

# Knowledge Building: Reinventing Education for the Knowledge Age

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## Abstract

This paper examines the Knowledge Age and how economic factors are causing educators to rethink and reinvent education. Two key factors in education in the Knowledge Age will be education for an economy of innovation, and the increasing virtualization of education.

We present knowledge building pedagogy as a model for education in the Knowledge Age and discuss Knowledge Forum, online knowledge building environment designed to facilitate and support the knowledge building process.

Built into Knowledge Forum is a suit of online tools that track the interactions that students have with Knowledge Forum. We focus on the social network tool that allows us to examine communication patterns among the students when working online.

Using the data obtained, we examine the growth and development of online community formation during the first week of class for a group of naïve users in a third-year university class. Examining the note reading and response networks, we see that the note reading network develops more rapidly than the responding network, and that it is more symmetric than the responding network. However, by mid-term, a highly connected network has developed for both note-reading and responding.

**Keywords:** Knowledge age, Knowledge building, Innovation, Virtualization, Online assessment, Community formation

## 1. Introduction

In 1991, something happened that received surprisingly little public attention: spending in the U.S. on traditional industrial goods was US\$107 billion, but spending on knowledge goods was US\$112 billion (Trilling, 2005; Trilling, Fadel, & Partnership for 21st Century Skills., 2009). This was the first time that U.S. spending on knowledge goods had exceeded that of traditional goods; this was the year that the U.S. quietly slipped into the Knowledge Age. Other industrialized economies were soon to follow, and in the succeeding twenty years, the pace has accelerated. This is a change as profound as the shift from Stone Age societies to Agricultural Age societies, as profound as from the shift from Agricultural Age societies to Industrial Age societies. The current recession has somewhat masked this change, but the offshoring of manufacturing jobs continues apace, and even when the economy recovers, this is unlikely to decrease in any significant way (Grant, 2006; Whitnell, 2008). In many societies, particularly the industrialized west, the knowledge economy will dominate.

This change is being felt in many ways. Some workers have experienced offshoring twice: once as blue-collar workers, and as offshoring moves up the skills ladder, again as white-collar workers (Thottam, 2004). Among the OECD (Organization for Economic Cooperation and Development) countries, wages overall are declining (Thottam, 2004). In Japan, wages have dropped twenty-five percent of the GDP since 1987 (2004). OECD countries make up about nineteen percent of the world total labor force; emerging economies account for forty-five percent (Love, 2007). Torres (in Love, 2007, p. 1) comments, "The thing now is to protect people, but not protect jobs, because some jobs have no future." What's to be done?

### 1.1 Education and Innovation

Uhalde, Strohl, and Simpkins, speaking of the U.S., note that to meet current economic threats, both the quality and level of educational attainment need to be improved, along with the need to nurture and realize innovative capacities

(2006). Similar statements can be made of many other industrialized countries.

Canada is an example. Canada scores well in international tests of education among school children (OECD, 2010), but does less well in upgrading the seven million adults who lack sufficient literacy skills to function in a Knowledge Age economy (Conference Board of Canada, 2008). As well, Canada lags behind other high-scoring countries in producing Ph.D. graduates, especially in fields such as mathematics, science, computer science, and engineering—fields that underpin the current economy of innovation (2008). And aside from some well-known examples, such as Research in Motion, makers of the Blackberry handheld devices, Canada does not do well in translating innovations into products and services (2008). Canada can and must do better. The same can be said of other countries if they wish to maintain their current standards of living.

Two main factors therefore need to be addressed by Knowledge Age societies: improving education and fostering innovation. At first these may seem unrelated, but on closer examination, they are closely linked.

When we speak of innovation in these terms, we are not speaking of rare strokes of genius, but of deliberate attempts to create and sustain a culture of innovation that regularly produces new knowledge. However Bereiter notes (2002, p. 79), "... deliberate effort to improve a body of knowledge is something quite rare in the world. Relatively few of the world's many societies have undertaken it, and in those societies that have done so, it has been the occupation of a small minority." Lewis, speaking of the Ottoman Empire, noted their attitude to innovation: "Knowledge was something to be acquired, stored, if necessary bought, rather than grown or developed" (2002, p. 39). This is the normal mode for most societies. The advancement of knowledge is a modern idea that is in conflict with previous modes of thought (Bereiter, 2002, p. 243).

Where does education fit into this? A culture of innovation does not just happen. It is the product of deliberate attempts to improve a body of knowledge. If we want children who can function in an economy of continuous innovation, we must provide them the opportunity to practice innovation while young: opportunities to produce knowledge products such as theories, designs, plans, simulations, scenarios, experiments and so forth. As Bereiter notes (2002, p. 361), "If an educational goal is to equip students for thinking in adult life, then discourse in school ought progressively to approximate the discourse adults engage in when they are seriously trying to understand something, to reach a decision, to solve a problem, or to produce a design." No one seriously suggests that a child wanting to be a concert violinist should avoid practicing the violin, but almost no one suggests that children in knowledge societies should practice innovation. The myth of the individual genius producing innovation is too deeply ingrained. Yet as Sawyer notes (2007, p. xi), innovation results from an invisible collaborative web in which members of a creative group produce small sparks of ideas that gradually accrue into a flash of insight. Therefore an important function of Knowledge Age schools is to provide students with opportunities to practice innovation, something that is currently lacking from most curricula.

### *1.2 Education and the Knowledge Age*

Knowing that we have entered the Knowledge Age, and that we must educate for innovation is one thing. Knowing how to achieve this is quite another. However some guidance is to be had. One of the scholars most advanced in thinking about the Knowledge Age is Pierre Lévy. His work contains two seminal insights that concern us here: the concepts of *anthropological spaces* and *virtualization* as they affect the Knowledge Age. Lévy uses his own terms for the concept of "ages", but here we will use the more common terminology for reasons of clarity.

Lévy notes the four principal ages in human history: the Stone Age (Upper Paleolithic Age), the Agricultural Age, the Industrial Age, and the still-nascent Knowledge Age. Each has different characteristics. However he views these as anthropological spaces—ways in which humans operate to create their societies (Lévy, 1997). A key insight here is that the institutions of previous ages continue to exist, but are profoundly affected by interactions with the anthropological spaces of newer ages. This already tells us a lot about the nature of education for the Knowledge Age: the institutions of Industrial Age education will continue to exist, but be deeply changed by the Knowledge Age. Schools will still exist—but students will learn quite differently.

Lévy also notes that a key characteristic of the Knowledge Age is virtualization (1998). However before continuing, we need to examine the use of the word "virtual", as in English it exists in a number of different contexts.

In everyday English, *virtual* means the same as *almost*. The statement that someone has lost virtually all of their money is the same as saying that they have lost almost all of their money. In Optics, virtual refers to a type of image that is produced by the projection of light rays by concave mirrors. In computer science, virtual refers to things that have no physical existence, but are made to appear so by software. Of these three usages, the latter is the closest to the philosophical definition used by Lévy. Virtual things are real, and we can interact with them, but they may not be physical objects. Writing a document on a computer produces a document that is real, but not physical. It is a

projection created by the interaction of software, the computer chips in the machine, the monitor, and the author.

Lévy gives four characteristics of virtualization, along with a fifth that is a resultant of the others: deterritorialization, detachment, sharing, elevation to a problematic, and the resultant heterogenesis (1998, p. 75). Recently, the Metropolitan Opera in New York (the Met) has created a project that nicely illustrates these points: their production of high definition digital broadcasts of their live performances.

The original performances of the Met productions could only be seen in New York at the Lincoln Centre, among a crowd of other opera patrons. The new high definition digital productions are shown in movie theatres worldwide and are available on DVD for home use. The result is a virtualization of the act of attending an opera performance.

The digital Met performances don't take place in a single location—they are deterritorialized. The performances are detached from a concert hall to a movie theatre or home. The performances can be shared with a much larger audience than before. A problematic arises with the live broadcasts: that of time for audiences in Europe, Asia, or the Western United States. The final result of all of this is heterogenesis. When things are virtualized, they undergo changes produced by the new environments in which they exist. For the Met performances, the directors have to take into account camera angles, close-ups, and other factors not present in traditional stage performances.

Like the opera, education in the Knowledge Age will be virtualized: it will move online into digital spaces of various kinds, resulting in deterritorialization, detachment, sharing, elevation to a problematic, and heterogenesis. Christensen, Horn, and Johnson (2008) note the rapid growth of online learning in the U.S. In 2000, the enrollment online in the U.S. was 45,000 students. By 2008, there were about one million students enrolled in online courses. They calculate that by 2019, fully fifty percent of high school courses will be offered online. Even if they are only half right, this will represent a massive shift in how education is done in the U.S. William Gibson famously said, "The future is here. It's just not widely distributed yet" (Gibson, nd). The growth in online education that the U.S. is seeing will spread to other countries. In some cases it already has (Bell, Bush, Nicholson, O'Brien, & Tran, 2002; Bloom, 2003).

One model of online education that is currently gaining attention is the blended or hybrid learning model. In blended classes, the student attends some form of school, but works on courses online in a variety of ways. Horn and Staker (2011) give six models of online learning; below we describe a seventh model based on knowledge building pedagogy.

Blended learning fulfills the qualities already suggested for Knowledge Age Education: it makes use of traditional educational institutions, but in a changed form; and it virtualizes aspects of education. The next section will deal with knowledge building pedagogy and how education works in that context.

### *1.3 Knowledge Building and Knowledge Forum*

Knowledge building is the process of creating new ideas through the modification and synthesis of existing ideas. Simply put, ideas come from other ideas, and sometimes they mate and have children. Knowledge building occurs through the deliberate attempt to improve an idea. It produces a product, which is itself a new idea such as an explanation, design, historical account, interpretation of a literary work, experiment, or theory (Bereiter, 2002).

Knowledge building can be contrasted to learning in the traditional sense. Learning is the process by which the knowledge of a society is distributed to learners; knowledge building attempts to increase the store of knowledge (Scardamalia & Bereiter, 2003). The new knowledge created need not be an earth-shaking breakthrough, but instead can be something new only to the local community. Typically knowledge building occurs during the process of solving a real-world problem of some sort. However, during the knowledge building process, much learning in the traditional sense occurs as learners consult authoritative sources, put forward theories, discuss ideas, and so forth. Traditional learning occurs as a by-product of the knowledge building process.

Using research groups as a model, knowledge building classes try to create a community of discourse to solve a problem. In so doing, students are expected to put forward their ideas for critical consideration by other class members, provide new information to the class, test the strengths and weaknesses of the theories and ideas proposed, and attempt the synthesis of new knowledge. Thus it becomes an important job of the teacher to create a knowledge building community in the class.

A knowledge building community is similar to the thought collectives first described by Ludwik Fleck in the 1930s. He defines thought collectives as,

*... a community of persons mutually exchanging ideas or maintaining intellectual interactions ... [which] also provided the special 'carrier' for the historical development of any field of thought as well as for the given stock of knowledge and level of culture (Fleck, 1981, p.39, original italics).*

The establishment of a knowledge building community is essential because as Gumpłowicz notes (in Fleck, 1981, pp. 47-47, original emphasis),

The greatest error of individualic [sic] psychology is the assumption that a *person* thinks. This leads to a continual search for the source of thought within the individual himself and for the reasons why he thinks is a particular way and not another. ... What actually thinks within a person is not the individual himself but his social community. ... His mind is structured, and necessarily so, under the influence of this ever-present social environment, and he cannot think in any other way.

Therefore by structuring the class as a knowledge building community, we are also structuring the mind of the student to think in the manner of a researcher in a group engaged in innovation. It is this mind-set and the resultant culture of innovation that we wish to give the students experience of.

### 1.3.1 Knowledge Forum

Creating a knowledge building community in the classroom is an idea that is often new to both teachers and students. To facilitate and support the process, the Institute for Knowledge Innovation and Technology ([www.ikit.org](http://www.ikit.org)) has built an online knowledge building environment called Knowledge Forum™.

Knowledge Forum is based on the idea that students can be formed into a knowledge building community capable of producing new knowledge. The focus shifts from individual knowledge to group knowledge. Students are encouraged to take control of their own learning and to facilitate the learning of others by contributing their ideas to a public space, in this case a common online workspace. Knowledge Forum has tools to allow students to revise, critique, modify, and organize their ideas and those of others. It has tools to allow students to attempt idea synthesis, and to reference the ideas of others. Every tool in Knowledge Forum is designed to support the knowledge building process and the formation of a knowledge building community. Further information about Knowledge Forum and how it works can be found at the Knowledge Forum introductory tour page (<http://www.knowledgetforum.com/Kforum/products.htm>). Figure 1 shows a Knowledge Forum Note, View Window, and some of the elements that are available.

(Insert Figure 1)

Figure 1. A Knowledge Forum View Window

This figure shows a Knowledge Forum view (workspace) window with an open note posting.

*Views* in Knowledge Forum are workspaces that centre on some aspect of the problem being solved. Work proceeds through *notes*, postings by the students in which they express their ideas, bring forward new knowledge, critique the work of others, produce new theories, and so forth.

Looking at the note window in the centre of Figure 1, we can see on the left the metacognitive scaffold “Theory Building” and the supports it provides. These can be added to a note as a kind of label or tag for the type of thinking the student is using. At the top of the note window is a space in which a description of the problem being worked on. This helps to focus the student on the right kind of work. Students can add keywords to draw attention to important concepts in the notes they post.

As can also be seen in Figure 1, Knowledge Forum supports graphics. In this case, it is an image captured from the analytic tools (see below) showing the note reading pattern for the group. The instructor used this note to provide formative assessment to the class.

There are more features in Knowledge Forum than can be included here, but we will focus on something new: the suite of online assessment tools.

### 1.3.2 The Suite of Online Assessment Tools

Online assessment tools are based on the idea that everything the students do online can be recorded and later assessed. Here, we can make an analogy between retail businesses and online assessment.

Formerly, retail businesses had to close two or three times each year to do an inventory of their stock. This was disruptive and time-consuming. Today, some modern businesses have automated systems to track the flow of stock in and out of their facilities. The data produced are of better quality and more up-to-date than doing inventory in the old way (Pelligrino, 2006). Likewise, keeping track of student work online arguably produces a richer and better data set than older assessment forms. Online assessment tools can provide assessments in real time. These new assessments have the potential to reduce the number of tests and other assessments that take up so much class time—their advent is regarded by some as inevitable (Bennett, 2002).

There are now two types of online assessment tool in Knowledge Forum: an older version, called the Analytic

Toolkit (ATK) that produces mostly raw data and is primarily of use to researchers, and a version that can be gotten through any Knowledge Forum view window, and designed for use by both teachers and students. The online assessment tools in Knowledge Forum are currently evolving, and the tools sometimes change. Here we will discuss the tools that teachers tell us are most useful: the vocabulary growth tool, the writing tool, the contributions tool, and the social network tool.

### 1.3.3 The Vocabulary Growth Tool

The vocabulary growth tool examines the students' writing and produces a graph showing the growth in the number of different words they use.

(Insert Figure 2)

Figure 2. The Vocabulary Growth Tool Window

Figure 2 shows the main window for the vocabulary growth tool, including a graph of vocabulary growth, the student name, and the corpus of words analyzed.

Figure 2 shows the vocabulary growth tool. On the left is a graph showing the overall growth of vocabulary over time. Typically, as a student works on a topic, the graph shows an S-shaped curve. Slow growth to start, then rapid growth as the student learns words relevant to the domain, and finally a tapering off of the growth rate towards the end of the period of study.

On the right of Figure 2 are three windows showing basic words used, advanced words used, and possibly misspelled words. The basic words are based on Oxford University's corpus of three thousand basic English words. Advanced words are those not found in the basic corpus. The possibly misspelled words are those found neither in the basic corpus nor a dictionary.

Using this tool, a teacher can monitor the growth of the vocabulary of each student.

### 1.3.4 The Writing Tool

The writing tools measures two things: word diversity, and writing activity. Word diversity measures the number of different words the student uses (one measure of the complexity of their thinking.) Writing activity measures the length of notes, the number of words in sentences, and the average length of notes. This can help the teacher to assess the level of a student's writing compared to others at the same age and grade level.

### 1.3.5 The Contributions Tool

In order to emphasize the goal of community formation, students never just *save* their note postings in Knowledge Forum. Instead they *contribute* to the community in a variety of ways using a "contribute" button. Contribution types can be various, but include note contributions (new postings), build-on (response) contributions, annotations to notes, automatic academic references to other students' notes, number of notes read, and so forth. These are presented in the form of a bar graph, sorted lowest to highest. In Figure 1, we have seen one such graph that has been inserted into a note.

### 1.3.5 The Social Network Tool

Having roots in Graph Theory, Social Network Analysis uses information about social relationships to examine the functioning of groups (Marin & Wellman, 2009). Data can be obtained through interviews, surveys, direct observation, or through the analysis of data saved during student and teacher interactions with Knowledge Forum. The data obtained can be displayed in a variety of ways, but one of the most common is the sociogram, a kind of network map. Figure 3 shows a sociogram created by Knowledge Forum's social network tool.

(Insert Figure 3)

Figure 3. Knowledge Forum's Social Network Tool

The social network tool window showing the various selections that can be made (left) and the sociogram produced (right).

Sociograms can be drawn in various ways. Some are presented as circles, with everyone presented on the periphery of the circle and represented as dots or squares called nodes and joined by lines called links. This is a traditional representation. However, computers are more powerful now than a few years ago, and we can do more. In Figure 3, we used a force-based or spring algorithm to position the individuals in the network. Using these algorithms, attractions or repulsions are assigned to each node (student or teacher) according to interaction frequency. Persons closer to the centre are more important to the network than persons on the periphery. Knowledge Forum uses indegree centrality as the measure to calculate position in our networks. Indegree centrality is based on how often

other students interact with note postings by a given student, and is considered a measure of importance, power, or influence (Wasserman & Faust, 1994).

To see how this works, Figure 3 displays directional links indicated by an arrow. A link starting at one node with an arrowhead pointing to a second node indicates an indegree for the second node. Here, we are looking at building-on (responding.) A close look at Figure 3 reveals that the response network is dense, highly connected and has many links with arrowheads pointing in both directions. Frequent, two-way interactions have been identified as being important in the transfer of complex information: one-way links are most useful in transferring simple information (Granovetter, 1973; Lai & Wong, 2002; Ogle, 2007). In a knowledge building community, we would prefer to see interactions with many two-way links.

The social network tool is useful for teachers in providing formative assessment to students. It is less useful to researchers because they cannot delete students who have chosen not to participate in the research, making ethics a problem. For that reason, here we use data from the Analytic Toolkit that is imported into professional social network analysis programs.

To review briefly, persons in the centre of the sociogram are more influential to the group. This can also be considered also as a measure of leadership. Two-way interactions are important for the transfer of complex information, one-way interactions are important for the transfer of simple information.

We have noted the importance of the formation of a community in the knowledge building process. According to some sociological definitions, the network showing the relations among individuals *is* the community (Barabási, 2002, pp. 17-18) and thus the sociogram allows us to see the community and examine its functioning. In terms of 21<sup>st</sup> century skills (Partnership for 21st Century Skills, 2008), sociograms show us teamwork, collaboration, and leadership.

Sociograms can display information in a number of different ways. Space does not permit us, in this paper, to cover all of the different variants. Here, we have discussed the basics.

## **2. The Study: Community Formation in a Blended Learning Undergraduate Class**

### *2.1 The Class*

This study examined the formation of an online community among undergraduates in a third-year class for students who are exploring the possibility of becoming science teachers. It was run the manner of a blended/hybrid class with traditional lectures on Thursday afternoons, and an online portion having considerable weight in the marking scheme. The latter was to ensure that the students actually participated online as many, having no experience of such classes, were reluctant to do so.

Each week there was a different view (workspace) in which the students were expected to work. The instructor would post a note indicating the purpose of the view, the topic being covered, the readings, and a discussion question designed to make the students think about the topic under consideration in light of the readings. The students were expected to reply to the discussion question and read and critique the responses of the other students. These weekly session views were available from the first day of class. Students could do their work in the weekly view at any time, but most, in the traditional manner of undergraduates, chose to do their work in the two hours before class.

### *2.2 Methodology*

Past results indicated that community formation happens rather quickly if the students actively participate (Philip, 2009). Therefore sociograms were created for the first eight days of the class and for a number of other points later in the class. Data obtained from Analytic Toolkit of online tools were used. These were imported into the NetMiner II social network analysis program to create the sociograms. The sociograms show the progressive development of the online community. Here, we used the data from the note-reading and responding data sets over a period of one week (Thursday to Thursday,) and then at mid-term.

## **3. Results**

The results show the development of the online community. Shown in parallel are the note-reading and response networks.

(Insert Figure 4)

Figure 4. The note-reading and response networks considered in parallel. The labels “a” and “b” denote the note-reading and response networks. Each set of “a” and “b” images represent the cumulative growth of the respective networks on a given day.

Figure 4 shows the development of the note-reading and responding networks. Note reading is important to a knowledge building class because this is how ideas spread through the community. Responding is important because it is through the building-on and elaboration of ideas that new knowledge is created. Both are needed for successful knowledge building. Thus, the networks that form as ideas are posted and elaborated are critical indicators of the communication patterns in the community. Since ideas cannot spread or be elaborated by unconnected members of the class, these are indicators of the formation of a knowledge building community. Consider Figure 4.1a and 1b as examples.

In 4.1a (the first day of class), we can see that there are two foci, central nodes in the network. Both are actually the teacher in a dual role as teacher/manager of the system (two separate login identities.) By the first day, most students had read some notes posted by the teacher/manager. However, some had read only notes by the teacher, some only notes by the manager, and none had read notes by anyone else, as no one else had posted notes. Two students are unconnected, meaning that they had not read any notes (and that they didn't know what they were supposed to have done before the first class). In 4.1b (the response network), we can see that no one had posted a response to a note by the first day. The response network is entirely unconnected, indicating that this network has not yet started to form.

The note-reading network in Figure 4.1a looks like two star-pattern networks, joined in the middle. Ideally, as students start to interact increasingly among themselves, we should be able to see a smoothing of the spikiness of the network into something more like a faceted crystal. The latter aspect will be made apparent in Figure 5.

Figure 4.2a shows an increasing density of connections among the students and teacher in the note-reading network, and a number of students who have posted notes and have formed a core group whose notes the others have read. Figure 4.2b shows that the response network is still completely unconnected.

Figure 4.3a shows a continuing increase in the number of students who have posted notes and whose notes have been read. Figure 4.3b shows that the response network has begun to form, with four individuals participating. The rest are still unconnected.

Figure 4.4a shows that by day 4 of the class, all students have now joined the note-reading network. Figure 4.4b shows that the response network is unchanged from the previous day.

Figure 4.5a shows the note-reading network continuing to develop, with an increasing number of students joining the core group. The network still looks spiky though, as some students still have not posted notes and are still "read only" participants (Nagel, Blignaut, & Cronjé, 2009). However, the response network (Figure 4.5b) is gradually starting to develop further, and in addition to the core group, an isolated dyad has formed. These trends continue in a similar fashion in Figures 4.6a and 4.6b.

Figure 4.7a continues the trend of students in the note-reading network moving from the periphery to the core, and an increasing density of connections among them. Figure 4.7b shows that the response network has connected the core group with the dyad, and that more students have joined. There is an increase in the connections among students as they respond to each other's postings, but the majority is still unconnected.

Figure 4.8 shows the state of community development on the day of the second lecture. Figure 4.8a shows that most of the students have joined the central core of the note-reading network and that there are eight students still on the periphery. Figure 4.8b shows that the response network is increasingly better-developed, but that about half of the students still have not responded to the postings of others.

[(Insert Figure 5)]

Figure 5 shows both the note-reading (a) and response (b) networks as they have developed by mid-term.

Finally, Figure 5a shows the development of the note-reading network at mid-term; Figure 5b shows the mid-term development of the response network. Figure 5a shows a densely connected network with only one student more distant than most of the others. Because this is a 2-D projection of calculations done in three dimensions, this is difficult to see. In reality, most students have joined the central core and there isn't much in the way of a true periphery in the network. The same cannot be said of the response network. Figure 5b shows that by mid-term, three students (12, 24, and 22) are still quite peripheral to the network. The network is not symmetrical, and has a true core and periphery structure.

(Insert Video 1)

Video 1 shows the note-reading network at mid-term, but in a rotation of a 3-D projection. As can be seen, there is no real centre to the group, and all but one are approximately even in distance from the centre.

### 3. Discussion

What we have seen in Figures 4 and 5 is the development of two aspects of an online knowledge building community: the note-reading and responding networks. The note-reading network results show that initially the network looks “spiky”—individuals are largely disconnected from each other, and the network centers on two individuals. However, as the week progresses, the connections become denser, a core group forms and more individuals are connected to the network. By Day 8, the network looks more like a central mass with some spikes projecting from it. By mid-term (Figure 5) there has been a considerable change: the network looks less like spikes and the connections are more evenly distributed. Video 1 shows that this evenness, when shown in 3-D, reveals that there is no true core and periphery structure (although one student is more peripheral.) Instead the connections appear almost as facets on a crystal structure. By mid-term, the students are reading each other’s notes, and as can be seen by the density of the connections, are having their notes read by others. This allows ideas to spread, which is conducive to knowledge building.

The response network tells a different story. The response network grows more slowly, not really starting until Day 3, and then only in a small way. It’s not possible to say exactly why from these data, but the students were inexperienced with online environments, and would also probably have some apprehension about putting forward their ideas. It’s not the kind of thing science students in large lecture classes usually get to do, and this was one of their first experiences with a small science class.

Likewise, the response network is smaller and less densely connected than the note-reading network. This is to be expected and is desirable. We want responses only when a student has something substantial to say, not just to generate a response. As well, both responding and note-reading take time. If a student reads as many postings as possible, they won’t have time to respond to very many. Therefore the response network will always be slower to grow and less dense than the note-reading network.

Finally, the response network by mid-term is still asymmetric, has a true core and periphery structure, and is overall less well-connected than the reading network. This is not as desirable as it could be. Responding is important to knowledge building, as this is how new ideas, critiques, and elaborations of existing ideas are contributed to the community. In Figure 5b, we can see that even by mid-term, some students are not participating well in the response network, and that some students are more central (more important) than others. An instructor would wish to see more evenness in response contributions for effective knowledge building.

### 4. Conclusions

This paper has had three foci: how the knowledge age, with its economy of innovation will affect education; the nature of knowledge building, and why it is likely to be important to an economy of innovation; and how new tools that use data about student interactions with online environments can enhance our understanding of the learning process and allow teachers to look into processes that have previously been invisible.

The still-nascent knowledge age is having a profound on every aspect of society. The emphasis it places on knowledge work makes education central to the emerging knowledge economy. The current educational system was designed to produce citizens educated for an industrial economy, but we need to re-think education in terms of the demands of the knowledge economy, an economy largely dependent on innovation. Currently few models of education include innovation as a goal. Knowledge building is a model of education that puts the innovation process front and centre, making a good candidate as an educational model for the knowledge age.

Knowledge building pedagogy evolved in parallel with the rise of the personal computer, and uses the online Knowledge Forum software suite to facilitate the knowledge building process. Knowledge Forum has many advanced features, and among them, featured in this paper, is an evolving suite of online analytic tools. Assessing student performance in this manner is quite new, and can provide valuable insights into the knowledge building process on both individual and group levels.

Knowing what knowledge building should look like will enhance a teacher’s ability to guide the process, to tell when things are going wrong, and provide clues as to what kind of action should be taken. As well, the same information can be provided to the students, allowing them to better understand how their own actions influence the group. This has the potential to be transformative of behaviour for both teachers and students.

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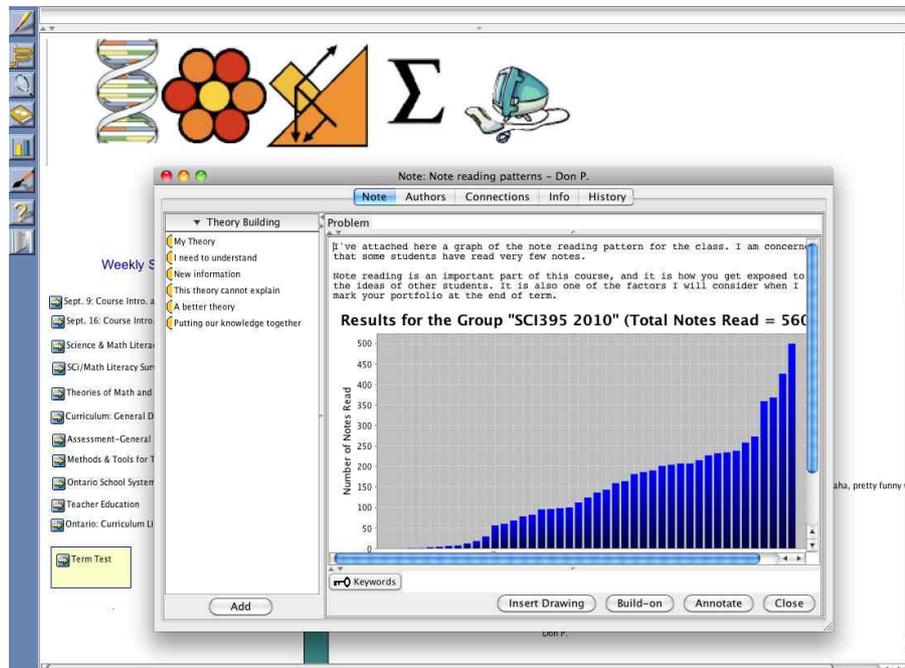


Figure 1. Knowledge Forum view (workspace) window showing an open note containing a graphic.

Views are workspaces in Knowledge Forum. It is through the posting of notes and responding to them that work is done in Knowledge Forum. Notes can contain graphics, and elements of the note can be tagged with metacognitive scaffold supports (as can be seen on the left of the open note.)

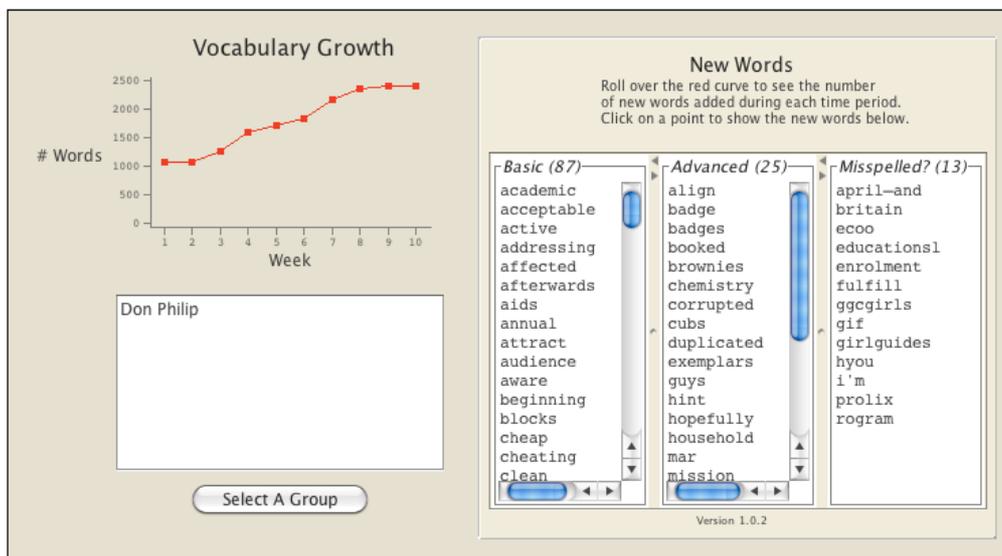


Figure 2. The vocabulary growth graph window.

The vocabulary growth tool provides a graph of the growth of vocabulary, and shows the basic, advanced, and possibly misspelled words used.

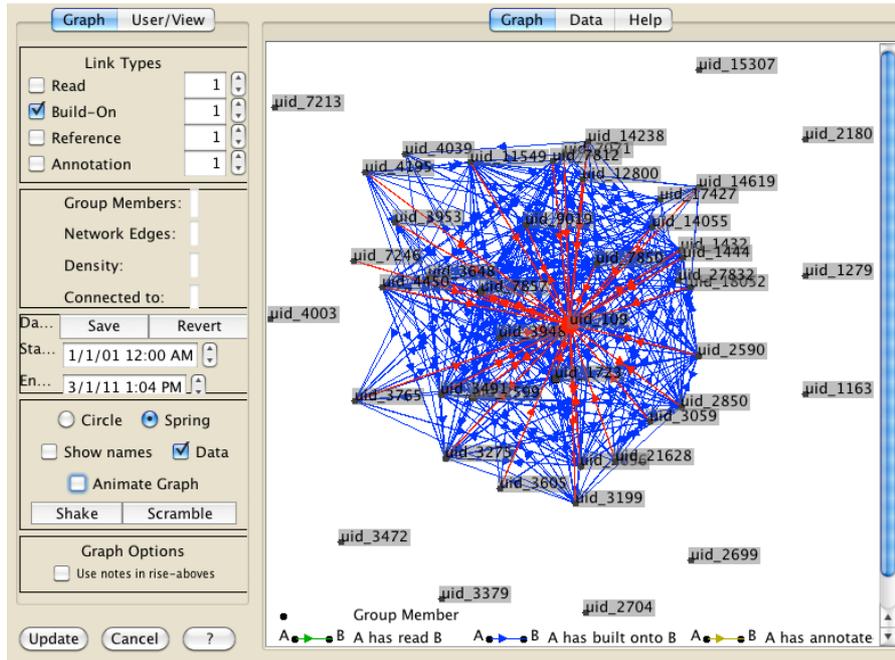
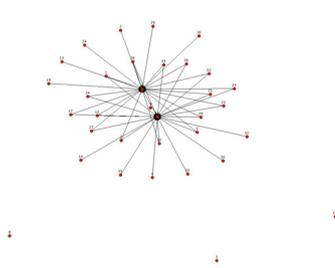


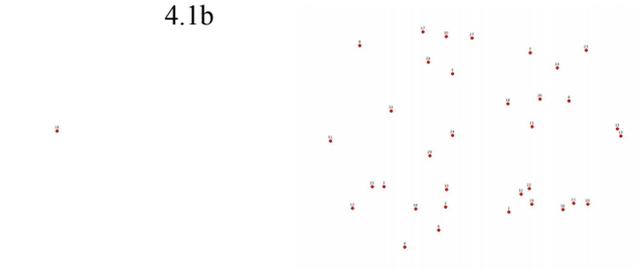
Figure 3. The Social Network tool.

The social network tool allows the user to select the network to examine, and presents a sociogram showing the communication links among the students for that network. Here the Build-on (response) network is shown.

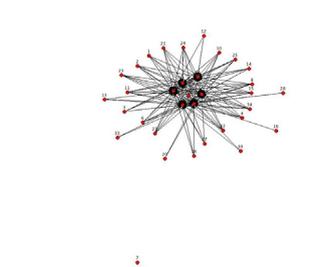
4.1a



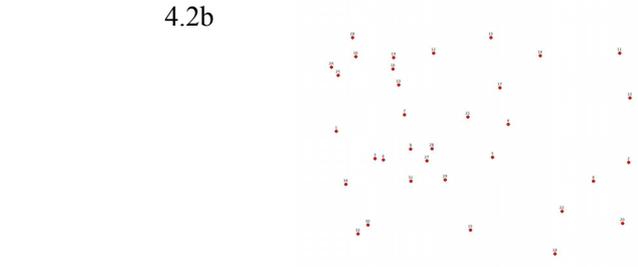
4.1b



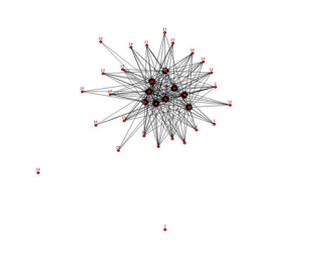
4.2a



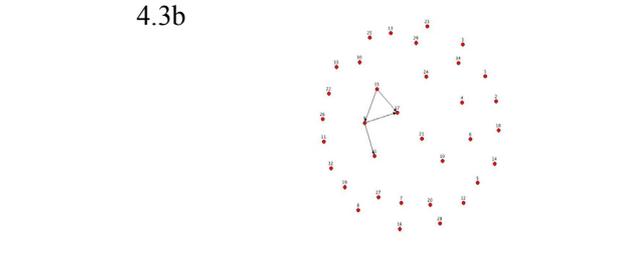
4.2b



4.3a



4.3b



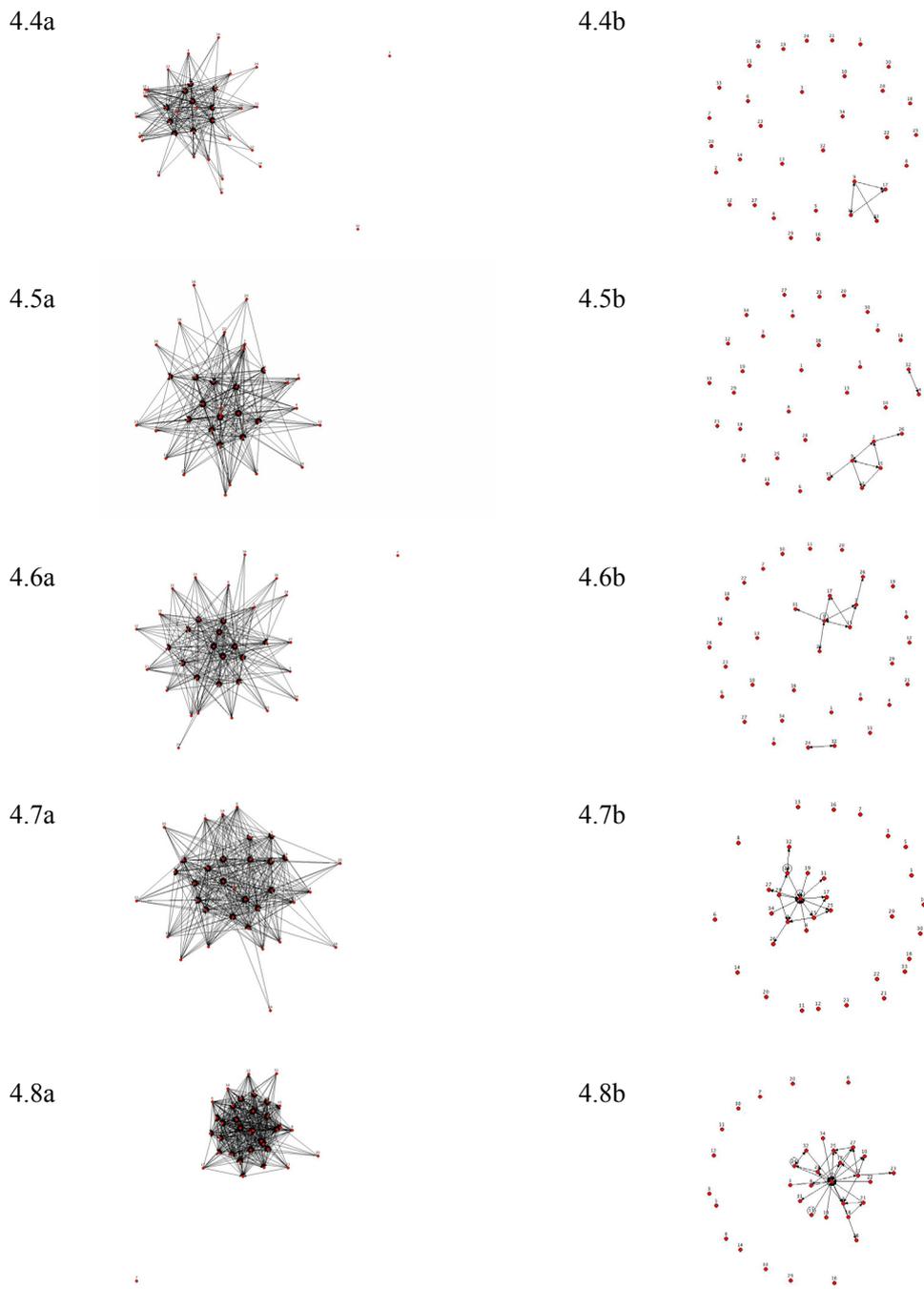


Figure 4. Growth of the note-reading and response networks over an eight day period.

4.1a indicates Figure 4, day 1, note-reading network, and 4.1b indicates Figure 4, day 1, response network. Other numbers are similar, with all “a” images being the note-reading network, and “b” images being the response network. Note that the response network grows more slowly and is less well-formed at the end of the eight day period than the note-reading network.

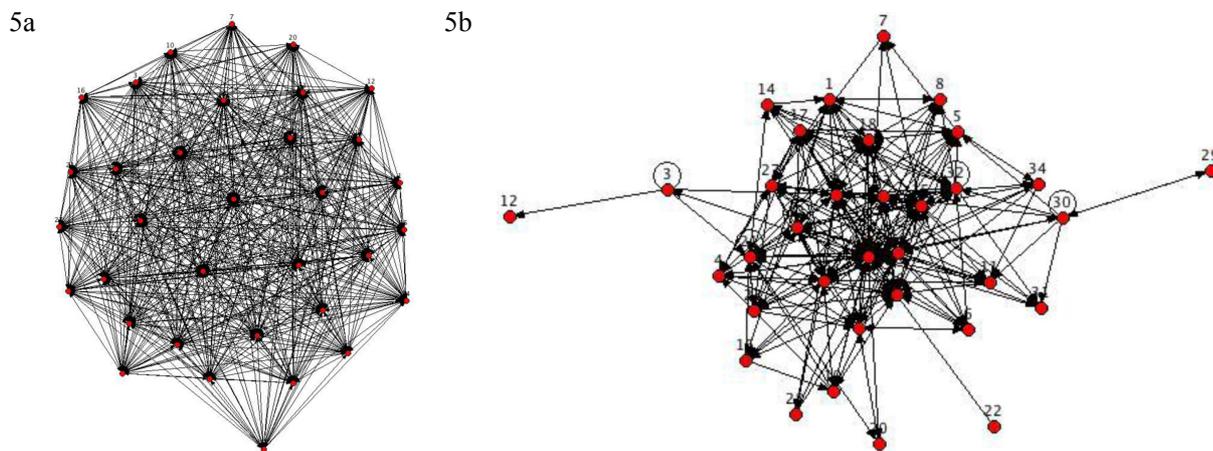
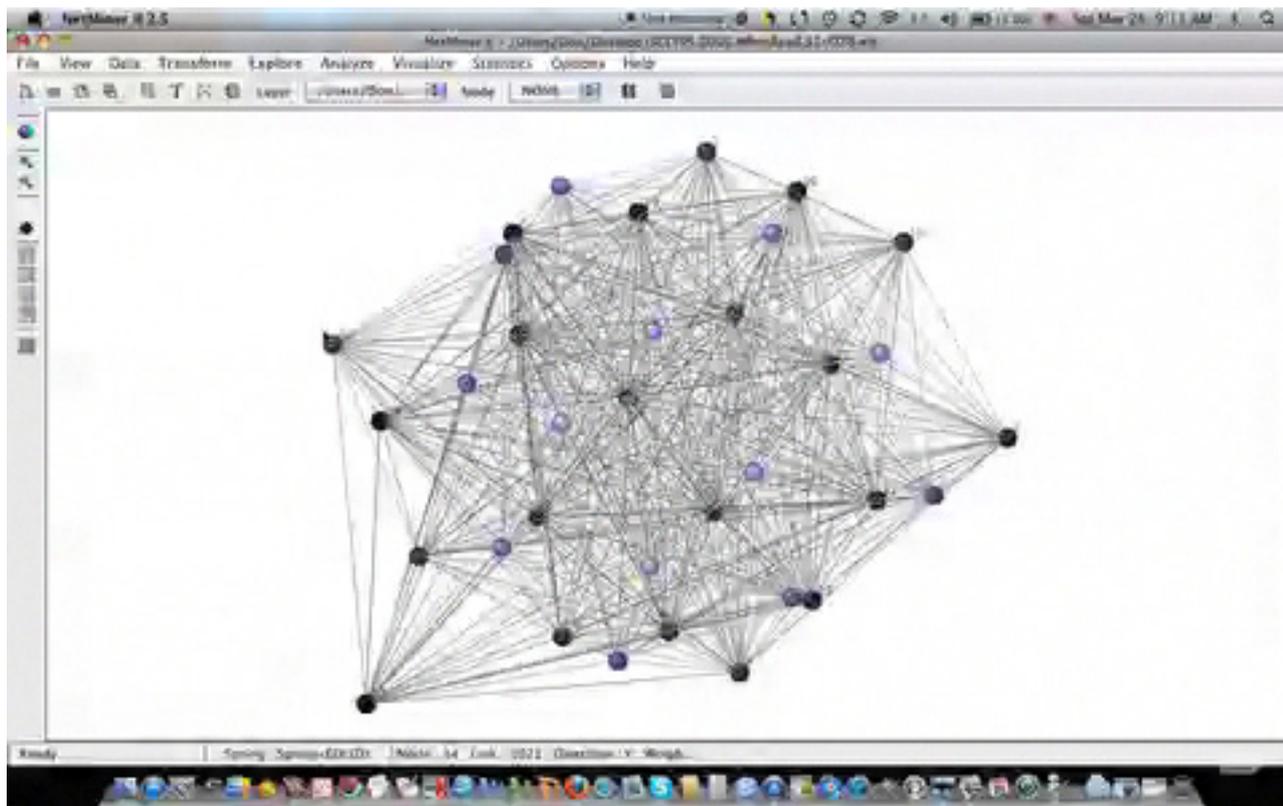


Figure 5. 5a shows the note-reading network at mid-term, and 5b shows the response network at mid-term. Note that the note-reading network (5a) is very symmetric, indicating quite even participation levels among the students. The response network (5b) is less well developed, asymmetric, and has a true core/periphery structure, indicating less even participation.



Video 1. Screen movie showing the 3-D image of the reading network at mid-term rotating. 2-D images of symmetric networks can give a false impression that there is a core/periphery structure. Using a 3-D image and rotating it demonstrates that this is an artifact.