from … not necessarily who the
author of that idea was, although that's available to us through the software, but just what was the first version of that idea, how was it developed through the subsequent build-ons.

The teacher also commented about Knowledge Forum allowing ideas to live on past the vagaries of short-term memory:

[If] you go on a field trip, and then you forget … a child might still be grappling with something, but if the structure in the classroom, on the schedule, in the curriculum is not supporting that, so that these ideas can continue to live on, then we're not going to get that depth or that interest. So that's what KF does … like those reflections at the end of the week, having children think about, what did they contribute.

This comment supports Smith’s (1994) idea that the online system can function as an external long-term memory for the group. Ong (1982) notes that for spoken language, the first syllable disappears before the last syllable is spoken, making oral interactions hard to remember accurately. Knowledge Forum supports reflective practice for the child who is trying to understand an idea that would be ephemeral verbally, but persists in the Knowledge Forum database.

The second set of comments was about the use of social network analysis and the newly-built social network analysis analytic tool. The teacher has found the ability to analyze the communication patterns among the students to be useful:
Teacher: I think this has been the tool that … has been the most effective of all the tools to be quite honest. One, as a teacher, when I've seen myself at the centre of that network, it was a very embarrassing moment, realizing that all the interaction was happening through me.

As well, he comments on the students’ use of the social network tool:

Teacher: [I]t was fascinating. I remember children often using that tool when we were doing a study of the long jumps. … [O]ften, because it's so visual, they realize who they're connecting to the most, and then in reflecting upon that. Are there good reasons for choosing those people? Is it because that's your twin brother? Or is it because that's somebody you respect when that person is speaking orally, or communicating orally? Or is it that that's a friend of yours’? And are there people that you're not reading? And children really were aware of that, that there were people's notes that they were not [reading], and that gave them, gave us all information. If a child isn't writing a note that's coherent, people are going to stop reading your future notes because there's only so much time and they're going to be selective. And so that I think had a great, great impact on the way, sort of their thinking of the way they were as researchers, as learners.

Researcher: D: So, it changed … your practice?

Teacher: Yes.

Researcher: And also the students do have access to it?

Teacher: The students do have access to it.

Researcher: And use it?
Teacher: And they like it.

This demonstrates that such analyses and tools have the potential to be transformative in the classroom. The teacher and students actually changed their behaviour in response to the new data the social network tool revealed.

Summary:

The teacher had two comments additional to the research questions. He supported the idea of Knowledge Forum as a channel for idea spread, suggesting that the software supplemented the students’ memories, allowing them to find the original idea source and what exactly it was like. This is similar to Smith’s (1994) view of online discourse systems functioning as external long-term memory for a group, as ideas in oral discourse can be ephemeral and easily forgotten (Ong, 1982).

Importantly, the teacher considered the social network tool now built into Knowledge Forum to have the potential to transform both his and the students’ classroom behaviour. He noted that when he saw that in some classes he was very central to the network and was embarrassed, and that the students have access to, use, and like, the social network tool.

5.7 Summary of Results

This chapter considered the results from four broad categories of analysis: the networks that formed outside of the regular class; the teacher’s role, including KB talk; the analyses of the ATK server log data that preserved interactions in Knowledge Forum; and the spread of ideas in Knowledge Forum, including the relationship between live-class interactions and the online discourse.
The outside of the class networks were found to be sparse and fragmented. In each of the three weeks studied, the number of students who did not report participation ranged from seven to ten students, indicating that up to 50% of the class did not report discussion of in-class ideas outside of the class. However, as noted in Chapter 3, the free recall method used here usually results in under-reporting of the actual network, resulting in networks that appear smaller and more fragmented than they actually are. It is therefore likely that more students participated than were reported and that the networks could be better connected than they appear here. Nonetheless, contact about in-class ideas cannot be considered to be common or frequent, and playground talk cannot be considered to be a major factor in idea spread for this class.

In-class interactions were revealed to be a mix of traditional and knowledge building techniques, with the teacher expressing uncertainty, discomfort, and ambivalence about moving towards relinquishing control to give the students as much agency as possible and still maintaining control of the class overall. He expressed this as a tension between the factory (direct teaching) model, and an organic (protocological control) model, and noted that sometimes he was more teacher-centered than he wished to be. He was constantly striking a delicate balance between traditional and non-traditional methods.

In studying the online interactions, we first noted that there was a difference in contribution levels among the class, with a high of 16 notes contributed by one student and a low of two notes (omitting the student who contributed no notes). Such a difference indicates at least the potential for higher-contributing students to have a greater influence on the course of online discourse than lower-contributing students.
Note contribution patterns also revealed gender differences in participation with the girls contributing about twice as many notes as the boys, a difference that was statistically significant. Similar gender differences were noted in indegree centrality in the building-on network. Whether these differences are unique to this class or would be present in another class is impossible to tell at this time.

Interview/questionnaire results demonstrated that the three main reasons students reported creating notes was (1) so as not to have to tell everyone individually, (2) if there was a lot of information to tell, and (3) if a particular idea was interesting and the student thought that everyone should see it.

The reading network was revealed to have a dense structure ($D = 92\%$) and was highly cohesive. All participating students were present in the network, and the $k$-core collapse sequence showed that it was robust to the five-interaction level. Clustering based on gender homophily was not observed, although it was predicted in the literature. Again, it is not known if this is unique to this class.

The reading network established itself quickly, with much of the network being in place within the first week of the unit. This is consistent with data about note contributions that indicated contributions in bursts and showed the largest burst in note contribution early on in the unit. By the end of the first month, the network showed a regular structure but careful examination revealed that there were positional changes among the students indicating that the network was still a dynamic, functioning entity. However in the last month, this dynamism stopped, indicating that little note reading activity took place. Data about note contributions revealed that there were few note contributions during this period, and classroom observations indicated that this
corresponded to the period when the students were either preparing their presentations or presenting them.

In contrast to the building-on network, indegree centrality values for the reading network showed considerable evenness of participation.

The building-on network was sparser than the reading network having 64 edges total in contrast to the 348 edges for the reading network. As well, the density, at 15% was considerably lower than the reading network density of 92%. Given that building-on is usually less frequent than reading notes, this should not be considered abnormal. However it is possible that it is not optimal.

Contributions patterns for building were similar to those for reading, with some students contributing much more than others. Again, similar to the reading network, statistically significant gender differences in build-on contributions were found, with the girls contributing about twice as many build-ons as the boys.

The build-on network grew more slowly than the reading network, and was not as robust to a $k$-core collapse sequence, fragmenting almost completely by the 3-interaction level.

Unlike the reading network, the indegree centrality scores showed that there was unevenness in centrality among the students, again indicating at least the possibility that some students were more influential than others due to the frequency with which their notes were read and built-onto.

The idea spread analysis of the organized religion and written language ideas revealed that rise-above star pattern clusters had formed. In one case, the rise-above note had four co-authors listed, but in the second case, there was only one author. Both rise-
above notes were focused on one topic and asked a question or questions about the idea being tracked.

The temporal analysis of idea spread showed that the religion idea tended to appear in bursts, while the written language idea had fewer large bursts and were somewhat more even. The teacher attributed this to the nature of the two ideas: the religion idea being immediately appealing to the multi-cultural class, and the written language idea being less quickly taken up.

Analysis of the KB talk sessions content and observational data compared to the online discourse did not demonstrate a connection between the live-class sessions and the database content, although this is an intuitive appealing idea. This may be unique to this class.

Analyses of note contents and teacher interview data indicated that idea improvement did occur in the class, and that Knowledge Forum was a channel for this. The teacher indicated that this might be due to Knowledge Forum playing a role in the persistence of ideas so that they are not forgotten. Smith (1994) viewed online systems as extensions of memory, as does Donald (1991), who includes them with other external memory fields, and this may play a role in idea improvement.

Finally the teacher, who has since used the new analytic tool suite in his class has found the social network tool to be useful and indicated that it transformed practice in the classroom.
CHAPTER 6: CONCLUSIONS

6.0 Overview

This chapter will examine the original research questions in light of the results from the previous chapter; highlight conclusions that emerged from the research but were not among the original questions; discuss and evaluate the research methods used; and point to future directions for this research.

6.1 Research Questions and Answers

6.1.1 What is the relationship between the social network structure and the spread of ideas in knowledge building environments?

Analyses 2 (idea spread questionnaire) and 5-8 (the analyses of the archived database material) addressed this question. Sociograms created from the idea spread questionnaire data show that in the reported outside of the class networks, interactions were sparse and the networks fragmented and short-lived. Hakkarainen et al. (2004) describe “knots” in modern businesses in which sub-groups of the larger community form small groups around a particular problem, and then quickly break up when the problem is solved. Groups of radiologists are the given example (2004). Radiologists frequently have informal consultations about difficult cases in groups that include technicians, residents, and other radiologists. Membership is informal, and these groups break up as soon as a decision is reached (Dr. Mary Ellins, personal communication). Hakkarainen et al. (2004, p. 136) describe persons working in this manner as “knotworkers”. Fisher and Fisher (1998, p. 106), again in business settings, similarly note teams whose membership
shifts, “… from time to time, forming and reforming like rapidly splitting amoebas.”

Zhang et al. (2009, p. 12) note that the opportunistic collaboration model used by this teacher resulted in groups in the classroom that formed and broke up quickly, “… as part of an emerging process.”

The ATK data and analyses of it revealed that the reading network formed quickly and was regular in structure for most of the unit, with small oscillations among the student positions that indicated that the network was still dynamic. This persisted until the final month, when much of the activity in the database stopped.

All of the students engaged in note reading during the inquiry. The density of the reading network was 92% of theoretical maximum. Zhang and Scardamalia (2007) found that most of the knowledge building classes they studied had note reading network densities of greater than 65%. The high note reading density is an indicator of high performing knowledge building activity in the class. Zhang and Scardamalia (2007, p. 4) note, “In a high performing knowledge building community, members should learn about and build onto the inquiries, resulting in dense note reading and note linking networks.”

As noted earlier, the highly connected nature of the network, resulting in a single large cluster (giant component), implies the formation of a community (Barabási, 2002; Bender-deMoll, 2008), an encouraging sign for teachers trying to establish a knowledge building community.

In contrast to the reading network, the building-on (response) network was sparser. The density of building-on was 15%, well below that of the reading network. While it is to be expected that the building-on network would have a lower density than a note reading network, it is unclear how dense a building-on network should be in a high
performing knowledge building class. The teacher indicated that the 14% level might be good, but as Zhang and Scardamalia (2007) noted, the note linking networks should be dense. This class was, however, higher than average in the number of students who participated in building-on. Of the twenty, nineteen participated, higher than the 80% note linking average found by Zhang and Scardamalia (2007). The $k$-core collapse of the building-on network revealed that only about a third of the class engaged in building-on more than once, so building-on was not routine for most students.

It was interesting to find that both the building-on and note reading networks established their basic structure early and changed relatively little except for an increase in the density of the ties. This was especially notable in light of the finding that activity in the database occurred in bursts. One would expect that the later bursts of activity might change the network structure in some manner, particularly that of the build-on network, but this was not observed.

Thus, communication patterns in the online environment were established early in the unit and tended to remain relatively stable during the course of the unit. The gender-based clustering patterns predicted by studies of acquaintanceship networks among school children did not appear, suggesting that online interaction is idea-driven rather than based upon friendships. However the differences in participation rates were evident for some behaviours such as note contributions. These remain unexplained and may be unique to this class, or perhaps even unique to this particular unit.

The relationship between the structure of the social network and the spread of ideas can be said to relate to the pathways available. In the live-class setting, the pathways are ephemeral, quickly formed and broken as the task demands. This means
that ideas can spread easily, with little friction, but are limited to the persons present in
the group at that moment. Conversely, students in Knowledge Forum read and responded
to many different people’s notes. The evidence suggests that live and online social
networks in this KB classroom form, and re-form flexibly around ideas of mutual interest
rather than (say) friendships.

6.1.2 What is the network structure of ideas in the database view?

The results of analysis 9 (the idea network analysis) were sensitive to non-
participating students. Nonetheless there are a few things that are clear. Notes containing
ideas appeared in clusters, largely due to rise-aboves. In the case of both ideas tracked,
there was a single large rise-above cluster, some other linked notes, and a number of
isolated notes containing the ideas. There is probably a greater degree of linkage than
these results indicate due to notes by the non-participants. Likewise, in both cases, both
notes that initiated the rise-above clusters were focused on one idea, and contained a
question or questions. The use of rise-aboves indicate attempts at synthesis.

Secondly, there were two temporal patterns shown. The first is a network that
grew by punctuated growth (growth in bursts)—periods of steady growth punctuated by a
rapid addition of notes during a short time period, as exemplified by the religion data.
The second is a pattern of growth in which the bursts were often smaller, as exemplified
by the written language data. The teacher’s comments here were interesting. He noted
that there are ideas for which the class might be better-prepared initially, while other
ideas might require more study before discourse really gets under way. This is consonant
with Rogers’ comments that innovative ideas tend to be more readily accepted if they are
compatible with the existing values and past experience of the population (1995, p. 16).
The punctuated growth pattern is interesting because it relates to similar recently-discovered patterns (Barabási, 2005). Since this is not well understood at present, it might provide a fruitful area for further study.

6.1.3 Does Knowledge Forum function to spread ideas, or is it used to record ideas after they have spread?

Analyses 1 (classroom observations), 2 (ideas spread questionnaire), 3 (idea source questionnaire), 4 (interview/questionnaire procedure), 5-8 (archived database material), and 11 (interview data from the teacher) addressed these questions. The student responses to the idea source questions showed that KF is a source of idea spread rather than a passive environment used to record ideas after they have spread. The building-on network proved to encompass ninety-five percent of the class, providing pathways for idea spread and improvement. Finally, the reading network shows that all students are actively engaged in reading KF notes, a source they identified as important for ideas.

The teacher data provided further support for this idea. He noted that sometimes, Knowledge Forum is indeed used to record ideas after they had spread, but that it definitely did function to spread ideas.

6.1.4 What is the Role of Knowledge Forum Features and Functions in the Spread of Ideas?

This question was addressed by analyses 3 (ideas sources questionnaire) and 4 (interview/questionnaire process). On the basis of these results, these students found that knowledge building talk and the Knowledge Forum database were two important sources
of ideas. The teacher was not considered central as a source of ideas, nor was the media or the internet.

Most students indicated the title of a note was an important factor in whether the note was read. The next most important factor was whether the note turned up as a result of a search. Students felt that building-on was more influenced by the content of a note.

When interviewed, students reported creating notes to spread information to the group; to inform the group of an interesting idea; and if there is too great a volume of information to just tell to people.

These students created build-ons to add additional information to a note, to disagree with a note, to ask a question, or to add something to an interesting note. These data suggest that students viewed notes and build-ons as tools for spreading knowledge, and responding to, each other’s ideas. There was no evidence that Knowledge Forum note-writing was seen as an assignment that students felt they had to complete.

6.1.5 What is the teacher’s role in the KF Classroom?

This question is addressed by analysis 11 (observations, and interview data). The teacher viewed his role as moving away from the factory model of schooling towards a more organic mode of teaching involving giving the students greater agency and using an opportunistic collaboration model. This finding is consistent those of Zhang et al. (2009).

In starting a unit, the teacher actively involved the students in evolving the goals and processes (Zhang et al., 2009, p. 47). From there, the teacher used a mixture of techniques, some traditional such as IRE teaching, and some directed specifically towards knowledge building, to achieve his pedagogical ends. An example of the former was
provided when the teacher directly told the students to read and build-onto a particular note; an example of the latter is provided by the teacher’s use of knowledge building terminology to reinforce knowledge building behaviours. As well, the teacher frequently took opportunities to connect students to each other, encouraging the “horizontal” interactions that have become increasingly common in business settings (Bell & Kozlowski, 2002). They further note (2002) that these kinds of reciprocal interactions are important when complex tasks are involved. Stein (2001, p. 4) notes that, “In contrast to hierarchies, flows in networks are predominantly horizontal rather than vertical.” This implies that the teacher is trying to be less hierarchical and trying to turn agency over to the students. However, as noted, the teacher was ambivalent about this as he moved from a factory model of schooling to a more organic, opportunistic collaboration model (Zhang et al., 2009), and sometimes reverted to a more direct teaching style.

6.2 Emergent Conclusions from the Study

6.2.1 Theoretical Advances

Knowledge building represents a disruptive innovation in education—an innovation that creates a new paradigm, a new way of doing things (Christensen, Horn, and Johnson, 2008). Scardamalia and Bereiter (1994, p. 269), speaking of research communities as a model for education note, “… educators have failed to grasp the social structures and dynamics that are required for progressive knowledge building …” Many educators remain fixed on either the Teacher A model, in which the students’ responsibility for their learning is solely completing work on set tasks with learning (theoretically) as a by-product (Scardamalia & Bereiter, 1991); or the Teacher B model
that is knowledge-based with a focus on understanding, but in which students’ responsibility for their learning is still limited to set tasks and activities (Scardamalia, 2002). The Teacher C model, in which strategic cognitive agency is relinquished to students (Scardamalia, 2002), requires a grasp, on the part of the teacher, of the social structures and dynamics necessary for progressive knowledge building.

Attempts to bring disruptive innovations such as knowledge building into schools often fail because they are “crammed” into existing structures and practices such as the Teacher A and Teacher B models. “Cramming” refers to the practice of inserting disrupting innovations into established practices (Christensen, Horn, & Johnson, 2008). Christensen, Horn, and Johnson note (2008, p. 75, original emphasis),

[U]nless managers actively manage this process, their organization will shape every disruptive innovation into a sustaining innovation—one that fits the processes, values, and economic model of the existing business—because organizations cannot naturally disrupt themselves. ... [This] explains why computers haven't changed schools.

Therefore one of the key problems in the preparation of knowledge building teachers is to help them avoid reconceptualizing Teacher C practices in terms of the more familiar Teacher A and Teacher B models. Indeed, as Scardamalia (2002, pp. 3-4) observes, this is a common phenomenon:

The Teacher C model, as we defined it, is distinguished by an effort to turn strategic cognitive activity over to the students. Many teachers would avow that this is what they are trying to do— to make students responsible for their own learning. However, in parallel interviews with teachers, we found that this often
means performing tasks in a responsible manner—a Teacher A view of responsibility.

Naturally it is difficult to make progress if teachers profess to understand the Teacher C model while simultaneously (and unintentionally) employing control structures that undermine it. Such teachers lack a means of recognizing deficiencies in their own practice. It is perhaps for this reason that teachers often find it difficult to fully reinvent their classrooms as knowledge building communities. It may also explain why many classroom-based knowledge building studies have directly or indirectly been concerned with teachers’ struggles with the Teacher C model (Hewitt, 1996; Scardamalia, 2002; Scardamalia & Bereiter, 1991), and why their efforts to rework their practices sometimes span years, e.g., Hewitt (1996). Indeed, the difficulties they encounter are arguably the largest and most daunting obstacle to the large-scale adoption of knowledge building pedagogies.

A major contribution of this study is the notion that social network tools can be used to help address the teacher education problem by providing teachers with visual representations of the communication networks in their classrooms. Such networks have been largely invisible until now. However, it is argued that the ability to study these networks is important for instructors who are trying to move closer to a Teacher C model. The distinguishing characteristic of a Teacher C approach is that it turns strategic cognitive activity over to the students (Scardamlia, 2002). Thus, one of the teacher’s challenges is to foster the kinds of classroom networks that support a student-centered locus of control, and avoid network patterns in which the teacher exerts centralized
control. For example, star pattern networks, with the teacher at the centre, are indicative of a Teacher A or a Teacher B model.

Figure 26. A simulated star pattern centered on the teacher.

Figure 26 shows a star pattern network that would be typical of the Teacher A style of teaching. The teacher is represented by a red triangle, the students by blue squares. Collaborative activities are absent and communication is limited to interactions between individual students and the teacher.

On the other hand, richly interconnected networks, with the teacher on the periphery or absent (e.g., Figure 27), are consistent with the communication patterns of a Teacher C classroom.
In Figure 27, we see a richly interconnected network with the teacher (indicated by a red triangle) on the periphery. Here, there is considerable student-student interaction, and they are visibly less dependent on interactions with the teacher. Of course, there would be a veritable bestiary of intermediate types between these examples, but they serve to indicate where a teacher might start, and try to move to, in the course of creating a knowledge building community.

Through this new ability to visualize classroom networks, the teacher and students now have opportunities to better understand the social structure and dynamics that have often proven elusive for aspiring Teacher C educators (Scardamalia, 2002).

Of course, it would be a mistake to assume that highly interconnected networks are always the product of Teacher C pedagogies. One can imagine ways that such networks could develop even in task-based, teacher-centered classrooms. Nevertheless, it
is suggested that the ability to map these networks serves as an important new tool for instructors who are trying to be more aware of their own teaching practices and move closer to a teacher C model. While teachers create and experiment with certain social network structures and practices, social network tools will allow teachers, for the first time, to monitor and measure the development of their classroom networks. As the current case study illustrated, this can lead to new insights about one’s class. The teacher in this study considered himself experienced in knowledge building, but was unaware of many of the networked patterns in his class. Thus, for knowledge building teachers, social network tools have the potential to help them better understand the communication patterns in their own classrooms, reduce the phenomenon of “cramming,” and hopefully make the Teacher C model more broadly accessible.

6.2.2 Practical Advances

Flowing from the preceding analyses are a number of practical things teachers can take from this work. It is possible to provide students with guidance that will enhance the chances that their notes will be read by including things like informative titles; that they build onto notes that contain questions, or with which they disagree, or if it is interestingly written and so forth.

This study shows how the teacher and students can be provided with a picture (literally, in the case of sociograms) of what the interaction patterns of high functioning knowledge building classes should look like. Cross and Parker (2004, p. 16) comment that such analyses can give managers “… a great deal of insight …” into employee roles and functions in the network. Similarly it is proposed that students and teachers can benefit from making these sociograms objects of reflection, analysis, and discussion.
This relates to assessment—the use of network analyses to analyze the class
dynamics at the group level. In the past, most assessment techniques were aimed at
evaluating the performance of the individual, but as we move into the knowledge age and
begin to emphasize collaborative work and group knowledge, it becomes essential to
have some means of evaluating group processes (Partnership for 21st Century Skills,
2008). Network analysis provides teachers and students with a means of looking inside
the dynamics of the classroom and online interactions to see if the class as a whole is
working in an effective collaborative manner. The tools for this are still in development,
but it is now possible for teachers to perform such analyses with a few clicks of a mouse.
And, of course, network analyses also allow teachers to see if individuals are not
contributing to the group; allow teachers to identify leadership clusters; and generally
allow for the evaluation of collaborative communication. These analyses are similarly
available to the students, who appear, as noted by the teacher, to both like to do them, and
reflect on their practice as a result. The teacher noted instance in which the use of the
analytic tools changed classroom practice. As 21st century skills are increasingly
emphasized, anything allowing a clear and simple way to evaluate these will be a boon.

6.3 Evaluation of Research Tools—What Worked and What Didn’t

6.3.1 Live-Class Communication Questionnaire (Analyses 2 & 3)

Students were, for the most part, able to identify to whom they communicated
about ideas; where they first heard of those ideas; and by what means they communicated
their ideas. As with all self-report techniques, it is vulnerable to misrepresentations, and
to the vagaries of human memory. In this case, there is no reason to believe that the
students would intentionally misrepresent, but they might conceivably confabulate in
order to please the researcher or teacher.

Human memory is another matter. Students may genuinely not remember where
they first heard an idea, and report where they first remember hearing it. The latter is
probably more important than the former, since what is remembered is more important
that what is forgotten when it comes to ideas.

The part of the questionnaire dealing with the sources of student ideas revealed
some interesting differences when compared with the interview/questionnaire results.
Students reported different ideas sources when asked about specific ideas than when they
were asked about ideas in general. Probably both sets of responses are accurate, and
reflect genuine differences between general sources of ideas and specific sources for a
particular idea.

6.3.2 The Interview/Questionnaire (Analysis 4)

The in-class interview process went quickly and would have taken much longer
had the researcher interviewed all students individually. Some statements that appeared to
be supported in class received little support on the questionnaire. Overall, this process
was not intrusive. Although the questionnaire was fairly long (about 60 statements in all)
the students were able to complete it quickly (about 15 minutes), making it an effective
tool for use in classrooms. An online version would be as quick to use, and the analysis
of it could be automated.
6.3.3 The ATK Analyses (Analyses 5-7)

Context is important in evaluating ATK results. For example, finding that a student is a non-participant in something like building-on might indicate a problem, or it might indicate that the student was on vacation with their parents during the analysis period. Thus the ATK data are most valuable when supported by contextualizing data. Nonetheless, such data provide a useful tool for teachers and researchers to gauge knowledge building behaviour at the individual and class level.

A special comment has to be made about the social network analysis. This class was highly clustered, in fact, a single large cluster, in both the reading and building-on networks. Each formed a giant component early on, and remained highly connected throughout. While this is probably a good thing for the class, it rendered some analysis measures useless. In the earlier discussion of social network analysis, the measures of closeness and betweenness were discussed, but not used in the analysis of the results. This is because, given that the class formed a single large cluster, the differences in closeness and betweenness among the students were not large enough to be meaningful. Therefore, social network measures can sometimes be calculated and still not be meaningful. Researchers need to know what each measure is supposed to tell about a group before applying the measure.

6.3.4 The Idea Spread Analysis (Analyses 9 & 10)

The temporal analysis proved to be sensitive to the disruptions in the class routine. While this problem could recur in other studies (technical problems are not uncommon), it is not highly probable.
In terms of the FileMaker database created to track interactions, this was too
detailed. Either outdegrees or indegrees need to be tracked, but not both, with outdegrees
being easier. Making this change would greatly reduce the amount of time needed to
complete the analysis.

6.3.5 Future Directions

There are a number of clear future directions indicated by this study. First, data
are needed both about how ideas spread in live-class settings (analysis 2) and about the
sources for student ideas (analysis 3), especially among groups of older students. It would
be good to have a cross-section of a number of different classes of differing ages and
experience levels to see how these patterns might change with age and experience.

Second, the interview/questionnaire technique used in analysis 4 could be
repeated in a number of classes to build up a picture of how and why the various KF
functions and features are used. It is possible that such a study could lead to a guide for
teachers as to how to get the students to make better use of the functions and features, or
to improve them.

Analyses 5-7, which analyzed student interactions using the ATK data have
already yielded two tools that are currently in use in newer versions of KF: a social
network tool, and a contribution tool (both programmed by Paul Johnson). The social
network tool allows for teachers and students to view the reading, building-on and other
networks, and to perform their own $k$-core collapse sequences on these data. The tool also
records basic network measures such as the number of nodes, edges, and network density.
The contribution tool graphically represents the number of notes contributed, number of build-ons, number of keywords used, etc. so that teachers and students can see who is and who is not contributing as they should.

In the case of both of these tools, work needs to be done in two areas: the tools need to be further refined and extended, and work needs to be done to find out how to best use these tools in classroom settings. Evidence from the teacher suggests that the use of these tools does change practice, but we need to know how classroom practices change in light of this new information.

In terms of refining and extending the social network tool, suggestions have already been put forward to attach attributes such as gender to nodes, and to include strong-tie and weak-tie analyses in the tool. Once included, the effect of these changes will also have to be studied.

Analyses 9 and 10 could be run on other databases, but because they are quite labour-intensive, their use should probably be restricted to databases of particular interest.

The analysis of idea improvement (Analysis 10) should be run on a number of classes ranging from inexperienced to experienced, and of different ages to see if idea improvement is ubiquitous across groups and ages (as anecdotal evidence suggests) or if it appears more in some groups than in others.

6.4 Protocological Control vs. Hierarchical Control–The Teacher’s Role

Earlier we discussed the distinction made by Galloway and Thacker (2007) between hierarchical control and protocological control. Hierarchical control is familiar to all, and is the traditional pattern of schooling. However, what we see in this knowledge
building class is *protocological* control, a way of controlling networks that is quite different. Sometimes, as in Kelly (1994), this is called bottom-up control, but that doesn’t really describe it. Hierarchical control systems tend to be both rigid and authoritarian. Protocological control systems are characterized by emerging through the horizontal interactions of the agents in the system, and by being highly flexible and contingent (Galloway & Thacker, 2007, pp. 29-30).

The teacher expressed some ambivalence towards the shift from hierarchical (factory model) towards protocological control (organic and contingent). Sometimes, he used the older model, but during the Ancient Civilizations unit continually tried to give the students epistemic agency wherever possible. The teacher also noted that contingent planning, as when he suggested that ten lesson plans needed to be ready at any one time, makes teaching in this way difficult.

### 6.5 Limitations of This Research

As with all research, there are limitations, both explicit and implied, in this research. These limitations fall into four broad categories: limitations with regard to case studies, limitations with regard to knowledge building theory, limitations with regard to the network approach used here, and limitations imposed by the structure of the classroom and what the researcher was allowed to do. The limitations imposed by the current state of knowledge building theory can be put into context by giving comparable examples from biology and music.

Biology is the study of living things, but there is no universally accepted definition of life. Instead, living things are recognized qualitatively by a series of characteristics that may or may not always be present. The five most common are growth,
energy use, motion, reproduction, and response to stimuli, but others are sometimes included. In practice, identifying life presents difficulties for biologists, as an observed (potential) organism may not show one or more of these characteristics at the time of observation. For example, ants are living things, but not all ants reproduce—only the queen does. Based on a single worker ant, ants might be classed as non-living. Viruses are not considered to be living, but exhibit some of the characteristics of living things. It gets complicated and tangled when one gets down to really simple forms like rikettsiae or pleuropneumonia-like organisms (PPLOs). Thus, research on living things is to a degree inhibited by the lack of a clear definition, and requires a level of qualitative analysis to clarify what is and is not living.

Music is another example: many people can state examples and characteristics of good music, but cannot define it—again, no universally accepted definition exists. Some compositions have all of the characteristics of good music but are actually dreadful, as a comparison of Beethoven’s Wellington’s Victory with Tchaikovsky’s 1812 Overture demonstrates. They are similar in structure, musical ideas, and intended function, but Wellington’s Victory is generally regarded among musicians as poor and the 1812 Overture is an established classic. Characterizing a composition as good music requires qualitative analysis in addition to knowledge of a set of characteristics.

Knowledge building theory is similar to the two examples above in that at our current state of knowledge about the knowledge building process, it is not possible to precisely define it. Knowledge building is identified by the set of knowledge building principles but these have to be analyzed qualitatively. Therefore, at present, it is not possible to directly map any of the measures used here onto knowledge building. It is
only possible to identify that the students are engaging in activities consistent with good knowledge building practice, but without supporting qualitative analysis, no identification of knowledge building is possible. However, it is worth noting that similar constraints affect other areas of human knowledge without crippling their study.

The next set of limitations on the current work has to do with the general limitations on social network analysis. As noted earlier, social network analysis is sensitive to missing data. For research purposes, this can be quite troublesome, but in the case of a classroom teacher, this is much less so–teachers have the right to examine student data in a way researchers do not, and have the right to assess students. As a result, teachers will probably be in possession of more complete data than researchers, most of the time.

The second limitation on social network analysis is that it is neutral regarding the content of the communications. It demonstrates what communication pathways existed at the time of measurement, but says nothing about the content or value of such communications. For example, a network analysis can tell that one student read a note by another student, but it cannot state if the student read the note carefully, and what, if any, benefit they might have derived from reading it. As a result, it is necessary to combine network analyses with qualitative analyses of note content. In the case of the classroom teacher, social network analysis does not relieve the teacher of the responsibility of reading the notes in the database and thereby knowing in a qualitative way in which the work is progressing and who is doing useful work, and who is not. But social network analysis can be a useful tool in guiding the teacher to those who might need extra
attention and encouragement, and might help students make better decisions as to what
and how much work they should be doing.

Because this work involved children, strong ethical constraints were placed on the
gathering of data. In the classroom setting, the researcher was restricted to observations
and written field notes except for one video recorded for other purposes that was made
available. This limited the ability of the researcher to observe what was going on at each
table. As well, the presence of a second room in which the students could work made it
impossible for the researcher to observe both rooms at once. Because of these gaps in the
data, it was not possible to draw definitive conclusions about the role of the face-to-face
student interactions and the relationship between Knowledge Building Talk and note
posting. These are some areas where further investigation is warranted.

Finally, we have the well-known limitations on the generalizability of case study
research. In this study, the number of students is too low to do any advanced statistical
work, and it is only one class. Things might happen very differently in a different class,
and in fact, this would be expected. This study was preliminary, and it may be possible to
repeat aspects of this study in different classes with different teachers and levels of
knowledge building experience to build a better picture of what might be typical,
exceptional, etc., but that is for the future. This study provides a snapshot of what
happened in one class during one unit of study.

6.6 Conclusion

This section has considered the research questions in detail, has examined
emergent information and ideas arising from the studies, has examined strengths and
weaknesses of the instruments and analysis techniques, and looked at future directions. It is difficult to boil all of this down into a few sentences, and it won’t be tried here. However a few comments can be made.

This study produced a huge volume of data. More data were obtained than was included here, and it would have been possible to generate more data still. One of the big challenges in this area is to present the data in meaningful forms and a variety of these have been given here: data tables, sociograms, graphs, and timelines. Because network research is a fast moving, rapidly evolving area right now, new forms of data presentation are emerging and new knowledge is being discovered almost daily. An example is the recent creation of a new algorithm (named Tesla) to determine links among networks as they age (Science Codex, 2009). These advances will move the research in new directions and may change the manner in which data is presented, and what data are meaningful and useful. Time will also reveal flaws in the forms of analysis and suggest ways to correct them as this type of research progresses–and this is always the way in science. As Popper (1979) notes, "All growth of knowledge consists in the improvement of existing knowledge which is changed in the hope of approaching nearer to the truth." (p. 71).
REFERENCES


Palonen, T., Hakkarainen, K., Talvitie, J., & Lehtinen, E. (Submitted for publication). Network Ties, Cognitive Centrality, and Team Interaction within a Telecommunication Company. In P. A. Boshuizen, H. Gruber & R. Bromme (Eds.), *Professional development: gaps and transitions on the way from novice to expert*.


Figure 28. Screen capture of the Idea Spread Questionnaire. It was pre-printed for the students with the idea being examined and the date.
APPENDIX B
THE INTERVIEW QUESTIONNAIRE

Name: __________________________________________________________

Instructions: Please read the statements and circle either Y for yes if you agree with the statement, or N for no if you disagree.

<table>
<thead>
<tr>
<th>Q</th>
<th>Statement</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>About what makes an idea interesting:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>If there are lots of ideas in a note, it is more interesting.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>An idea is more interesting if it’s surprising.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>An idea is more interesting if I disagree with it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>An idea is more interesting if there is an argument about it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>An idea is more interesting if you talk about it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>A note looks more interesting if there are a lot of build-ons to it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>An idea is more interesting if we think of it and question ourselves about it.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>8</td>
<td>An idea is more interesting if it’s about what you like.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>9</td>
<td>An idea is more interesting if it’s about what you like to do.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>10</td>
<td>If you don’t care for an idea, it’s not interesting.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>11</td>
<td>In KB talk, an idea is more interesting if it is very different from others.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>12</td>
<td>If there is a lack of information about an idea, it is more interesting.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>About the sources for ideas:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>I get ideas from the Internet</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>I get ideas from reading.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>I get ideas from my own head.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>I get ideas from hearing/reading other people’s ideas.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>I get ideas from talking with friends.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>I get ideas while taking a walk.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>I get ideas from my dreams.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>About creating new notes:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>If the KB talk is going too fast, I sometime create a new note to explain.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>2</td>
<td>I create a new note to make something more interesting.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>I create a new note rather than go around and tell everyone the same thing.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>I create a new note if there’s a lot of information–too much to tell.</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>I create a new note if an idea is very interesting so everyone can see it.</td>
<td>Y</td>
<td>N</td>
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</table>
### About build-ons:

<p>| | | | | | | | | | | | |</p>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>I build onto a note if I like the title.</td>
<td>Y</td>
<td>N</td>
<td></td>
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<tr>
<td>2</td>
<td>If I like a note, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>3</td>
<td>If I disagree with a note, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>4</td>
<td>I build onto unhelpful notes.</td>
<td>Y</td>
<td>N</td>
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<td>5</td>
<td>If a note makes me question myself, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<td>6</td>
<td>If the content of a note fits well with the scaffolds, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>7</td>
<td>If I have more information to add to a note, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>8</td>
<td>If I have a question to ask about a note, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>9</td>
<td>If I have an opinion about a note, I build onto it.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>10</td>
<td>I build onto a note if it’s interesting.</td>
<td>Y</td>
<td>N</td>
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### About rise-aboves:

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</thead>
<tbody>
<tr>
<td>1</td>
<td>If there are many notes about the same thing, they should go in the same place.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>2</td>
<td>I create rise-aboves so I don’t have to read all of the notes.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>3</td>
<td>Rise-aboves make it easier to find the notes you need.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>4</td>
<td>I create rise-aboves to share notes about a particular topic.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>5</td>
<td>Rise-aboves reduce the number of build-ons.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>6</td>
<td>Rise-aboves are good for expressing your opinion.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>7</td>
<td>Rise-aboves allow your thinking to “rise above” to the next level.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>8</td>
<td>Creating rise-aboves makes you read notes you otherwise might not.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>9</td>
<td>Rise-aboves un-clutter views (make them less crowded.)</td>
<td>Y</td>
<td>N</td>
<td></td>
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<tr>
<td>10</td>
<td>Rise-aboves summarize all of the notes on a topic.</td>
<td>Y</td>
<td>N</td>
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<tr>
<td>11</td>
<td>Rise-aboves stop you from writing the same thing over and over.</td>
<td>Y</td>
<td>N</td>
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### About other Knowledge Forum features:

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</thead>
<tbody>
<tr>
<td>1</td>
<td>I use scaffolds to classify information.</td>
<td>Y</td>
<td>N</td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>Scaffolds tell you what the information is about.</td>
<td>Y</td>
<td>N</td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>3</td>
<td>Scaffolds help to distinguish between what we know and what we think.</td>
<td>Y</td>
<td>N</td>
<td></td>
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<tr>
<td>4</td>
<td>I use annotations to correct spelling and grammar.</td>
<td>Y</td>
<td>N</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>If a note has no title, I don’t read it.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6</td>
<td>A note’s title tells me if it’s information I need.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>7</td>
<td>Keywords help you search for information.</td>
<td>Y</td>
<td>N</td>
<td></td>
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</tr>
</tbody>
</table>

### About reading notes:

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I read a note if it has an interesting title.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>2</td>
<td>I read a note if I do a search and it comes up.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td>I read a note if someone recommends it.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>I don’t read notes with spelling errors in the title.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>5</td>
<td>I don’t read notes that have serious spelling or grammar errors.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>6</td>
<td>I read a note because of who wrote it.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>I read a note if it has scaffolds.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>I read a note because I disagree with the author.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
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</table>

### Other:

<p>| | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I enjoy using Knowledge Forum.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>My note-writing style has changed from when I was younger.</td>
<td>Y</td>
<td>N</td>
<td></td>
<td></td>
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</tbody>
</table>
APPENDIX C

THE ONLINE IDEA SPREAD DATABASE

Figure 29. Screenshot of the database used to track the spread of an idea through the database.
APPENDIX D

THE CODE BOOK FOR DATABASE IDEA SPREAD ANALYSIS

CODE BOOK/CODING SCHEME
Idea Spread Research

Don Philip

Introduction

The purpose of this research is to examine the spread of ideas in an online learning environment from a network perspective. There are two parts to the research: the investigation of idea spread within the classroom, and the investigation of idea spread within the online database. This code book/coding scheme pertains to the latter part of the research, which will involve examination of the online database and classification of notes into categories relating to the presence of certain ideas.

Ideas as a Research Focus

The concept of the idea is poorly defined for research purposes. For example, The American Heritage Dictionary ("American heritage(r) dictionary of the English language: Fourth edition", 2000) gives the following as a definition of idea:

NOUN: 1. Something, such as a thought or conception, that potentially or actually exists in the mind as a product of mental activity. 2. An opinion, conviction, or principle: has some strange political ideas. 3. A plan, scheme, or method. 4. The gist of a specific situation; significance: The idea is to finish the project under budget. 5. A notion; a fancy. 6. Music A theme or motif. 7. Philosophy a. In the philosophy of Plato, an archetype of which a corresponding being in phenomenal reality is an imperfect replica. b. In the philosophy of Kant, a concept of reason that is transcendent but nonempirical. c. In the philosophy of Hegel, absolute truth; the complete and ultimate product of reason. 8. Obsolete A mental image of something.

As can be seen, this is very general. It is a noun, ranges from a single thought or conception, to opinion, to the gist of a situation. Apparently, almost any form of mental activity can be considered an idea from this set of definitions. Roget’s Thesaurus ("Roget's ii: The new thesaurus, third edition", 1995) gives this slightly more helpful definition:
NOUN: 1. Something believed or accepted as true by a person: belief, conviction, feeling, mind, notion, opinion, persuasion, position, sentiment, view. See OPINION. 2. A method for making, doing, or accomplishing something: blueprint, design, game plan, layout, plan, project, schema, scheme, strategy. See PLANNED. 3. Intuitive cognition: feeling, hunch, impression, intuition, suspicion. See THOUGHTS. 4. That which exists in the mind as the product of careful mental activity: concept, conception, image, notion, perception, thought. See THOUGHTS. 5. The gist of a specific action or situation: import, meaning, point, purport, significance, significancy.

Again, this is very general, but the notions of opinions, persuasion, positions, and views as ideas can be used in analyzing student work in the database.

In psychology, the concept of idea is avoided altogether in favour of the term proposition. Stepinsky (n.d.) gives this definition of a proposition:

> The proposition is a concept borrowed by cognitive psychologists from linguists and logicians. The proposition is the most basic unit of meaning in a representation. It is the smallest statement that can be judged either true or false. Anderson (1990) gives the following example of a sentence divided up into its constituent propositions:

> "Nixon gave a beautiful Cadillac to Brezhnev, who was the leader of the USSR."

> This sentence can be divided into three propositions:

1. Nixon gave a Cadillac to Brezhnev.
2. The Cadillac was beautiful.
3. Brezhnev was the leader of the USSR.

Originally, it was suggested that the proposition be the unit of analysis for this research, but that concept foundered on a closer examination of the database. Often, the students treated the writing of notes as more of a conversation that a series of written exchanges. Therefore, the students often used implied propositions rather than specifically stated ones. This would mean that a coder would have to justify their coding of a particular proposition on the basis of what preceded it—very cumbersome, and subject to criticism by persons who do not have access to the database. For example, this exchange comes from a set of two linked notes:

> Student 1: “I believe that ancient civilizations did have contact on a minor level. When the Greeks and Romans were around (at the same time) both were very much a like.”
Student 2: “yes civilizations had communication with other ones because the Indus Valley civilization had contact with the Ancient Sumerians and as you know now they are very much alike.”

Now, although Student 2 appears to be talking about the Indus Valley civilization and the Ancient Sumerians, he is actually talking about the Greeks and Romans as well, as evidenced by his keywords which included both Romans and Greeks. It will readily be seen that this provides difficulties for analysis, especially when the number of notes exceeds 100. There are simply too many propositions, and too many implied propositions, to examine the database effectively in any reasonable space of time. For that reason, it was decided to try another approach.

When fishing, one doesn’t catch every fish—just some of them. Likewise, it is not necessary for this research to examine every idea—just the relevant and important ones. In many cases, this could be determined by consultation with the classroom teacher as to what ideas are important, but that was not necessary in this time. Instead, a set of suitable ideas was provided ready-made courtesy of a field trip to the Royal Ontario Museum (ROM) at the beginning of the unit. The presenter at the ROM indicated to the class that scientists had decided on a set of characteristics that had to be present for a society to be considered to be a civilization. Among these, two in particular intrigued the students and these have been chosen to be the ideas to be tracked through the database. They are:

- A society must have an organized religion in order to be judged a civilization; and
- A society must have a written language in order to be judged a civilization.

These would be recognized by any reasonable person to be ideas, and can easily be tracked through the database (and through the in-class work as well.)

The Coding Process

Coding will proceed in two main stages using FileMaker Pro (www.filemaker.com) and Access (www.microsoft.com) databases created to track the results. (These will be later merged.) The database will not be empty upon receipt. It will contain information about the database, author, note name, the part of the visible note cluster it belongs to, and other information. It will not contain information about the actual coding: that will be the responsibility of the coders. Each note will be opened in the Knowledge Forum database, and coded on the basis of the presence of either of the two ideas given above (according to the coding scheme below.) When finished, this will allow the researcher to find all notes relating to each idea, and to compare the inter-coder results, etc., ensuring reliability and validity.

The first stage of the coding process will be to read all of the notes in the chosen view at least once. This will give an overview of the student work and allow the coders to see how the chosen ideas manifested themselves at various points in the discourse. As well, as a general principle in choosing ideas to be tracked, this will allow the coders to get a sense of ideas at the macro level—the gist, as it were, of the view, and the significance of various ideas in it.

The second level of coding will be to code each individual note in the view for the ideas being tracked. This coding will be based on keyword coding in which a set of keywords associated with the identified ideas will be used to guide the coding of the note.
as pertaining to the idea or not. This can be justified by the observation that the noun is
the most basic unit of idea given in the sources above—all other conceptions are
essentially compounds of this atomic-level concept of the idea. However, the context of
the note might preclude the idea being coded if the context of its use is not appropriate.

While reading a note, the coder will identify whether or not the note contains a
relevant idea. If so, that is recorded in the database, along with the rationale for choosing
this coding, and other relevant data. Figure 1 shows a screen snapshot of the database and
data fields.
Figure 30. Screen snapshot of the Idea Analysis Database.
CODING SCHEME

Coding for the concept of organized religion:

Roget’s ("Roget's II: The New Thesaurus, third edition") gives the following for religion:

A system of religious belief: confession, creed, denomination, faith, persuasion, sect. See RELIGION.

Under RELIGION (the reason for all capitals is unclear,) it gives additionally the word myth. As well, there are some obvious ones like god, gods, etc. For the purposes of this study then, the a note in KF will be considered to relate to the idea of religion if it contains or refers back to the words religion, creed, denomination, faith, sect, belief, myth, god, gods, goddess, or goddesses.

Coding for the concept of written language:

Roget’s [1995] gives the following for written …

Of or relating to representation by means of writing: calligraphic, graphic, scriptural.

… and for language:

A system of terms used by a people sharing a history and culture: dialect, speech, tongue, vernacular.

Therefore, any reference to writing, calligraphy, and graphics (including hieroglyphics) would be included. Two other terms also had importance for the students in reference to written language:

• any reference to quipu, a form of record keeping used by the Inca will be included, as the students had many questions as to whether or not this constituted a written language; and
• any reference to Nordic runes will also be considered a form of written language.

Summary of coding scheme:
Table A-2.
Summary of the keywords for coding the identified ideas.

<table>
<thead>
<tr>
<th>Idea</th>
<th>Keywords to be used to classify a note as containing that idea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Civilization need an organized religion</td>
<td>Religion, creed, denomination,</td>
</tr>
<tr>
<td></td>
<td>faith, sect, belief, myth, god, gods,</td>
</tr>
<tr>
<td></td>
<td>goddess, or goddesses.</td>
</tr>
<tr>
<td>Civilization need a written language</td>
<td>Writing, calligraphy, graphics,</td>
</tr>
<tr>
<td></td>
<td>hieroglyphics, runes, or quipu</td>
</tr>
</tbody>
</table>

Note that the keyword or any of its variant forms are to be accepted. For example, belief, believe, beliefs, etc. are all acceptable variants of the word. There may be times when belief or believe do not refer to religion, but these can easily be sorted out from the context. Likewise, implied ideas will also be coded on the basis of the context of the overall discussion, including the preceding notes (see sample codings, below.) Should keywords in addition to these be found, the coders will consult as to whether these should be added to the codebook.
### Table A-3.

Samples of coding from the database under study.

<table>
<thead>
<tr>
<th>Example from the database</th>
<th>Coding</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Title:</strong> Was Mythology Fought Over?</td>
<td>Religion</td>
<td>The keyword believe is present, as is the keyword mythology (in the title.)</td>
</tr>
<tr>
<td>Excerpt: “...what if someone in a culture did not believe in what the rest of his culture did would he/she be banished? I think she/he would be burned at the stake or thrown over a cliff.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Title:</strong> Ancient Religions</td>
<td>Religion</td>
<td>The keyword god is present in this excerpt. As well, the word religions is in the title.</td>
</tr>
<tr>
<td>Excerpt: “Ancient civilizations tried to understand any force or event in their world that they did not understand, or could not control, by naming it a god and trying to learn the characteristics of that god.”</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Title:</strong> Language</td>
<td>Written language</td>
<td>This is a very obvious one, of course. The keyword written language is present very clearly, as is the reference to language in the title.</td>
</tr>
<tr>
<td>Excerpt: “This rise above is about language because every civilization needs a written language”</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Title:</strong> “The Maya are NO exception??”</td>
<td>Written language</td>
<td>This is a difficult one in that the note has to be taken in the context of the preceding discussion, which contains a number of references to written language. The keyword language is present, and the statement that it needs to be decoded implies that this is a written,</td>
</tr>
<tr>
<td>Excerpt: “The Maya were a civilization, and a great one at that, but their language is not yet decoded.”</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
There are no keywords here that would alert us to one of the ideas we are tracking. However, if the author had used believe instead of think, then the context would tell us that this is a personal belief, and not about religion.

Other Coding Matters

Limits to keyword coding

Although keywords are being used to identify ideas here, the context in which they are present is important. The mere presence of a word does not guarantee that the idea we are tracking is present. Therefore, if the context is not appropriate, the note should not be coded as having the idea being tracked present.

Example:
A note in the group contains the word witchcraft in the context of prejudice. While it could be considered that witchcraft is a religion, in the context of racial and other prejudice, it does not relate to the idea that an organized religion is necessary for a civilization to be great.

Network analysis coding

As these data are to be analyzed using network analysis techniques, we are also coding for indegrees and outdegrees. To explain these concepts in terms of notes in a database, consider two notes, Note 1 and Note 2. Note 2 is a build-on to Note 1. Therefore, for Note 1, the build-on is an outdegree (linkage away) to Note 2; and for Note 2, being a build-on is an indegree (link into) from Note 1. Therefore, Note 1 has one outdegree, but no indegrees, and Note 2 has an indegree, but no outdegrees. Some notes may have both indegrees and outdegrees.

Idea being tracked
The ideas being tracked are indicated clearly above, but for the purposes of entry into the database, please use the keyword religion for ideas about an organized being necessary for a society to be a civilization; and use the keyword written language for the idea that a society needs to have a written language to be a civilization.
Number who have read this note:

In coding this, remember that the researcher is someone who has read the note. Therefore, if 23 people have read the note, the actual number would be 23-1 (subtracting the researcher) or 22 people.

Boundary for this study

The boundary for this study is the Ancient Civilizations view. Unfortunately, even before the study began, the students began to alter the view, placing notes in rise-aboves. The problem this creates is that notes in rise-aboves do not appear in build-on trees (although they retain this information in the notes itself.) As well, rise-aboves may contain notes from other views. These should be followed to the end of the build-on tree, even if they spill over into another view, as they are part of the discussion in the Ancient Civilizations view. Care, however, should be taken to ensure that only notes from students who have given ethical permission are included (see below.)

As part of this boundary, we will also exclude notes by non class-members. There are some notes by persons whose names are not on the class list: these are researchers. The teacher is, of course, a class-member and is included.

Ethical Considerations

Some class members did not give permission for their data to be used in this study. In the database the coders have been given, records of notes by those students have been removed. However, we will do a check at the end to ensure that no data from these students has been included. Coders will also be given the list of students who are participants.

If Both Ideas are Present in a Single Note

There may be instances in which both ideas pre present in a single note. If so, in the Idea Being Tracked field, enter Religion, Written language. In the Present? field, simply enter Yes. If necessary, a rationale can be entered for both, but may not be needed.

Date Format

The date format used by FileMaker Pro (which will be used for the final analysis) is dd/mm/yyyy, so Canada Day 2005 (July 1st, 2005) would be 01/07/2005. Please use this date format, as when the databases are merged, there may be errors if this isn’t done properly.
REFERENCES


DATA SOURCES AUDIT ATTESTATION

Networks and the Spread of Ideas in Knowledge Building Environments

Confidentiality waiver

As an Auditor for research conducted by Ph.D. candidate Don Philip, Ontario Institute for Studies In Education, University of Toronto, I agree not to discuss or disclose any of the confidential information I might obtain as a result of my role in this research.

Date: March 20, 2008

Name: Vanessa Peters (please print)

Signature: "Signature"

Audit

The audit consisted of the following steps:

a. Performed counts of hardcopies of all raw data.

b. Reviewed written field notes, verified that they were transcribed accurately.

c. Compared contents of FileMaker database to hardcopies of raw data.

d. Compared video and audio data to transcriptions.

e. Reviewed both raw and analyzed spreadsheet data.

Audit Results

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Auditor’s Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw Data</td>
<td></td>
</tr>
<tr>
<td>Field Notes</td>
<td>Reviewed two handwritten journal notebooks. The dates transcribed in each of them is as follows:</td>
</tr>
<tr>
<td></td>
<td><strong>Book 1:</strong> 14/01/05 26/01/05 18/01/05 20/01/05 21/01/05</td>
</tr>
<tr>
<td>Transcriptions of Field Notes</td>
<td>Counted 16 separate journal entries (all different dates). Included in the transcription is a floor plan of the classroom. Random entries were chosen and compared to the transcribed version, and were found to be verbatim.</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Metadata DB of Field Notes</td>
<td>Confirmed metadata in database corresponded to data recorded in journal books and the transcriptions. Categories in database reflected themes and descriptors in field notes.</td>
</tr>
</tbody>
</table>
| Idea Spread Questionnaire     | Questionnaire #1: 27 hardcopies filled out by students (no blank copies)  
Questionnaire #2: 20 hardcopies filled out by students (plus 2 blank copies)  
Questionnaire #3: 18 hardcopies filled out by students (plus 6 blank copies) |
| FileMaker DB of Idea Spread Questionnaire | Performed random checks of all three Idea Spread Questionnaires to ensure they were entered into the database correctly. In each instance the content was transcribed correctly from the hard copies into the electronic versions. |
| Interview Questionnaire       | There were 21 hardcopies filled out by students (each questionnaire is 2 pages). |
| Interview audio files         | Listened to audio files in Garage Band, the audio quality was excellent. Compared random audio data to transcriptions. The transcripts were very precise, with murmurs, hesitations, and false starts excluded. Inaudible data was indicated as such. |
| Interview video files         | Confirmed video files corresponded to transcripts. Videos were transcribed and analyzed using the software program Transana. |
| Transcripts of Teacher and class videos | Performed random checks of transcripts in Transana to ensure they corresponded to video segments. Transcriptions of the videos were found to be remarkably accurate, and even included references to bodily gestures (e.g. X turns to the right to look at Y). |
| Coding Scheme                 | There was a 9-page document that outlined the unit of analysis used in the research. This included a definition of a noun, and a justification of using it to measure ideas in the data. Keywords were used to identify notes that contained an idea. Keywords were considered those words that were included in the formal (i.e. dictionary) definition of a noun. The document also describes the limits to keyword coding. |
| Server Log Data & Analyses   | Reviewed raw text files as downloaded from Analytic Tool Kit. |
| Raw downloads                 | Performed random checks of spreadsheet analyses (e.g. Umbrella Idea; Ancient Civilizations). Two sets of raw data were maintained: 1) Direct downloads from the Analytic Tool Kit; and 2) Imports of the same data into various spreadsheets. Spreadsheet analyses were performed in workbooks containing multiple tabs which included raw data and analyzed data. Raw data were maintained in a separate tab from the analyses. |
| Social network analyses | Raw data cleaned and imported into Excel in the form of a matrix. To make it compatible with software, spreadsheet data were imported into Social Network Analysis software (Ucinet, Agna and NetMiner). After analyses were performed and saved, the data were imported back into Excel. This engaged the researcher keep both raw data and analyses in the same workbook. |

Attested to by Vanessa Peters on this 20 of March, 2008

Vanessa Peters
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