Design, Implementation and Testing of a Visual Discussion Forum to Address New Post Bias

by

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Abstract

One challenge of using asynchronous online discussions in educational settings is that students have a tendency to read only new posts and reply to just the most recent ones. This has a variety of negative consequences for learning through discussions. In this thesis, I used information visualization techniques to design a visual discussion forum interface and studied students' behaviours using this visual forum as compared to a traditional text-based linear forum. A hyperbolic tree, which presents the higher-level posts with bigger nodes, was used to present the structure of the discussion. In the visual forum, students (re)read higher-level posts before their new replies. Additionally, students more actively selected which threads to read as compared to the text-based forum. Students' pointed out the visual design and layout as one of the most useful features of the interface. However, students' feedback raised concerns about some interface features that should be investigated further.

Keywords: Online Discussion Forums; Visual Interface; Text-based Interface; Information Visualization

Acknowledgements

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1. Introduction

The popularity of online and blended (face-to-face with online component) courses in higher education has increased (Allen & Seaman, 2011; Allen, Seaman & Garrett, 2007). The emergence of online education helps to address some barriers to post-secondary access, such as distance and relocation costs in vast countries like the US and Canada. Online education, particularly courses that are delivered asynchronously, also offer economic cost advantages and flexibility in time and location (Carr-Chellman & Duchastel, 2000).

With the increase of online and blended courses being offered, online discussion forums have been an important component of classes. Online discussion forums can help students share ideas and facilitate knowledge co-construction (Boulos & Wheeler, 2007). Online discussion forums also offer learners an opportunity to interact with peers and instructors during the learning process, and thus have became a popular tool for distance education (Jonassen, & Kwon, 2001; Pisutova-Gerber & Malovicova, 2009). Moreover, in online discussion forums participants can play an active role in the discussion regardless of their physical location and such discussions can lead to more interaction with the class than in entirely face-to-face courses (Curtis & Lawson, 2001). For these reasons, some instructors use online discussion forums in addition to face-to-face discussions in the classroom.

Online discussion forums have some typical shortcomings. Most online discussion forums are text based and linear. Many online discussions do not converge to a conclusion (Hewitt, 2001). Fractured and incoherent conversations

(Herring, 1999; Reyes & Tchounikine, 2003), a low level of interactivity among learners (Thomas, 2002), student difficulties in deciding which posts to read and reply to in a highly branched discussion (Hewitt, 2003), and long delays between a post and its response (Wise & Padmanabham, 2009) are some examples of the shortcomings in online discussion forums.

One major shortcoming in linear text-based online discussion forums is that participants in these forums tend to only read posts that are flagged as new, and only reply to the most recent posts in the threads (Hewitt, 2003). This problem, which in this thesis is referred to as "new posts bias", may be a cause of several other problems in online discussion forums, such as the unintentional "death" of threads, unintentional drift of the discussion topic, the neglect of synthesizing or summarizing tasks, and the neglect of difficult questions (Hewitt, 2003; 2005).

While multiple factors contribute to learners' tendencies to read new posts and reply to the most recent ones, several scholars have pointed to the standard text-based discussion forum interface as a major cause (Hewitt, 2003; Swan, 2004). Hewitt (2003) suggests that redesigning the interface may prevent the negative educational consequences of new posts bias.

A visual interface that highlights the structure of the discussion may prevent students from engaging in the unproductive behaviour of new post bias. Some researches argue that visual presentation of online discussions have benefits not only for students but also for instructors and researchers (Scardamalia, 2004; Teplovs, 2008; Wise & Padmanabhan, 2009). Several research studies have been conducted to examine the effects of visualizing discussion forums. However, most of these studies focused on using the visualizations in analyzing and evaluating students' participation in an online discussion forum after it has ended. Thus the visualizations cannot be used by students during the discussion.

Despite the promise of visual interfaces to improve students' participation in online discussions, only one well-known example exists. Knowledge Forum (Scardamalia, 2004) is a well-known tool used in education that visualizes the reply

structure of the discussion. However, the Knowledge Forum visual view has some shortcomings, and using it may result in a disorganized forum that confuses learners. Thus, while visual interfaces present a promising avenue for research and practice in online discussions, much work remains to be done.

The aim of this thesis is to design and test a new visual interface for online discussion forums in an attempt to prevent the unproductive behaviour of new posts bias. Chapter 2 reviews the theoretical foundations of online discussion forums and introduces the new posts bias problem, its educational consequences, and possible causes. This chapter also explores visual interfaces as a possible solution for this problem. Chapter 3 reviews basic concepts of information visualization, and then describes different methods for presenting of the structure of a discussion. It also explores methods of differentiating between new and read posts, in an attempt to prevent unproductive behaviour of new post bias in online discussion forums. The design of a new visual forum has also been explained in this chapter. Chapter 4 describes the research methods for the present study to test the new interface, including its hybrid design, in which students were asked to interact with a discussion that they had generated for a prior class, the data collection (via logged clickstream data, screen capturing and recorded think aloud data), and data analysis (processing of clickstream data, creating activity sequence diagrams and framing the cases). Chapter 5 reports the results of students' reading patterns in the new visual forum, and compares them with their previous participation in the same discussion in a text-based interface during a prior class. Chapter 6 discusses the reading patterns in the visual forum and compares them with the designed goals and prior research. The thesis concludes with a discussion of the limitations of this study and its implications for future research and practice.

2. New Post Bias: Unproductive Behaviour in Online Discussion Forums in Education

Despite the prevalent use of online discussion forums in education, traditional text-based online discussion forums have some major shortcomings. In this chapter, I review some of these problems and focus on one of them, new post bias, in which students in online discussion forums tend to read primarily new posts, and reply to the most recent ones. This behaviour has a major impact on students' learning in online discussion forums (Hewitt 2003; 2005) and can be a cause of several other problems.

To understand the problem from an educational perspective we need to be informed by learning theories that explain learning in online discussion forums. Because online discussion forum learning theories are built on more fundamental learning theories in education, I review these theories first in this chapter. After explaining theoretical perspectives, I describe the new post bias, its causes, consequences, and possible solutions.

2.1. Theoretical Foundations of Online Discussion Forums

Online discussion forums are virtual online spaces where learners can share their ideas about a subject, read others' ideas, and reply to them. Online discussion forums are one example of a collaborative technology for learning, an emerging paradigm of research in educational technology (Koschmann, 1996). The aim of collaborative technologies in general is to engage individuals in the process of

creating shared knowledge and facilitate this process by enhancing their interactions (Gunawardena, Lowe & Anderson, 1997; Lipponnen, 2002). These interactions can occur among peers as well as between learners and instructors (Jonassen & Kwon, 2001; Pisutova-Gerber & Malovicova, 2009).

In education there are different perspectives on collaborative learning and how learning may take place in online discussion forums. These perspectives go back to two different theories in educational psychology about cognitive development and learning. The first theory revolves around the Piagetian notion of cognitive conflict (Piaget, 1928) while the other is based on Vygotsky's conceptions of learning as a social process (Vygotsky, 1978). Reviewing these theories, including important interactions during the learning process, helps us to understand productive behaviors during online discussion.

2.1.1. Piaget's theory of cognitive development

Piaget describes different stages of cognitive development starting from an egocentric stage and progressing to more social stage in which the individual takes into account others' ideas. According to Piaget (1928) during interaction with their environments individuals try to balance between their cognitive schemes (what they already know) and information from the environment. If applying the existing cognitive schemes works in a situation, assimilation occurs and the new information fits into current cognitive schemas. In contrast, if applying the existing cognitive schemes does not work, accommodation occurs which leads to changes in the current cognitive schemas or the creation of new ones to understand the new information. While others may play a role in the process, in Piaget's theory, learning takes place in the individual mind as a result of interaction with others; this stands in contrast to the next theory that views learning as a shared process of co-construction.

2.1.2. Vygotsky's socio-cultural theory of learning

In this perspective learners interact with others to construct knowledge together. Vygotsky in his socio-cultural theory suggested that social interactions as

well as activities and cultural tools (e.g. language) lead to development and learning. These social interactions help groups of individuals create cognitive structures and thinking processes together (Vygotsky, 1978). "Vygotsky conceptualized development as the transformation of socially shared activities into internalized processes" (John-Steiner & Mahn, 1996, p. 192). In other words, learning occurs in two phases: first on the social level and between people, and later on the individual level and inside individuals.

Vygotsky explained how social interactions and external actions are internalized in the private thoughts of an individual. To explain the influence on mental processes by social interactions Vygotsky introduced the idea of higher mental processes. Higher mental processes appear during social interactions and are co-constructed during shared activities via interaction and negotiation (usually verbally). Then the process is internalized by the individuals and becomes part of their cognitive development. Individuals can use this process independently in future. So, social interactions have an important role in cognitive development and creating thinking processes.

Tharp and Gallimore (1988) provide an example that helps to understand higher mental processes and how these processes are internalized by the individuals:

> A six-year old has lost a toy and asks her father for help. The father asks her where she last saw the toy; the child says, "I can't remember." He asks a series of questions – did you have it in your room? Outside? Next door? To each question, the child answers, "no." When he says "in the car?" she says "I think so" and goes to retrieve the toy. (p. 14)

In this example, the child was not able to find the toy by herself and her father did not know where the toy was. Thus, neither of them could find the toy individually. They used a particular thinking strategy to find the toy, which can be considered a higher mental process. This process was co-constructed between them

via interaction. After a few times using this process with her father, the child may internalize this process and she may be able to use it individually when she loses something in future.

2.1.3. Social interactions in Piaget and Vygotsky's theories of learning

Even though Piaget and Vygotsky have different perspectives about cognitive development and learning, they both identify social interactions as an important part of the learning process. In Piaget's theory of cognitive development, learning is a process that takes place in the individual's mind during attempts to assimilate or accommodate new information. This new information comes from the outside world including during social interactions. Brown, Metz, and Campione (1996) note that in Piaget's theory, peer interaction is an ideal form of interaction to "decentre" learners' thinking and consider different perspectives. The new information from peers leads to assimilation and accommodation, which are central in Piaget's theory of cognitive development (Brown et al., 1996). In contrast, social interactions are more central in Vygotsky's socio-cultural theory. According to this theory, the learning process starts in social interactions. During these interactions a shared understanding is co-constructed and learning is a result of internalizing these processes.

In both perspectives, social interactions among learners (and between learners and instructors) are an important part of the learning process. Online discussion forums are one of the tools that can help facilitate social interactions. Both Piaget and Vygotsky's learning theories can help to understand the learning process during participation in online discussion forums, at both the individual and group levels, which is described in the next section.

2.1.4. Learning in online discussion forums

Drawing on both Piaget and Vygotsky's perspectives, Stahl (2004) provides a model of collaborative knowledge building in online discussions that includes both individual and group levels. This model, which helps to understand the learning processes in online discussion forums, describes how expressing ideas in

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statements and sharing them, as well as reading others' ideas and discussing them, can lead to shared understanding and knowledge construction. Figure 2.1 (Stahl, 2004, p. 76) presents important phases in the knowledge building process. These phases are partitioned into two iterative cycles: "building personal knowing" (individual level) and "building collaborative knowing" (group level). In Figure 2.1, arrows represent processes and rectangles represent the outcomes of each process, which are different forms of knowledge. Starting from the lower left, it presents the cycle of personal understanding. The rest of the diagram shows how different people with different ideas achieve share understanding and collaborative knowledge as well as create cultural and cognitive artifacts via expressing their ideas to others, reading (or hearing) others' ideas, discussing alternatives and negotiating perspectives. These artifacts then influence personal understanding and change individuals' knowing.
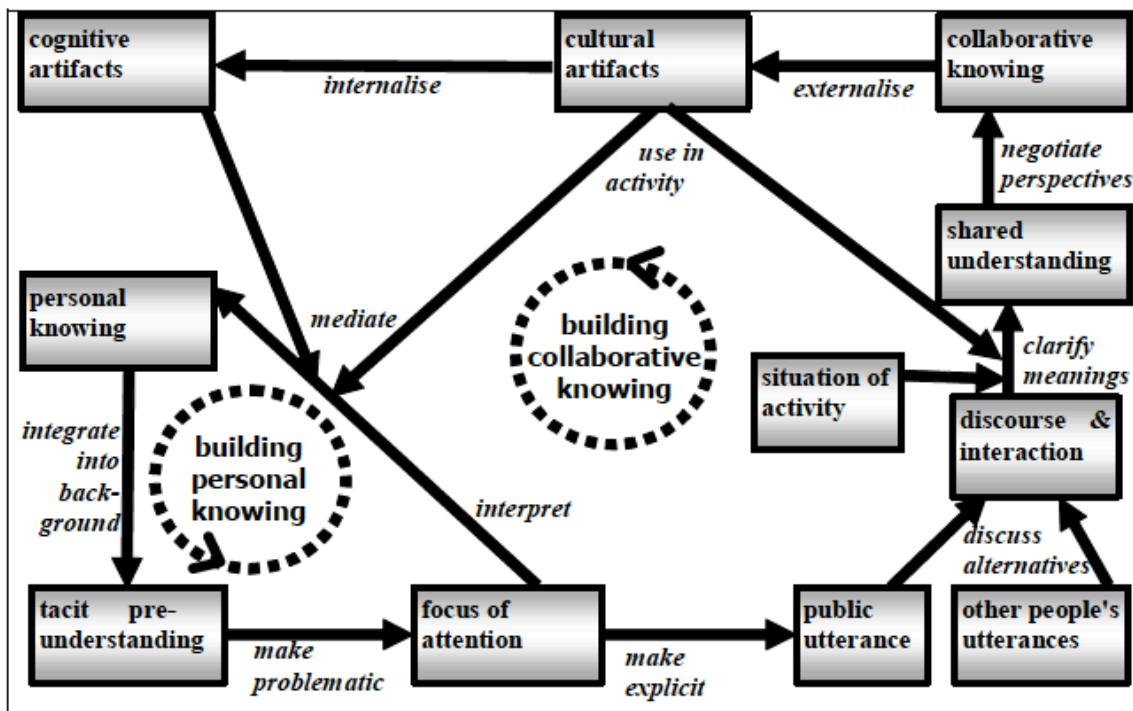
Figure 2.1. A diagram of the cycle of knowledge building (Stahl, 2004, p. 76).
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In summary, personal understanding contributes to the collaborative knowledge process through interaction with others, including discussion, clarification and negotiation; then the shared collaborative knowledge is internalized by the individuals (Stahl, 2004). Although the knowledge building process has been shown in a series of limited number of sequential phases, in practice this process is more complex and may vary in different situations. However, Stahl's model helps as a starting point to understand the learning process in online discussion forums.

2.1.5. Being exposed to other's ideas, an essential step of learning in online discussion forums

Although the learning process consists of different steps and all of them are necessary, being exposed to others' ideas is an essential step in the learning process. Based on Piaget (1928) and Vygotsky's (1978) theories as well as Stahl's (2004) model, reading or listening to others' ideas is a starting point of the learning process. Consequently, in online discussion forums reading others' ideas and reflecting on them are important activities for learners.

In Stahl's (2004) model, the "building personal knowing" cycle draws on Piaget's theory of cognitive development. The starting point of this cycle, which is doubting some personal understandings, is a result of receiving new information via interaction with the world (e.g. reading others' ideas). This doubt leads to assimilation or accommodation, which could change cognitive schemas or create new ones. The starting point of the "building collaborative knowing" cycle in Stahl's model is sharing personal understanding with others, reading others' ideas, and discussing them. In this cycle, which draws on Vygotsky's socio-cultural theory, interacting with others via cultural tools (e.g. language) can lead to higher mental processes. One example of these interactions in online discussion forums is building on other's ideas (or synthesizing them) when reading and replying to the posts. During these interactions students read others' ideas, discuss alternatives, clarify meanings and negotiate perspectives. Higher mental processes, which take place via

discussion and negotiation during reading and replying to posts in online discussion forums, can then be internalized by individuals.

As described in this section, being exposed to others ideas, which can happen during reading others' posts, is an essential step of learning from multiple theoretical perspectives. In practice students' interactions in online discussion forums, including how they read and reply to posts, can be influenced by features of these forums. For example, how posts are represented via the interface may influence students' behaviour such as deciding which posts to open. In the next section, I review one of the major problems in online discussion forum related to exposure to others' ideas and discuss its effects on collaborative learning.

2.2. New Post Bias and its Educational Consequences

2.2.1. Introducing the problem

One major shortcoming in linear text-based online discussion forums is that participants in these forums often tend to only read posts that are flagged as new and just reply to the most recent posts in the threads (Hewitt, 2003). This problem may be a cause of several other problems in online discussion forums such as unintentional death of threads, unintentional drift of the discussion topic, ignoring synthesizing or summarizing tasks and ignoring difficult questions (Hewitt, 2003; 2005).

Hewitt (2003) studied online discussions in five different online graduate-level classes that were taught by different instructors. In this study, 92 students participated in online discussions during 13 weeks and created 673 threads with more than one post. As the following data shows, students had a tendency to read posts that were marked as new and reply to the most recent posts. On average 82% of the posts students chose to read were the posts that were marked as new and 80% of the replies were posted in less than 48 hours of the parent post (65% within first day and 15% between first and second day). Figure 2.2 illustrates the delay

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between a post and its replies based on Hewitt's (2003) data. The rate of creating replies to a post decreases drastically over time.

In a later study, examining patterns of activity in discussion forums, Hewitt (2005) found similar results to his previous research. Fourteen Masters students enrolled in an online class participated in this study. Students contributed in 5 discussion topics during 13 weeks and created 105 threads including 517 posts. 83% of posts students chose to read were marked as new.
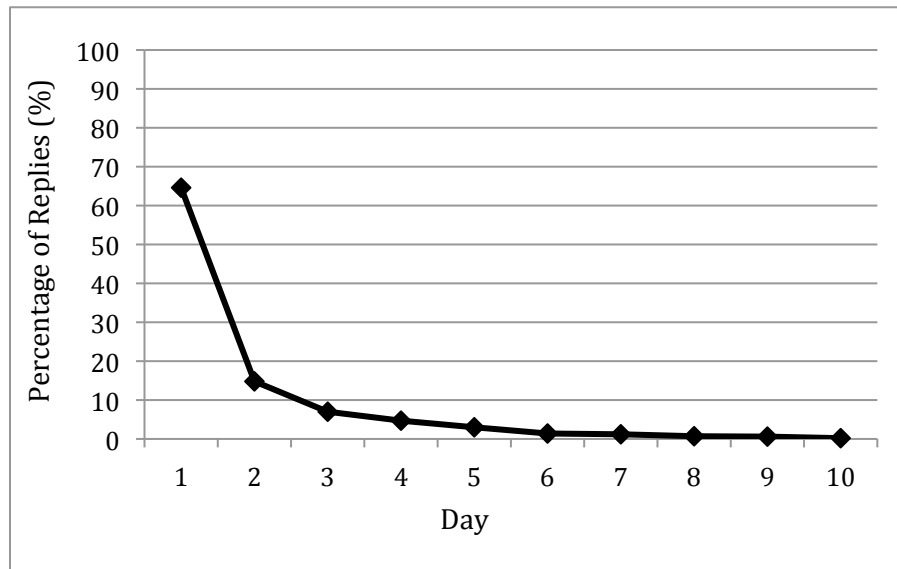
Figure 2.2. Delay between a reply and its parent post in days (graph based on data from Hewitt, 2003).

To investigate how much new post bias influences students' interactions and growing patterns of the threads, Hewitt (2005) simulated the new post bias behaviour using a Monte Carlo simulation. This simulation was based on online activity patterns such as the number of times students visited the discussion and the number of replies they created in each visit. In this simulation, computerized "students" read all new posts in each visit (all the posts that had been created after their last visit) and replied to some of them. No other factor (e.g., author, subject, or content of the post) was used to decide which posts to read and reply to. Figure 2.3 shows the frequency of thread sizes in computer simulation and actual discussion

forums. The very close values of two series of data substantiates the claim that new post bias affects growth pattern of threads and students interactions in online discussion forums.
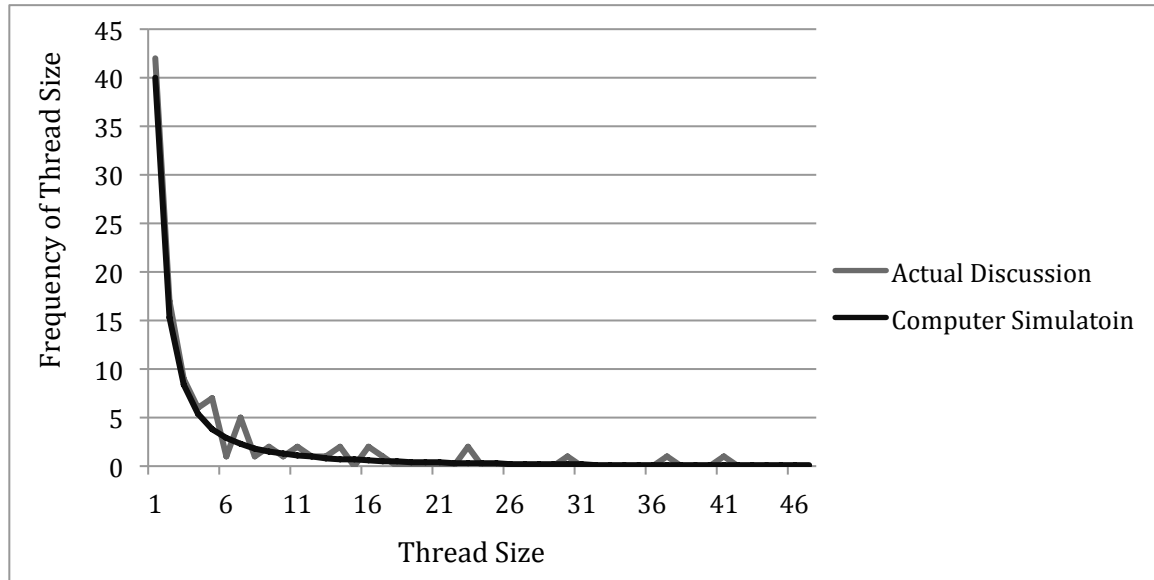
Figure 2.3. A comparison of the frequency of thread sizes predicted by a computer simulation to the frequency of thread sizes observed in an actual online discussion forum (graph based on data from Hewitt, 2005).

In a more recent study Chan, Hew and Cheung (2009) examined growth patterns of threads in online discussions in a master level course on the "Design of Asynchronous Online Discussions." The results of this study further substantiate Hewitt's (2003; 2005) finding of users' tendency to read new posts and reply to the most recent posts in the threads. They also demonstrate the influence of new post bias on the growth pattern of threads in online discussion forums. Fourteen students participated in 3 weeks of discussions. Among 36 threads in seven discussion forums, they found three different patterns. Almost half of the discussion threads (42%) grew in a liner pattern of replies to the last post, 30% remained unelaborated with two posts or less and just 28% had a "broad" structure containing more than one sub-thread.

2.2.2. Implications of new post bias for collaborative learning

Reading only new posts and replying just to the most recent posts is a serious problem from a pedagogical perspective (Hewitt, 2003; 2005). For example if many of the ideas being shared go unnoticed, theoretically this can have a negative effect on the quality of the discussion and the learning process in online discussion forums. If a learner does not read all (or at least most) posts in an online discussion forum, he or she receives less information and limited perspectives about the learning topic. From a Piagetian perspective and Stahl's personal knowing cycle, learning takes place as a result of adaptation of new information via assimilation and accommodation. Thus limitation in receiving new information may lead to no or limited adaption, and consequently impair understanding of the learning content. Moreover, from a Vygotskian perspective and Stahl's collaborative knowing cycle, if learners in an online discussion forum do not take into account most of ideas during the discussions by reading and replying to them, there is less likely to be a shared understanding (including different perspectives) created and internalized. Ignoring some posts (not reading or not replying to them) in online discussion forums prevents learners from being engaged in the collaborative knowledge building. It may also lead some learners to feel ignored and thus disengage from the conversation.

In his research, Hewitt (2003; 2005) investigated four specific consequences of new post bias in online discussion forums: unintentional death of threads; unintentional drift of the discussion topic; ignoring synthesizing or summarizing tasks; and ignoring difficult questions. First, entire threads might die without learners' noticing. Because learners have a tendency to read new posts and reply to the recent posts, posts in the threads with no new posts have a lower chance to be read. Some of these threads may have important ideas, but because they don't have any new and recent posts, students are less likely to read and reply to them. Hewitt (2003) notes the discussion group may not be aware when a discussion with an important topic has stopped growing. This is one example of not taking into account

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all ideas in the discussion, which can negatively influence collaborative learning in online discussion forums.

A second problematic result of focusing only on new and recent messages is unintentional change (or drift) in the discussion topic (Hewitt, 2003). When learners only read new posts, they may forget the main ideas introduced earlier in the thread. Thus when they create a reply they just take into account recent ideas in the thread and this may change the discussion topic. By changing the discussion topic the primary ideas in the discussion may be ignored. Therefore, while learners read some posts in the threads and may even reply to them, they do not read the main ideas that should be shared and then discussed in the online discussion.

Third, because of the new post bias, learners will less likely be engaged in synthesizing or summarizing tasks (Hewitt, 2005). Synthesizing or summarizing tasks usually require reading all or most posts in the thread. As described earlier in this chapter, these tasks are important interactions among learners in collaborative learning. These social interactions are examples of higher mental processes that can be internalized by individuals.

The fourth and last consequence of new post bias is that learners will more likely ignore difficult questions in the discussions, when they just read new posts and reply to the most recent ones (Hewitt, 2005). These difficult questions are usually important and valuable for the discussion. As a result of this behaviour, learners do not discuss and negotiate these issues in the discussion and they remain unelaborated. This lack of elaboration leads to lack of understanding of others' ideas, negatively impacting shared understanding among learners, and consequently collaborative learning in online discussion forums.

All four of these problems are the collective results of the combined effects of individual reading and replying behaviours, but they also point to a lack of student metacognitive awareness of discussion processes. If learners are not being conscious and purposeful in deciding which posts to read and reply to, their decision is more likely to be impacted by features of the online environment, such as

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the representation of posts via the interface (Swan, 2004). The next section describes the influence of the interface on students' behaviours in online discussion forums in more detail, and suggests how common interface features contribute to new post bias.

2.3. New Post Bias: Causes and Possible Solutions

The design of software and its features affect students' interactions and their behaviour in online collaborative spaces (Preece, 2000). While a variety of computer software is used for online discussion forums in education, many of them have common features. Some of these features and how students use them can influence reading and replying behaviours and collaborative learning in online discussion forums (e.g. causing new post bias), and thus are important to study.

2.3.1. Asynchronicity

Asynchronicity in online discussion forums means the discussion may not happen in real time (unlike online chat-rooms or face-to-face discussions) and learners have "time-unlimited" access to the discussions (Wise & Padmanabhan, 2009). Certainly in asynchronous forums, learners have some time limitations (e.g., a week to participate in a course topic) but they can contribute when it is convenient to them during the period. In addition, they can communicate with others (e.g. tutors) without fear of interrupting them (Kaye, 1989; Hammond, 2000). In asynchronous online discussion forums learners can take time to read others' posts and think about the subject as well as others' ideas. Therefore, learners will more likely be engaged in more thoughtful contributions (Hiltz, 1997).

Although asynchronicity has some benefits in online discussion forums, it may also be a cause of some problems. In asynchronous online discussion forums learners do not need to participate in the discussion at the same time with others. This may lead to long delay between creating a post and its replies. Wise and Padmanabhan (2009) argue that such a long delay is a problem, because the learner

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may no longer be engaged with the ideas from their initial post. Thus the students would not be engaged in discussing their ideas, which according to the Stahl's (2004) model is one of the primary steps of collaborative knowledge building. These delays may be one of the reasons for incoherent discussions and a low level of interaction among learners (Thomas, 2002).

2.3.2. Threading

Most online discussion forums organize posts into threads, which demonstrate the relationships between the posts. Each thread includes a topic and its replies. Threads can be different discussions on different topics. Within a discussion thread, different subtopics are called subthreads. Each thread may consist of several subthreads. Learners can more easily follow and contribute in discussions that are categorized in separated threads (Kear, 2001). In this structure, learners can choose where to make a new post and specify that they are replying to a specific post. Using this feature, participants can understand which posts are responses to which posts. Therefore, good threading structure in an online discussion forum can assist learners in knowledge construction and reduces the effort to participate in the discussion (Salmon, 2000). In addition, students can make sense of each thread and the discussion more quickly (Guzdual & Turn, 2000).

Despite the benefits of organizing posts into threads in online discussion forums, sometimes threading may cause problems. For example in highly branched threaded online discussion forums, learners may have difficulty deciding which posts to read and reply to (Hewitt, 2003). Therefore, the learners may not be able to find and read some important ideas that have been shared in the discussion. They also may make their replies in the wrong places, leading to more confusion for other learners to find these ideas. From a theoretical perspective (as described earlier in this chapter) not reading others' ideas would lead to no or limited learning in online discussion forums. This problem may also be a result of the next feature discussed, representing threads and posts via a linear text-based interface.

2.3.3. Linear text-based interface

Most online discussion forums in education have text-based interfaces (Suthers, Vatrapu, Medina, Joseph, & Dwyer, 2008). In text-based interfaces with no threading, *posts* are sorted chronologically. If an online discussion organizes its posts into threads, these *threads* are sorted chronologically instead. Within each thread, replies to the same post are also sorted chronologically. In text-based interfaces usually subject, author, and date/time of a post are represented in a linear chronological list. In most text-based interfaces, posts within a thread are represented using indentation to reflect the reply structure. In addition, most text-based interfaces have a method to differentiate between posts a user has already read and new posts (posts the user has not read yet).

In education, three kinds of interactions are commonly thought to influence learners: interaction with content, interaction with instructors, and interaction among learners (Moore, 1989). In addition to these interactions, in online environments interaction with interfaces also affects learners (Hillman, Willis, & Gunawardena, 1994). Swan (2003) conceptualizes interactions with interfaces as affecting other kinds of interaction (see Figure 2.4). In online environments, all interactions, including interactions with content, peers, and instructor, happen via interfaces. Consequently, the interface can also affect students' interactions in online discussion forums (Kear, 2001). One such effect is new post bias. In online discussions, which posts to read (i.e. interaction with content) and which posts to reply to (i.e. interaction with peers) are influenced by the interface. Thus how the interface represents the posts (e.g. a linear chronological list) can influence students' reading and replying behaviours, which can lead to the new post bias.

While multiple factors contribute to learner's tendency to read new posts and reply to the most recent ones in a discussion forum (for example some learners may read only new posts as a strategy to deal with information overload), several scholars have pointed to the standard text-based discussion forum interface as a major cause (Hewitt, 2003; Swan, 2004). Hewitt (2003) suggests that redesigning the interface may prevent new post bias and its' educational consequences. He

proposed that designing interfaces that "make context of the discussion more
visible" (Hewitt, 2003, p. 42) could reduce this tendency.
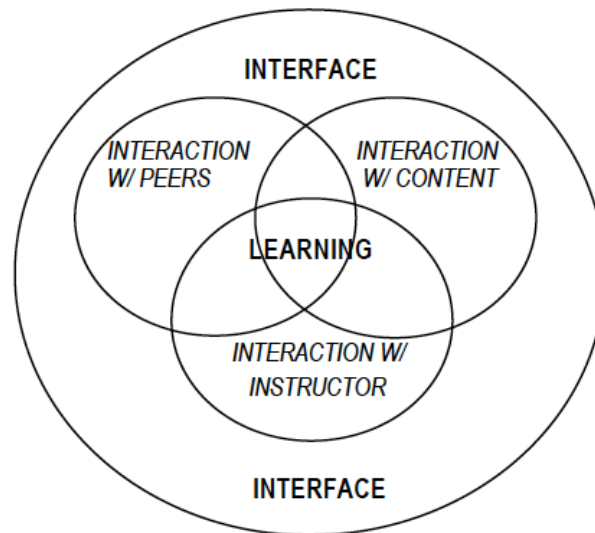
Figure 2.4. Interaction with interface conceptualized (Swan, 2003, p. 31).
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2.3.4. Effects of highlighting structure of discussions on students' interactions

Kear (2001) examined the influence of highlighting the structure of the
discussion via interface in online discussion forums. She compared posts made by
42 students who participated via 3 different interfaces during 2 years of teaching a
course. Although all of the software used in the study supported threading (the
students could indicate to which post they were replying), the interfaces showed the
posts and the threaded connections in different ways. The first two interfaces were
text-based. The first interface did not illustrate threading and the posts were
represented in a simple chronological list (see Figure 2.5). The second interface had
a text-based interface that showed just one level of indentation of replies to the first
post. Figure 2.6 illustrates this semi-threaded interface. The last interface had a
mixed text-based interface and a graphical component to illustrate the full threading
structure. Figure 2.7 illustrates this interface with a graphical component. The
graphical component of this interface highlighted the structure of the discussion by
showing the connections between posts.
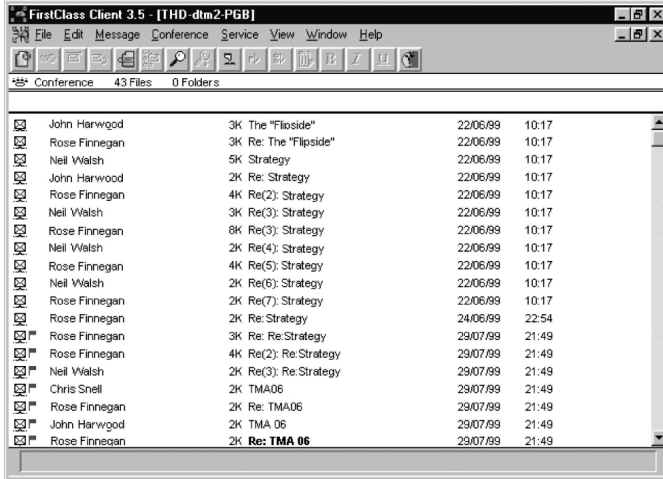
Figure 2.5. Posts in no threaded interface (Kear, 2001, p. 85).
© 2001, Elsevier, Reprinted with permission.
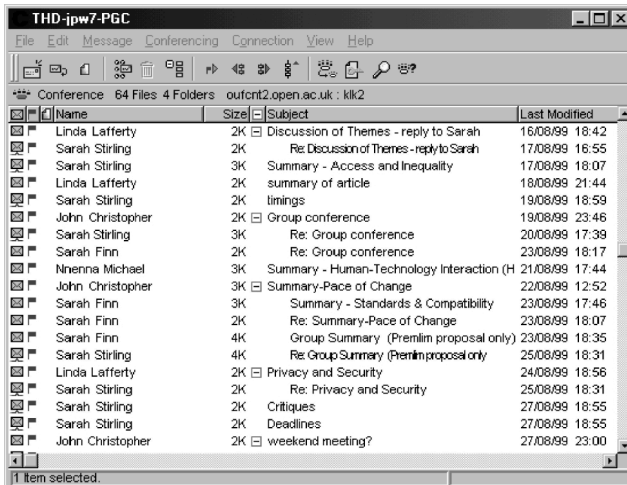
Figure 2.6. Posts in semi threaded interface (Kear, 2001, p. 86).
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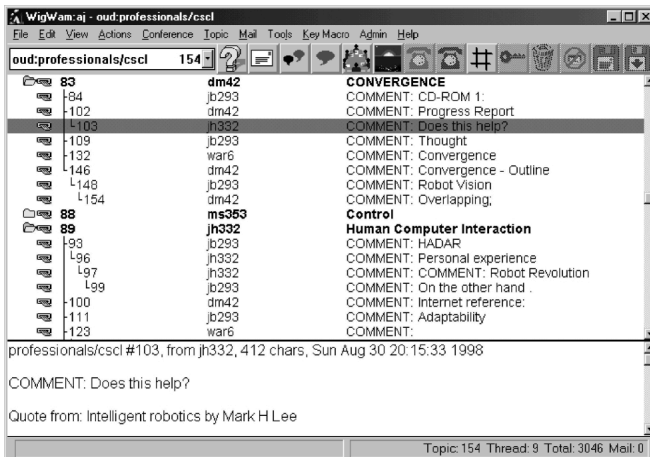
Figure 2.7. Posts in the interface with a graphical component (Kear, 2001, p. 84).
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In the interfaces that did not show the full structure of the discussion (Figures 2.5 and 2.6), students made more unthreaded posts even if they should have been connected to some other posts (based on their content). In addition, it was more difficult for students to follow the conversation in the unthreaded interface (Kear, 2001). From 277 posts created by users in the two text-based interfaces (no threading and semi threaded) 68 posts (about 25%) were isolated posts (not part of a thread). However, from 133 posts created in the interface with a graphical component, only 6 posts (about 5%) were isolated posts. In addition, the average number of posts in a thread was 5.2 for the text-based interfaces and 7.8 for the interface with a graphical component. Fifteen percent of posts in the text-based interfaces but only 3% of posts in the interface with a graphical component had missing links. These were posts that were created as isolated posts that should have been submitted in threads based on their title or content.

As Kear's (2001) findings indicate, an interface that highlights the structure of the discussion can help students have a more connected and coherent discussion and makes it easier for students to follow the discussion. Thus highlighting the structure of the discussion can be a solution for new post bias, as described in more detail in the next section.

2.3.5. Highlighting the structure of the discussion, a possible solution for new post bias

Jonassen and Rohrer-Murphy (1999), and Kear (2001) argue that a good interface can reduce learners' cognitive load and support them in collaborative learning. Learners in an interface that highlights the structure of the discussions do not need to mentally keep track of relations between posts and can concentrate on the content of the posts.

Designing a visual interface that highlights the structure of the discussion may also help reduce the problem of new post bias. In text-based forums, the threads and posts in each thread are sorted chronologically. Therefore, recent posts, which are usually the last posts in the threads, may attract more attention than

other posts. In addition, flagging these posts as new may draw additional attention to them. These two interface features (chorological order of posts and new flags) are likely to contribute to new post bias. One possible solution for new post bias could be a non-linear visual interface that highlights the structure of the discussion instead of the chronological order of posts. Highlighting the structure of the discussion may help students to follow and understand the discussion, and may help them in selecting which posts to read and reply to based on the structure of the discussion and content of the posts, instead of the posts' position in the list or their new flag. The next section explains more about visual forums and reviews the existing visual forums with respect to the new post bias problem.

2.4. Introduction to Visual Forums

Some researchers argue that visual interfaces can help students to participate more effectively in discussions (Scardamalia 2004; Suthers et al., 2008; Teplovs, Donoahue, Scardamalia & Philip, 2007) and help instructors better evaluate the discussion and students' participation in it (Kim & Johnson, 2006; Smith & Fiore, 2001; Teplovs, 2008; Teplovs & Scardamalia, 2007; Wise & Padmanabhan, 2009). Teplovs (2008) proposes that visualization of data in the discussion forums can lead to better understanding of the discussion and more effective contributions by learners. Kim and Johnson (2006) suggest information visualization can increase learners' reviewing speed of the discussion and improve their understanding of the content. Furthermore, Teplovs (2008) proposes highlighting the structure of the discussion via visualization of online discussion forums can help learners to better understand the interactions that generated the discussion.

Although several research studies have been conducted to visualize discussion forums, most of them have been designed to analyze and evaluate students' participation in the discussion after it has ended and cannot be used by students during the discussion period (e.g. Smith & Fiore, 2001; Kim & Johnson,

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2006; Wise & Padmanabhan, 2009; Teplovs, 2008; Teplovs & Scardamalia, 2007).

Thus, despite the promise of visual interfaces to improve students' participation in online discussions, only one well-known example exists. Knowledge Forum (Scardamalia, 2004) is a well-known tool used in education that visualizes the reply structure of the discussion. However, Knowledge Forum has some shortcomings with respect to new post bias that will be described in the next section. Nevertheless, reviewing Knowledge Forum visual features can help inform the design of a new interface to avoid new post bias. The following sections describe Knowledge Forum visual view, its benefits and shortcomings in order to avoid new post bias.

2.4.1. Knowledge Forum Visual View

Knowledge Forum is a well-known online discussion forum, which has both text-based and visual interfaces for learners. Knowledge Forum's visual view is a two-dimensional visual interface. Nodes and links are the main visual elements of this view. In the Knowledge Forum visual view the nodes represent the posts and are connected to each other by directed links based on the replies. The direction of the link is from the reply post to its parent post. Thus, the Knowledge Forum visual view represents the reply structure of the discussion. The Knowledge Forum visual view keeps track of new and read posts for each learner and the colour of the node changes after being read by the learner. Figure 2.8 (Teplovs, 2008) shows one example of posts in Knowledge Forum visual view.

The Knowledge Forum visual view can be used in different ways. In some cases the horizontal and vertical axes have some interpretable meanings. In other words, the position of the posts on the screen can carry meaning. For example, in one use of the Knowledge Forum visual view, students were contributing about dinosaurs. They categorised their posts based on the dinosaurs' food chain. So each post was placed in a specific area on the screen based on its content (what kind of food that dinosaurs were eating) [Scardamalia, 2004]. However, in this example Knowledge Forum was not used as a true discussion forum. Its use was more akin to

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an information repository since students made their posts in one of the categories but not connected to other posts. In other cases, in which Knowledge Forum has been used as a discussion forum, the axes generally do not have a specific meaning and the two-dimensional space just shows the contributions. In these cases students just need to find an appropriate place for the post (usually close to the post they are replying to). Thus from its position, other students can understand the post's relation to the other posts (see Figure 2.8).
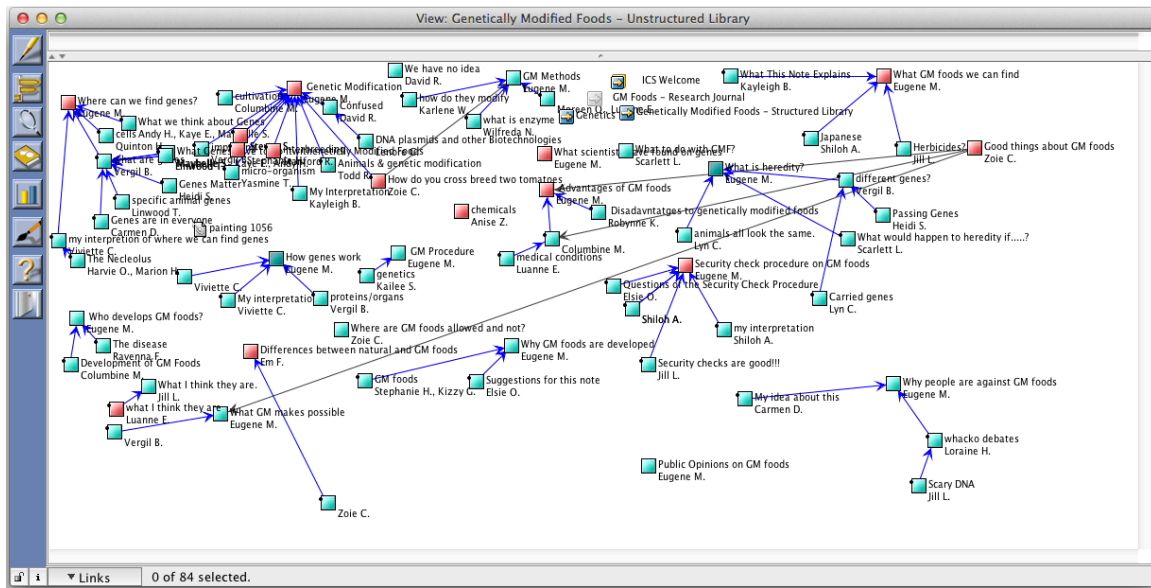
Figure 2.8. An example of posts in Knowledge Forum visual view (based on Teplovs, 2008).

2.4.2. Shortcomings of the Knowledge Forum visual view

Although the Knowledge Forum visual view represents the structure of the discussion, it does not provide any guidelines for posts' location and allows learners to position their posts when they create them. This may help students to categorize their posts based on different factors. It may also provide cognitive benefits as learners consider what is an appropriate position to place their posts, or learners may place their posts without considering these issues. Especially in a discussion with a large number of posts finding an appropriate place for a post can be frustrating for learners or they may create their post without taking into account

these issues. Similarly the fact that other learners can move posts to any other position could be beneficial or result in a disorganized forum that confuses learners. A disorganized representation of posts without a clear layout may prevent learners from understanding the structure of the discussion. Having difficulties in understanding the relationships between posts may also result in difficulties connecting different ideas in the discussion and thus limit learning.

Using an automated method to place the posts in suitable places can save learners extra effort and result in a more organized and comprehensible representation of the discussion. As described in the previous sections, learners benefit from seeing the structure of the discussion (via an organized representation) and this can lead to more coherent and connected discussion. A well-organized representation of the structure of the discussion is more likely help students to choose posts to read and reply to based on connections with other posts, instead of just whether they are new posts are not.

Even if students try to create organized discussions in Knowledge Forum, the visual view has some other shortcomings that make it difficult to understand the structure of the discussion. In Knowledge Forum, in the visual representation of posts with many replies, the reply arrows collide with each other around the parent node. More importantly, each post's content opens in a new window not allowing the learner to read the post in the context of its connections to other posts. This may cause extra cognitive load for the learner while reading a post when he or she tries to understand its connection with the other posts at the same time. This can influence the learners' comprehension of the post content. Representing the post content and the structure of the discussion in the same window could avoid extra cognitive load and help the learner to concentrate on the post content. Moreover, unlike most forums that use the colour red to indicate new posts, Knowledge Forum shows read posts with the colour red, which could confuse some learners. Using colour as the method of differentiating posts and its benefits and shortcomings will be discussed in detail in the next chapter.

2.5.   Call for Designing a New Visual Interface

As described in the previous section, despite some useful features of Knowledge Forum's visual view, it has some shortcomings in presenting the structure of the discussion. Surprisingly, the extensive literature published on Knowledge Forum pays little attention to the potential benefits and challenges of the visual interface. Thus, while visual interfaces present a promising avenue for research and practice in online discussions, much work remains to be done.

The aim of this thesis is to design and test a new visual interface for online discussion forums in an attempt to prevent unproductive behaviour of new post bias. To design and test this interface, the following questions are considered:

- What is an appropriate method to present the structure of the discussion in an attempt to prevent unproductive behaviour of new post bias?
- What is an appropriate method to illustrate posts as read or unread in an attempt to prevent unproductive behaviour of new post bias?
- How does the visual forum change students' reading patterns regarding which threads to visit and which posts to read?
- How does the visual forum influence students' behaviour in reading new posts?

Drawing on the literature from both online discussions and information visualization, in this thesis I will design a visual interface for a discussion forum and study how learners using it to engage in reading and replying behaviours. The next chapter describes some information visualization concepts that can be useful in designing a visual interface.

3. Designing a Visual Discussion Forum

The goal of this chapter is to design a new visual interface that highlights the reply structure of the discussion in an attempt to prevent unproductive behaviour of new post bias. Learners using existing linear text-based interfaces tend to read primarily new posts and reply to the most recent ones. This behaviour negatively influences collaborative learning in online discussion forums and has educational consequences (Hewitt, 2003; 2005). For example learners may not be aware of the main ideas that have been shared and are being discussed in the online discussion. Furthermore, learners will less likely be engaged in synthesizing or summarizing tasks, which are important interactions among learners in collaborative learning.

Two main design questions that were raised in the previous chapter (finding appropriate methods to present the structure of the discussion and illustrate posts as new and read) can be investigated with respect to information visualization concepts. Information visualization is concerned with finding visual techniques to represent information in order to help users to understand it more easily (Spence, 2007). In this chapter I review basic information visualization design principles, possible solutions for different methods of representing the structure of the discussion and different methods of illustrating different posts, and evaluate their benefits, and shortcomings for preventing unproductive behaviour of new post bias. As described in the previous chapter the selected solution for each of these issues may influence students' reading and replying behaviour in online discussion forums.

3.1. Introduction to Information Visualization

In this section I describe basic information visualization concepts including what is visualization, different types of data, and how the human visual information processing system works.

3.1.1. What is Visualization?

Many research studies have used visualization techniques for different purposes and applications. Despite the variety of these research studies, one aspect is the same in all of them; the results of looking at the diagrams are created in the mind. This can be interpreted as gaining insight or understanding (Spence, 2007) and is consistent with the dictionary definition of the word "visualize", which is "to form a mental image of something" (Visualize, Merriam-Webster dictionary). Spence (2007) provides a simplified process of information visualization that has been illustrated in Figure 3.1. Data is represented as a diagram or picture. We look at the diagram or picture and interpret it. The result is understanding the data or gaining insight about it (Spence, 2007). Visualization techniques have been used many years before using computers. However, computational support has had an essential role in the development of advanced visualization techniques in recent years.

The data in Figure 3.1 can be any type. It can be text, numbers, or even some sort of graphical presentation. The goal of visualization (or problem solving in information visualization) is to represent the data in a form that make the solution to the problem transparent (Simon, 1996). In other words, visualization is finding a method of representing data that can be understood easily. In this thesis, the solution is a visual representation that highlights the structure of the discussion in order to reduce new post bias.

Finding a suitable method to visualise data depends on the type of data. Different types of data require different visualization techniques. The next section describes different types of data.
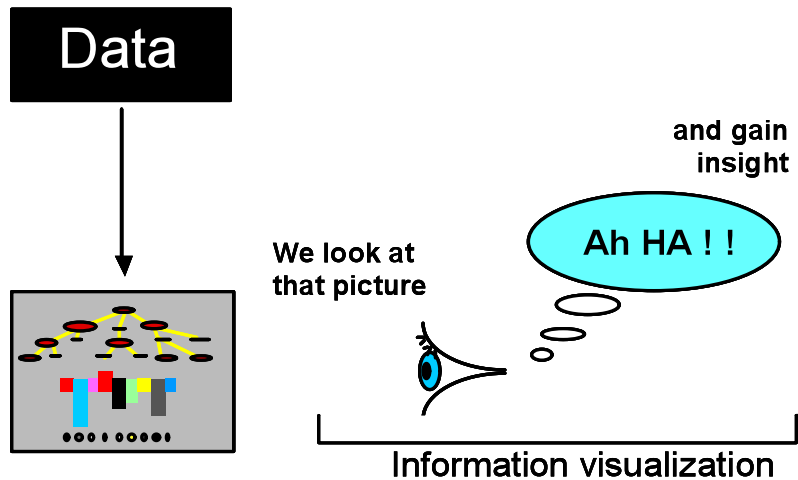
Figure 3.1. The process of information visualization (Spence, 2007, p. 5).
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3.1.2. Types of data

The goal of visualization is to transfer data into visual elements that can be understood easily. Ware (2004) has suggested that there are two basic types of data: entities and relationships. Entities are the objects that we want to visualize (e.g. posts in a discussion). Relationships are structures that relate the entities together (e.g. reply relations in a discussion).

Both entities and relationships have attributes. An attribute is a property of an entity or a relationship and cannot exist independently of it (Ware, 2004). For example, the colour of something is an attribute. Attributes have values that can be measured and presented by visualization techniques.

3.1.3. How the human visual information processing system works

In this section I review a simplified human visual information processing system introduced by Ware (2004). Figure 3.2 illustrates this system, which provides an overall conceptual framework that helps us to understand information visualization concepts. This system has three stages. In stage 1, basic features of the environment are extracted via parallel processing. In stage 2, structures of the visual

scene are perceived by active pattern perception. In stage 3, a few visual elements are held in the visual working memory by active attention.

Stage 1 is the parallel processing stage. In this stage, a large and fast computational system processes visual information in parallel and extracts low-level features. A large number of neurons in the eye process the visual information. Neurons individually interpret their input into information such as colour, orientation of edges, texture, and movement patterns. In this stage, billions of neurons process the input in parallel and extract basic features simultaneously. This parallel processing does not even need human attention and it happens whether we want it to or not.
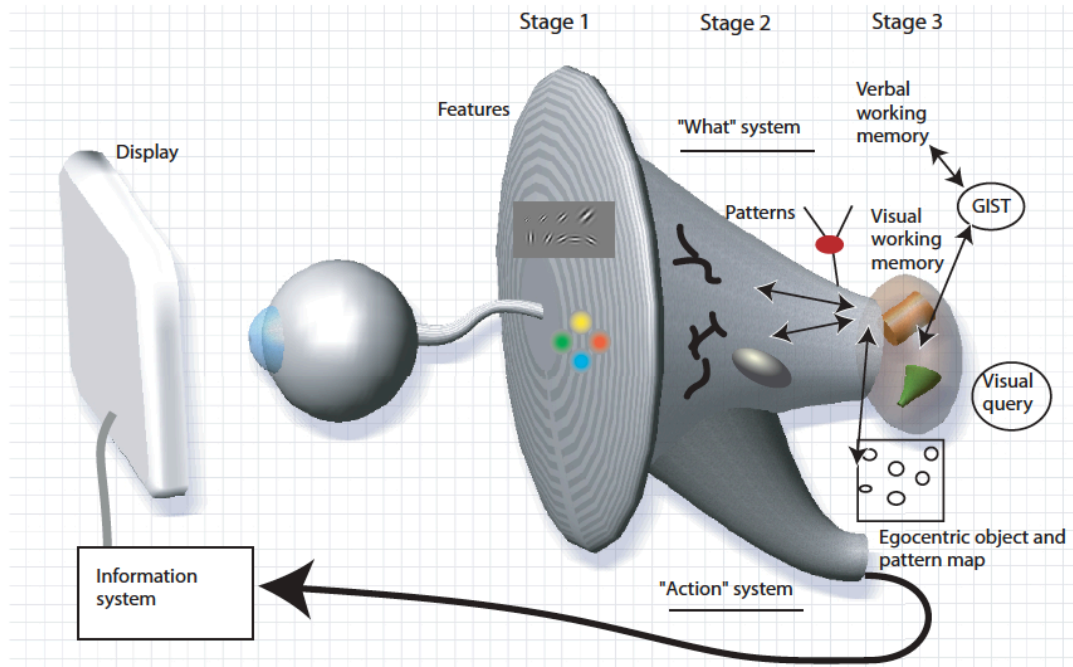
Figure 3.2. A three-stage model of human visual information processing (Ware, 2004, p. 21).
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Stage 2 is the pattern perception stage. In this stage, active processes partition the visual scene into regions and simple patterns, such as continuous contours, areas with the same colour, or the same texture. This pattern-finding stage uses information from the previous parallel processing stage. There is a hypothesis

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based on some evidence that there are two visual systems in this stage, an "action system" and a "what is it system" (Milner & Goodale, 1995). Based on this theory, tasks that include coordination of eye-hand and movement may be processed in a different system than object recognition tasks. Visual information processing in this stage is serial and slower than stage 1.

Stage 3 is the highest level of perception and called the sequential goal-directed processing stage (Ware, 2004). In this stage, visual objects can be held in the visual working memory by active attention. However, the number of objects that can be held at the same time is limited (Ware, 2004). These objects are usually held as a result of answering a sequence of visual queries. For example if we look at a road map to find a route, we will have a visual query for connected contours (major highways), which connect two visual symbols (cities). There are also other systems and sub-systems (e.g. verbal linguistic system) that are connected to the visual processing system.

This section described the basic concepts of information visualization. The design goal of this thesis is to find a visual solution in representing online discussion forums that highlights the structure of the discussion in an attempt to prevent unproductive behaviour of new post bias. To represent the online discussion forum data, which includes posts and the discussion structure, I reviewed different types of data. Learning about how the human visual perception system works helps to evaluate different methods of representing posts and the discussion structure in online discussion forums in order to achieve this thesis design goal. In the next sections, I review different methods of representing the structure of the discussion and posts within it with respect to the information visualization concepts that have been presented in this section. Because the structure of the discussion and post characteristics are two different types of data, I review their possible representing methods in two different sections.

3.2.   Different Methods of Presenting the Structure of a Discussion

The Knowledge Forum visual view (Scardamalia, 2004) and a number of studies that used visualization of discussions for analysis purposes (e.g., Hara, Bonk & Angeli, 2000; Aviv, Erlich, Ravid, & Geva, 2003; Teplovs, 2008; Wise & Padmanabhan, 2009) use tree diagrams to visualise the structure of the discussion. A tree is a network of connected nodes and links that has no loops. In other words, starting from a node, there is no path that ends back at the same node without retracing any links (Cormen, Leiserson, Rivest, & Stein, 2009). Figure 3.3 illustrates an example of a tree structure. In this structure the root node is the starting point of the tree. Each node may have one or more children but only one parent. The only exception is the root node that has no parent. For example in Figure 3.3 node D has three children (E, F, and G) and its parent is node A.
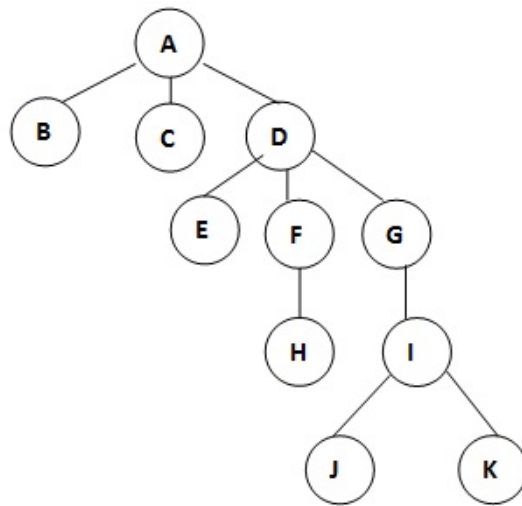
Figure 3.3. An example presentation of a tree structure

A tree is an appropriate and useful structure to represent the structure of online discussion forums for several reasons. A tree structure matches exactly with the discussion reply structure. Similar to the tree structure, in the discussion each post can be a reply to one post (its parent post) and have more than one reply (its children). The discussion prompt is like the root node that is not a reply to any other posts. Thus, the posts can be represented as tree nodes. Both posts and tree nodes

are entity type of data. In a tree representation of a discussion, the reply relations of posts can be represented as links, which are relationship type of data. Because of these reasons and based on the past work in the visualization of discussions that have used tree structures, in this thesis, I focus on different kinds of tree structures as the main solution for representing the structure of the discussion and exclude other data structures such as lists, graphs, and hashes. In this section, I review different methods of illustrating tree structure with respect to represent the structure of the discussions.

Because the tree is a useful data structure and has many applications, many research studies (e.g., Robertson, Mackinlay & Card, 1993; Johnson and Shneiderman, 1991; Lamping & Rao, 1994; 1996; Plaisant, Grosjean & Bederson, 2002) have examined the visualization of tree structures. In this section, after introducing the design goal of representing the structure of the discussion, I review some of the most well-known tree representation methods (including basic representation, cone tree, tree map, space tree, and hyperbolic tree), and their benefits and shortcomings for highlighting the structure of online discussions.

3.2.1. Design goals of representing the structure of the discussion

The goal of this chapter is to design an interface that prevents unproductive behaviour of new post bias. As described in the previous chapter, a possible solution to achieve this goal is to highlight the structure of the discussion via a visual representation. As described in this chapter, a tree structure is a suitable solution to represent the structure of the discussion. Linear text-based interfaces attract more attention to recent and new posts compared to the others, which may lead to reading only new and recent posts. Thus an important factor in designing or finding a tree representation to use is that the tree structure should reduce learners' attention to the recent and new posts. While representing the structure of the discussion may reduce new post bias, particular methods of representation may increase or decrease learners' attention to the recent and new posts because of their design features. Thus, among different methods of representing the structure of the

discussion, those that reduce this attention are potentially more helpful to reduce new post bias.

In the previous chapter, I reviewed the educational consequences of new post bias. While reading new posts is necessary to receive new shared information in an online discussion, reading only new posts (new post bias) is the problem. Thus reading (or at least skimming) the higher level posts (even if a student had read them in an earlier session) before reading their new children, would help the student to understand (or remember) the context of the discussion and connect the ideas in different posts. In this case, the student would read the new information with respect to all previous discussion about it. If a tree representation, in addition to highlighting the structure of the discussion, is also able to attract more attention to the higher level posts, it is more likely to reduce the new post bias. The next sections review different tree structures to find a suitable method to represent the structure of the discussion for this purpose.

3.2.2. Basic presentation of trees

Unlike trees in nature, in the virtual world trees usually grow upside down. The root is usually at the top and its children are in a lower level. Figure 3.3 represents an example of presentation of a tree. Node A is the root of the tree (e.g. a discussion prompt). Some research studies (e.g. Hara et al., 2000; Aviv et al. 2003) have used this presentation of the tree (with some modifications) to represent the reply structure of the discussion. These studies have used directed links (arrows) from the reply post to its parent post to represent the reply relation between two posts. These methods used different strategies to represent the posts as nodes. For example Hara et al. (2000) labelled the posts based on their creation order, while Aviv et al. (2003) labelled them based on their authors. Figure 3.4 illustrates a discussion represented by these techniques. Wise and Padmanabhan (2009) argue these representations of the discussion make its structure visible more than regular text-based representations.
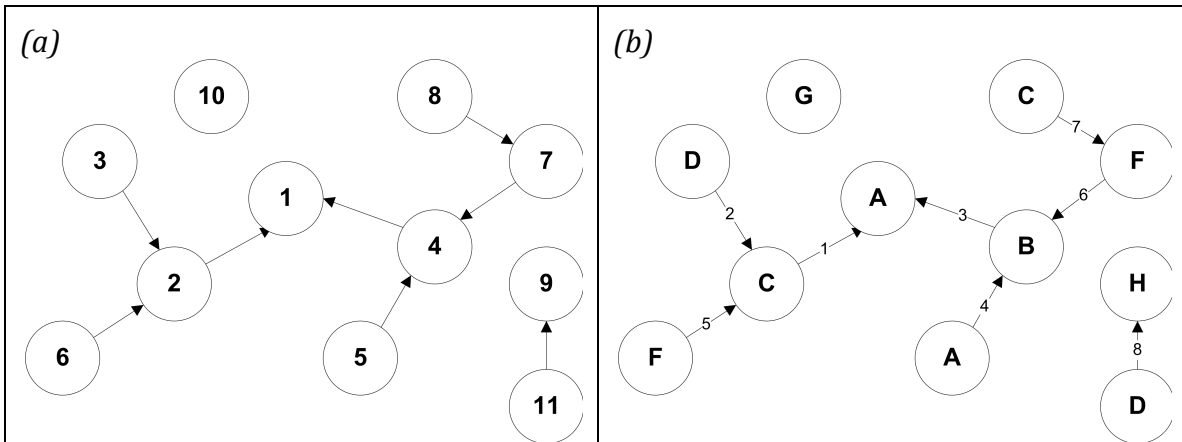
Figure 3.4. Representing the discussion by tree structure. Labeling nodes based on (a) creation sequence (b) authors (Wise & Padmanabhan, 2009, p. 4).
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Although this presentation of a tree is useful and clear for trees with a few number of nodes, presenting larger trees in this way (especially nodes with a higher number of children) is challenging. For example in Figure 3.3 the extension of node C has been blocked by node E. Most practical applications such as presenting discussion forums as trees usually include quite a few nodes. In these cases, representing the tree via basic representation would lead to a distorted tree representation. Based on the information visualization concepts, the representation method should make the solution transparent and easier to understand. In most cases, a distorted representation would not lead to such understanding. In addition, because basic representation of a tree the lower level nodes (i.e. lower level posts in a discussion) are at the bottom of the screen, similar to a linear list this might attract attention to these posts that may lead to new post bias. Unlike the basic presentation of tree illustrated in Figure 3.3, the techniques illustrated in Figure 3.4 do not necessarily present a tree vertically (root at the top and children in lower levels). While there is more flexibility in the location of nodes in these methods, students may have difficulties finding root or higher-level nodes.

3.2.3. Cone tree

To address presentation problems of trees in 2D space one solution is presenting tree nodes in a 3D space. This presentation is called a cone tree (Robertson, Mackinlay & Card, 1991). A cone tree is useful for presenting nodes with many children, which need a big horizontal space. Figure 3.5 illustrates a cone tree. However, Ware (2004) argues a 3D space may not be a good choice for representation of a tree. Using cone tree to represent discussion forums may lead to extra cognitive load for learners. Working with a 3D representation usually requires more complex interactions than the 2D representation (Ware, 2004). Furthermore, a tree can theoretically always be presented in a 2D space without any intersection of links. Because there is no record of evaluation of usability of cone trees (Spence, 2007), I cannot provide more evaluation details of this tree. However, because of the possibility of presenting trees in a 2D space, which is easier to work with compared to a 3D representation, in this thesis a suitable 2D tree representation for online discussions would be preferred to a 3D solution.
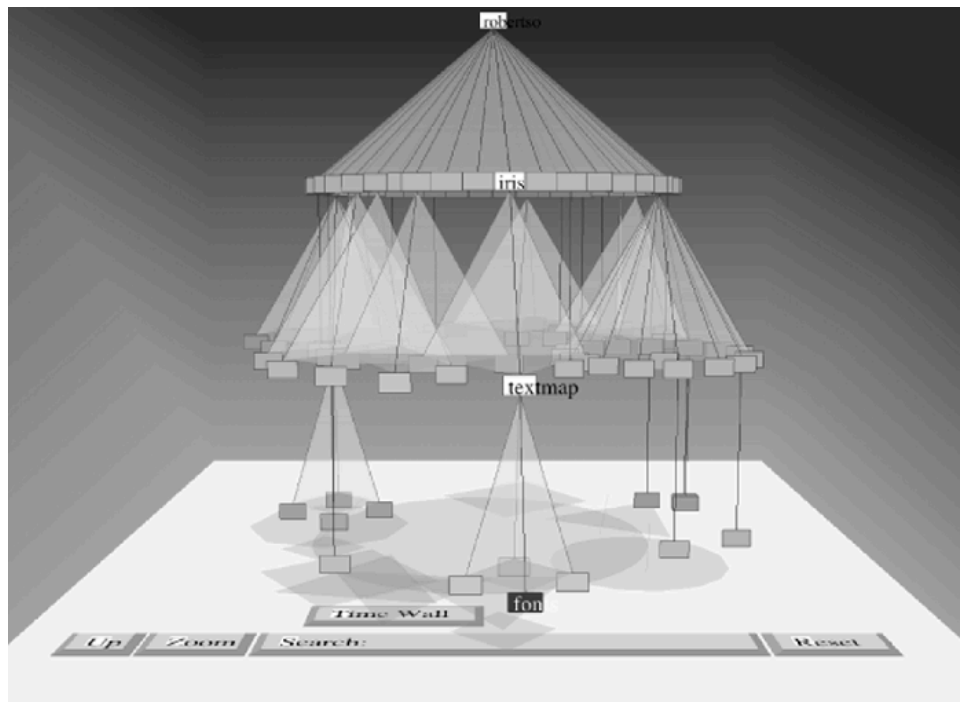
Figure 3.5. Presenting a tree using cone tree (based on Robertson et al. 1991).

3.2.4. Tree map

Another technique of representation of trees is the tree map (Johnson and Shneiderman, 1991). The basic concept of the tree map is representing nodes as rectangles and their children as smaller rectangles inside them. Figure 3.6 illustrates a sample tree map. The size of the rectangle can be related to an attribute of the nodes. Rectangles can also be colour coded. Tree maps are useful in many applications, such as presenting the file system structure. Folders and files inside them can be shown as rectangles based on their size. File types can also be shown in different colours.

However, in this representation end nodes are more visible than their parents. Therefore, representing the discussion via a tree map highlights the lower-level reply nodes, which in most cases have been created recently. For this reason the tree map may exacerbate new post bias by attracting more attention to the most recent posts. Thus a tree map is not a suitable method to present the structure of the discussion.
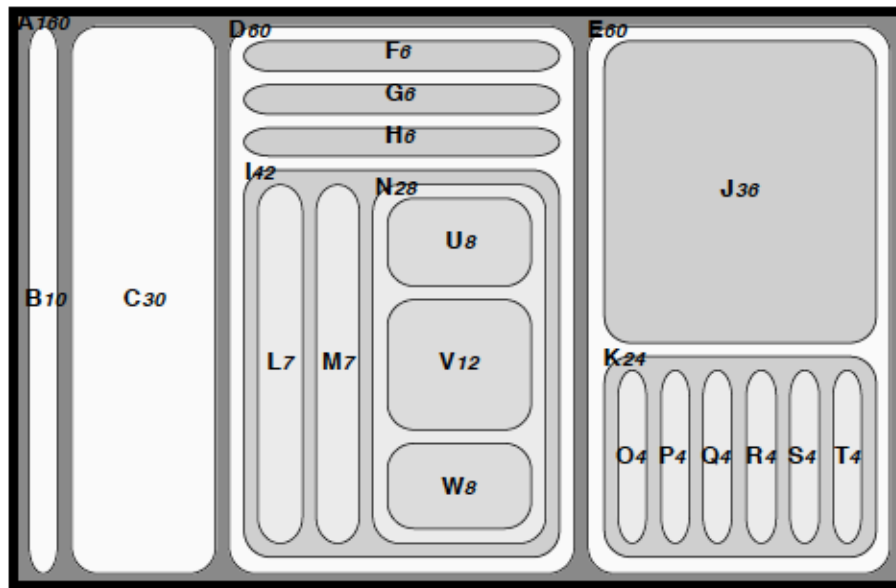
Figure 3.6. Presenting a tree using tree map (based on Johnson & Shneiderman, 1991).

3.2.5. Space tree

Another technique of presenting trees with many nodes is the space tree method (Plaisant et al., 2002). In contrast to showing all the nodes in the other techniques, the main idea of space tree is just showing a part of the tree that the user selects. This technique is particularly useful in representing trees with many posts that cannot be shown all at the same time on the screen. In the space tree, by selecting a node, this node and a few levels of its children will be shown, so the user can focus on a small proportion of the tree that being presented. Because other nodes are not being presented at the same time, there will be enough room for a clear and organized presentation of the selected part. By selecting another node, the previous selected part will be condensed and the new selected node will expand. Figure 3.7 illustrates a sample space tree. Children of the condensed nodes are represented by a small triangle. The shape of the triangle is an estimation of the structure of the hidden nodes. The depth and breadth of the triangle are related to the average number of reply levels and the average number of posts in each level. In addition, a darker triangle means a higher number of hidden posts.
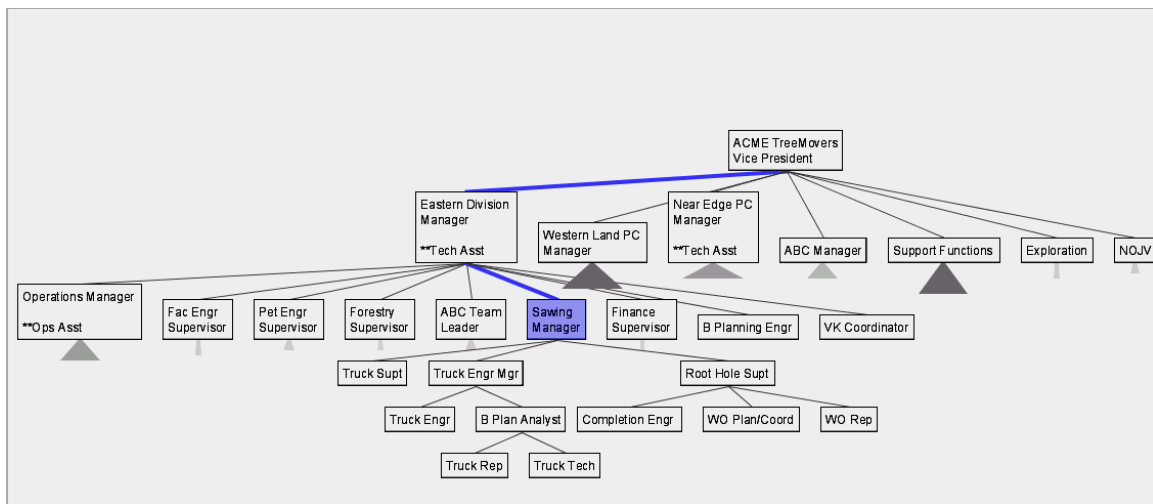
Figure 3.7. A sample space tree (Plaisant et al., 2002, p. 57).
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Although the representation of trees via space tree helps to focus on small proportion of the tree, the user loses insight about other parts. Thus, representing

the reply structure of the discussion via space tree may prevent the learners from gaining an overall idea about the discussion. Without having an overall idea about the structure of the discussion, selecting posts to read or reply to may become difficult for learners. They may focus on the visible part of the discussion, and not pay enough attention to the shared ideas in the hidden parts. In addition, nodes in each level are presented in a row. This representation of posts gives them an order and may have similar effects to linear text-based interfaces. For example, the first or last posts in the row may attract more attention than others. Thus, this representation of posts in rows may also exacerbate the new post bias.

3.2.6. Hyperbolic tree

A technique that keeps the entire tree with in a circular area is called hyperbolic tree, and is based on sophisticated mathematical calculations (Lamping & Rao, 1994; 1996). A hyperbolic tree is based on hyperbolic geometric transformation that can locate all nodes in a specific area. In this presentation the root is at the centre of the area and its children are located around it. The size of the nodes is based on their distance from the root node (the centre). Farther nodes from the centre are presented with a smaller size. In addition the distance between nodes decreases as they locate farther from the centre. Thus the representation of lower level posts is more condensed than the higher-level ones. This method helps to show all tree nodes on the screen at the same time by allocating different spaces to different levels of posts. Thus, while all nodes are represented on the screen, the node at the centre and its direct children may attract more attention. When selecting a node, the chosen node moves to the centre and the tree structure and nodes' sizes rearrange based on this selection. Thus the user can change the focus of the presentation of the tree. Figure 3.8 illustrates a sample hyperbolic tree.

Using a hyperbolic tree to represent the reply structure of the discussion can highlight this structure and may help learners avoid new post bias. By using this technique all nodes can be displayed on the screen at the same time but the discussion prompt and the higher level replies may attract more attention; they are

presented at the centre of the screen with bigger nodes. Thus, representing online discussion forum via a hyperbolic browser may reduce the new post bias.
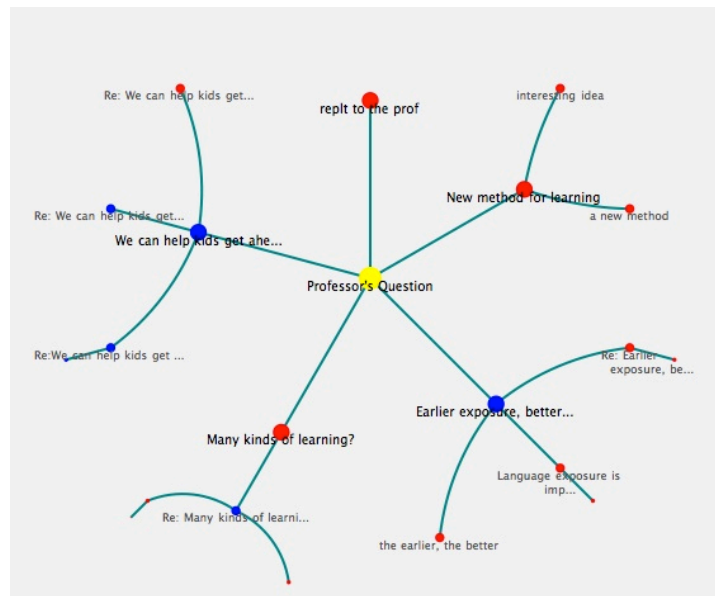
Figure 3.8. A sample tree in hyperbolic representation.

3.2.7. Design decisions on representing the structure of the discussion

Based on the design goals, among different solutions for representing the structure of the discussion, I believe that a hyperbolic tree may be most effective in reducing new post bias, compared to the other techniques. First of all, unlike some other methods (e.g., space tree), a hyperbolic tree shows all posts at the same time and helps students to develop an overall sense of the discussion. It also represents the structure of the discussion in a 2D space, which is easier for students to interact with than 3D representations such as a cone tree. Importantly, a hyperbolic tree more likely reduces users' attention to the lower-level posts compared to other methods such as a tree map.

In this thesis, for the purposes of design and implementation, I assume that all online discussions have one discussion prompt. The presentation method of the structure of the discussion with one specific prompt can be extended to other online

discussions with no or more than one discussion prompt by creating a pseudo-prompt post or presenting the online discussions with more than one tree.

A hyperbolic tree provides a unique way of representing different levels of posts in the discussion, which can help in reducing new post bias and lead students to read posts in their reply order from higher level posts to lower level ones. When a student visits the discussion forum that has been represented by a hyperbolic tree, the discussion prompt and its first level replies are presented by bigger nodes and more space has been allocated to them, while lower level posts are represented by smaller and closer nodes (see Figure 3.9-a). Thus the discussion prompt and higher level posts attract more attention and are more likely to be read by the students. As described in the design goals section, it is important that students read posts in their reply order to understand the discussion. In addition, higher level posts are more likely to contain broader central ideas and it is important that the learners read these posts before reading their replies. Thus in the hyperbolic tree, while the learner can see the structure of the discussion, he or she will not get initially distracted by lower level posts even if they are marked as new. This way of representing posts in discussion forums may prevent learners to read reply posts (including new posts) without reading their parent posts.

If the learner chooses to explore a branch of posts by selecting one, that post moves to the centre and its replies are presented as bigger nodes. In this way the selected post, its parent and replies are presented as bigger nodes and in the centre of the presentation (see Figure 3.9-b). Thus the learner can focus on a part of the discussion, while other parts are still visible. This representation of posts may lead learners to read more connected posts that would more likely result in obtaining more connected ideas compared to reading new but scattered posts.

However, in the hyperbolic tree by moving a post to the centre learners may lose a sense of the reply level of the posts, because the position of all posts would change, and posts would be rearranged based on the selected post in the centre. So while changing the position of posts on the screen creates the opportunity to focus
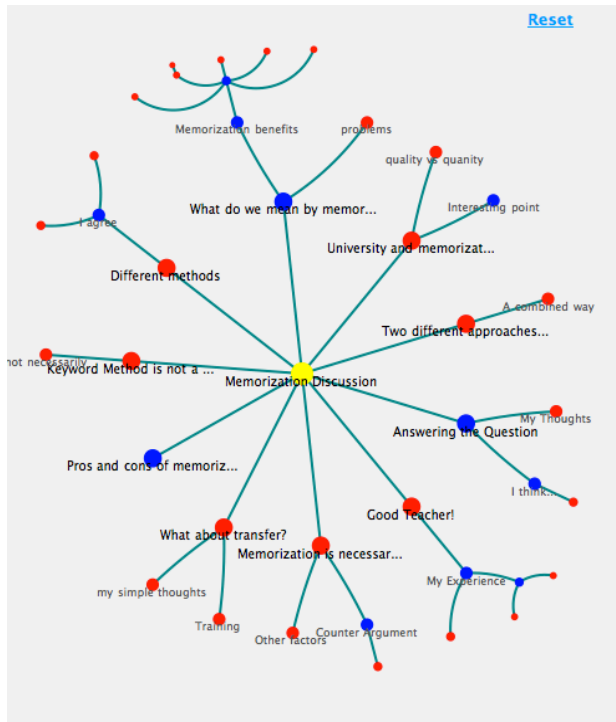
(a)
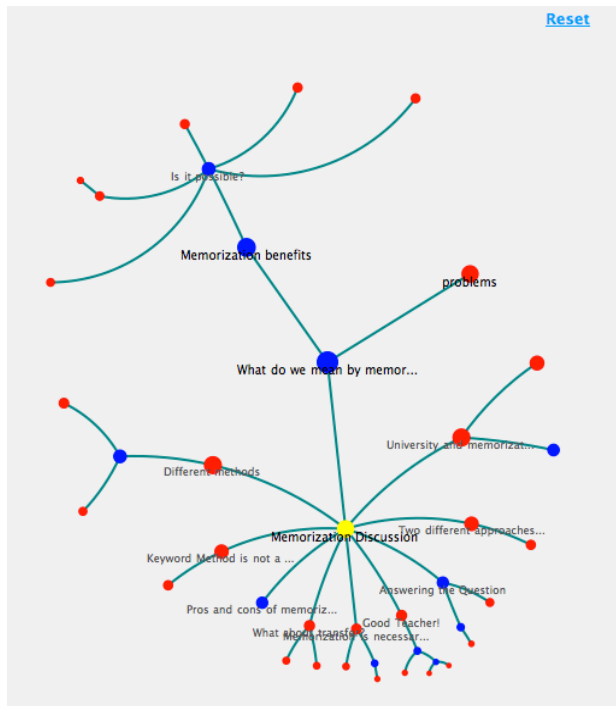
(b)

Figure 3.9. Presenting a discussion forum by a hyperbolic tree with (a) the initial discussion prompt post selected and (b) a particular reply that has been selected to read.

on the selected post and its connected posts, it might also have some negative effects. This trade-off is one the aspects that should be investigated through testing the designed interface. However, it is possible to illustrate the discussion prompt post in a different way that makes it easier to be found in the discussion. This will be described in detail in the next section, which describes different methods of illustrating posts with respect to the hyperbolic tree structure.

3.3. Different Methods of Illustrating Post Characteristics

As described at the beginning of this chapter, posts in the online discussion forums are entity data that we want to visualize. By selecting a tree structure to represent the discussion, posts are illustrated as nodes. Nodes have visual attributes that can be associated with posts' attributes. These visual attributes can be used to differentiate posts. In this section, after introducing design goals of illustrating different posts, I review some of the visual attributes that can be useful in illustrating different post characteristics in online discussion forums.

3.3.1. Design goals and limitations of illustrating posts characteristics

The selection of the hyperbolic tree to represent the structure of the discussion causes some challenges and limitations that should be addressed. The main goal in this chapter and in selecting hyperbolic tree is to reduce new post bias by highlighting the structure of the discussion and increasing students' attention to higher level posts (in the beginning of their visit to the discussion). While the goal is to reduce students' attention to new posts, these posts are also an important source of new information and students should be able to recognize and read them. Thus one of the design goals in this section is to find a method to differentiate between new and read posts in the discussion.

The new challenge, which is the result of representing the discussion with a hyperbolic tree, is that the structure of the discussion and the focus of the representation change with students' interactions with the interface. In other

words, the root node, which represents the discussion prompt and is usually used as the reference point of reply levels in the discussion, moves. Thus it is important that students be able to find the root node in the discussion easily. Thus representing the discussion prompt in a different way that can be easily distinguished is another goal of this section. One constraining factor is that a hyperbolic tree uses node size to represent the level of the nodes (i.e. reply level of posts in the discussion), thus this aspect of posts cannot be changed and may interact with any other design decisions that are made.

In summary, the design goals of illustrating posts in the tree structure are that students be able to find the discussion prompt post and differentiate between new and read posts. The next sections, introduce visual attributes that can be used to differentiate different posts in online discussion forums.

3.3.2. Information that pops out

There are some visual attributes that humans can perceive quickly. For example certain shapes or colours pop out without careful attention (Ware, 2004). The theoretical framework that explains pop-out is called pre-attentive processing, because it happens before conscious attention (Ware, 2004). Based on the human visual processing system described earlier in this chapter, most of these features are mainly processed in stage 1 and some in stage 2. Spence (2007) provides several examples of pre-attentive features. Differences in colour, shape, and size are examples of these features that may be useful in visualization of online discussion forums. Although it seems helpful to know which pre-attentive features are stronger, there is no single answer for this question. Because these features are usually used in conjunction, the answer is based on the specific design (Callaghan, 1989). Because of the importance of colour in the human visual system, I review it first and in particular detail.

3.3.3. Colour

Colour is one of the primary ways of detecting different objects. Detecting different colours happens in the parallel processing stage of the human visual

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system, which is fast and does not need attention. Ware (2004) provides a very simple example that shows the importance of colour vision in detecting different objects. Figure 3.10 illustrates some cherries and leaves in both black-white and colour pictures. As you can see, finding cherries among leaves is much easier and faster in the colour picture. Thus, in online discussion forums one way of differentiating posts is using colour.
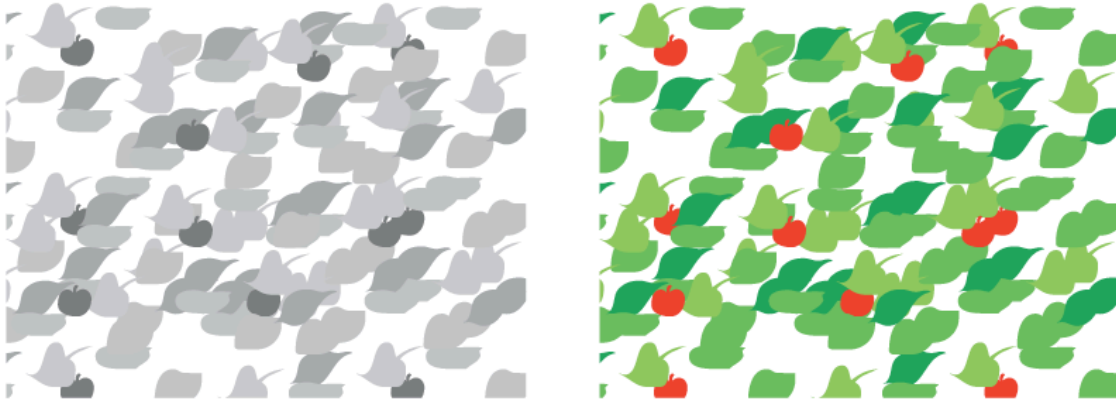
Figure 3.10. Finding the cherries among the leaves is much easier if we have colour vision (Ware, 2004, p. 98).
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One of the applications of colour is labelling. Labelling or nominal information coding does not need to have an order. Because colour perception is fast and easy, colour coding is an effective way to differentiate nominal data. The important task in using colour is selecting appropriate colours. Based on Opponent Process Theory (Hurvich, 1981) humans perceive colours via three different channels: the luminance channel for black and white, the red-green channel, and the yellow-blue channel. Ware (2004) suggests 12 different colours that can be used for labelling in visualizations. Figure 3.11 illustrates these colours on white and black backgrounds. These colours have enough different contrast with each other as well as both white and black backgrounds. Thus they can be perceived by humans relatively quickly and easily. Although colour coding is an effecting way to differentiate objects, the number of colours that can be perceived quickly is small. This number for different individuals varies between five and ten (Healey, 1996).

Figure 3.11. A set 12 colours that can be used in labelling in black and white backgrounds (Ware, 2004, p. 126).
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3.3.4. Shape and size

There are some other features that can be perceived quickly. One of them is shape. Different shapes are often easily and quickly distinguishable (Spence, 2007). Figure 3.12 illustrates an example of representing objects by different shapes. Perception of orientation of edges happens at the first stage of the visual processing system and is very fast. However, perception of shapes happens in the second processing stage. Colour often pops out more quickly than shape, although as described before, specific design features as well as the conjunction of different attributes can influence these perceptions.
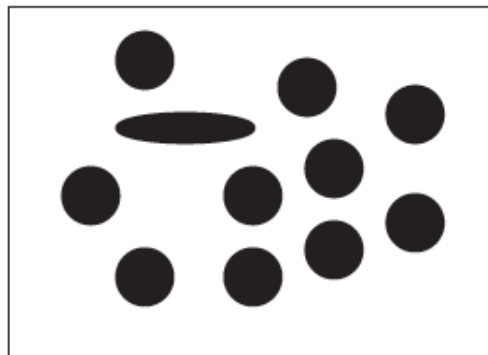
Figure 3.12. Different shapes can be easily detected (Ware, 2004, p. 153).
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Another way of distinguishing between different kinds of entities is based on their size (Spence, 2007). Figure 3.13 illustrates circles with different sizes. One

common use of size is to represent continuous quantitative data, for example representing the population of cities on a map. Perception of size happens in the second stage of the human visual processing system, and thus is not as fast as colour and shape. However, size can influence the perception of other attributes.
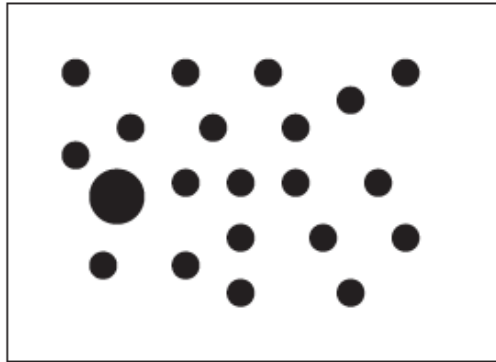
Figure 3.13. Circles with different sizes can be easily detected (Ware, 2004, p. 153).
© 2004, Elsevier, Reprinted with permission.

As mentioned earlier, different attributes can be used in conjunction; they also may affect each other. For example, changing the size of objects can make other factors (e.g. colour, shape) easier or more difficult to detect (Ware, 2004). While different colours or shapes may pop out easily (see Figure 3.10 and Figure 3.12), a combination of them might not work in that way (Spence, 2007). Figure 3.14 illustrates an example of using both colour and shape. The red circle cannot be detected quickly in this example. This example does not mean combining features is not useful, but it should be used appropriately and with consideration of other design decisions (e.g. in this thesis how to represent the structure of the discussion).
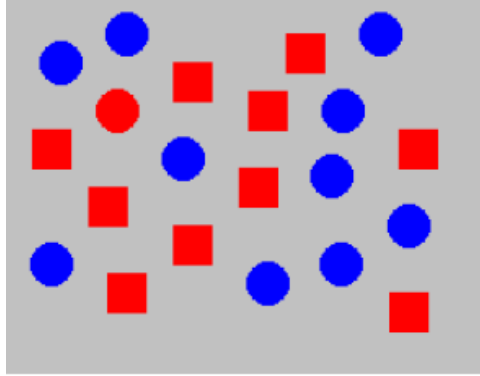
Figure 3.14. Combination of using colour and shape. Red circle does not pop out (adapted from Spence, 2007).

3.3.5. Design decisions on illustrating different posts

As described in the previous sections, a hyperbolic tree uses the size of nodes to represent the level of posts in the discussion. When a student enters the discussion the discussion prompt is at the centre of the screen and is represented by the biggest node; other higher-level posts (the posts closer to the discussion prompt) are also represented with a large size. So first reply level posts (which are important to be read before their replies) may attract more attention in the structure of the discussion.

In this structure, size is a necessary feature to illustrate the level of the post, and thus cannot be changed. Combining colour with size is a possible solution to represent different posts while not making them too salient to attract too much attention. Recognizing different colours is often very fast and does not require conscious attention; the different colour pops out. Thus, it might seem that using colour to differentiate read and unread posts attracts too much attention to the new posts, and may exacerbate new post bias problem. However, in this case, using colour must be combined with size, which can influence its perception. Size of a coloured area is also important in perception of colour. Larger coloured areas attract more attention than smaller ones. In a hyperbolic tree, posts are represented by different sizes. At the beginning, higher-level posts are represented by bigger nodes compared to lower level posts; thus they have a bigger coloured area and

attract more visual attention. This attention to the larger nodes may reduce learners' attention to the new posts. Thus while the learners can recognize new posts in the discussion, they may read higher-level posts before reading their new replies.

Another possible solution is using shape to differentiate between different posts in online discussion forums. However, with a hyperbolic structure, shape is not a useful option. Detecting differences in the shapes of small objects is difficult. Using shapes instead of colour for this purpose would make new posts in lower levels unrecognizable. Thus learners would not be able to see if any new posts (i.e. new information) have been added to the discussion.

In summary, because size can increase or decrease learners' attention to the other visual attributes, using colour with size may be a possible solution to differentiate posts, including the discussion prompt, as well as new and read posts. The next sections describes design and implementation details of the new visual forum, based on design decisions of representing structure of the discussion by hyperbolic tree and illustrating different posts by different colours.

3.4. The Design of the Visual Discussion Forum

Although the important design decisions from this thesis perspective have been made in the previous sections, in practice, designing a forum requires more than just general decisions on how to present the structure of the discussion and how to differentiate between posts. This section describes the other design decisions that have been made in order to design and implement the visual discussion forum.

Figure 3.15 illustrates the visual discussion forum that was developed. The screen has been divided into two main areas: the visual area, which represents the posts and their reply structure, and the content panel, which contains the posts' content and the reply form. Presenting the posts' content, the structure of the discussion, and the reply form in the same window allows the learners to read and

(a)

(b)

Figure 3.15. Visual discussion forum including the visual area and the content panel showing. (a) the initial discussion prompt post and (b) a reply that has been selected to read.

reply to the posts in the context of their connections to other posts. This may have benefits for the learners during reading a post when they try to understand its connection with the other posts at the same time. This may also improve learners' comprehension of the post content. Representing all components in the same window can avoid extra cognitive load and help the learners to concentrate on the post content. The next sections describe the visual area and the content panel in more details.

3.4.1. The visual area

In the visual area, a hyperbolic tree represents posts and their reply relations. As discussed in the previous chapters, different posts are illustrated by different colours, so the students can easily distinguish them. The colours used were chosen from 12 colours suggested by Ware (2004). Read posts are representing by blue nodes and new posts by red. In addition, the discussion prompt is represented by a yellow node. Finding the discussion prompt in the presentation of the discussion can help students to recognize which reply-level of the discussion they are reading.

Typical forum interfaces usually represent the post's subject, author and date. Unlike the text-based linear interfaces, which represent each post's information in one line, the space to represent posts information is limited in the visual area. Thus it is not possible to represent all of this information. Between the three post attributes, subject is the most important one to represent. First of all, a post's subject is the closest attribute (compared to author and date) related to its content and representing it may help students in selecting posts to open. In addition, some information like date and time the post has been created, may exacerbate the new post bias. Because of these reasons, only the post subject is displayed in the visual area (Other posts' information is presented in the content panel after clicking on a post). Long subjects (more than 25 characters) have been truncated to avoid text overlapping. Because lower-level posts are presented by smaller nodes and are closer to each other, displaying their subjects is practically not useful (readable).

Thus the subjects for only three levels of posts from the post in the centre are displayed at any time.

A reset link in the visual area resets the visual presentation of the discussion; by clicking on this link the discussion prompt moves to the centre of the visual area. Thus, if a learner, after reading lower level posts, decides to go back to the discussion prompt to explore other branches, he or she can easily go back to the top level of the discussion by clicking on the reset link.

3.4.2. The content panel

The content panel displays the selected post's content including subject, the date was the post is created, author, and the post's body text. It also has a reply section, so the student can make a reply to the post while he or she can also see the post's content and the structure of the discussion. The reply subject is empty (unlike some forums, which have a default for it) to encourage students to enter a more meaningful post subject. This can help other students to select posts to read based on their content rather than other factors like time/date and may help to reduce new post bias. In addition, in an attempt to encourage students to connect different ideas from different posts, the content of the reply box is maintained while reading different posts.

3.5. Implementation of the Visual Discussion Forum

To implement the visual discussion forum, different technologies including HTML, CSS, PHP, MySQL, JavaScript, and AJAX have been used. Figure 3.16 illustrates the visual forum technical infrastructure. The main page has been divided into two CSS divisions: the visual area and the content panel. In the visual area, the hyperbolic tree (hyperbolic geometric transformations) is implemented by JavaScript InfoVis Toolkit (Belmonte, 2011). The content panel area includes two parts: the post's content area and reply form. A MySQL database contains posts' content and information about which user has read which post.

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The hyperbolic tree visualization connects to the MySQL database (via a php module) to get the posts' information to load in the visual area. By clicking on each node, in addition to recalculating posts positions, the hyperbolic tree sends the selected post's information to both the content panel and the database. The AJAX technology enables browsers to change a part of the page (which has been defined as a CSS division) without reloading the whole page. Using this technology, the content panel changes and displays the selected post's information. By sending the selected post's information to the database, the selected post is flagged as read in the database and its related node colour will change from red (indicating a new post) to blue (indicating a read post). The content panel shares the post's information with the reply form. So if the user decides to make a reply to the post, the created post will be connected to its parent post. The reply form sends the created post's information to the database and the page reloads to display all posts including the recent created one.
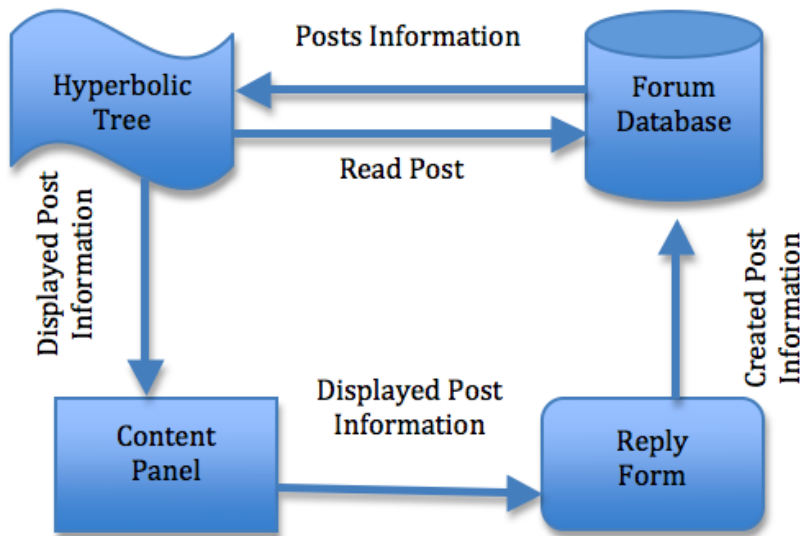
Figure 3.16. Visual discussion forum technical infrastructure

4. Methods

In the previous chapters, I reviewed prior research on both online discussion forums in education and information visualization techniques, and evaluated different methods of illustrating posts and presenting the structure of online discussions. Based on these reviews and evaluations, I designed and implemented a visual discussion forum in an attempt to prevent unproductive behaviours, such as the new post bias, and help students read more connected posts (rather than reading new but scattered ones). This design uses a hyperbolic tree to represent the structure of the discussion, and colour to illustrate different posts in the discussion. This section describes testing procedures for this visual discussion forum to investigate how students interact with this interface and how the interface influences students' behaviours interacting in an online discussion.

4.1. Methodology

4.1.1. Hybrid design

This being the first attempt to design a visual interface to encourage productive reading behaviours, the goal of the testing process is not only evaluating the interface by asking the learners to interact with it, but also to obtain their feedback to understand why they do what they do, and identify the benefits and weaknesses of the interface. Thus the learners' feedback during the interaction with the interface as well as their interactions with the interface are important to help understand how learners interact with the interface. For these reasons, it is

necessary at this stage to invite participants to interact with the interface in a lab space where their moment-to-moment feedback and interactions can be recorded. However, a traditional lab session, in which students interact with a researcher-created discussion, is not suitable for this study. A traditional lab experiment lacks ecological validity due to the lack of an authentic learning context. In a classroom, students build up the online discussion as a group on a topic that they study. They know other participants in the discussion. In contrast, in a pre-existing researcher created discussion, all names are pseudonyms, thus all authors are the same for the participant. In addition, the topic of the discussion is selected by the researcher and all posts are created by him/her. Thus, the discussion may not make sense to the students and they may lack incentives to do their best work.

Because the authenticity of students' interactions is critical for this study, and at the same time it is important to receive detailed feedback from participants, this study uses a hybrid method suggested by Forde (2008). In this hybrid method, students are asked to add to a previously archived online discussion in which they themselves had participated for a course. Thus, while the participation occurs in a lab setting and the researcher is able to monitor student's activity, they participate in a discussion that they have been a part of. Thus they are familiar with the topic of the discussion, the posts and the other participants.

4.1.2. Comparison reference point

In this study, to use the described hybrid method and create the closest scenario to a natural setting possible in a lab session, the researcher obtained permission from an instructor to use a prior online discussion that had been a part of a graduate course. An online discussion from the course, which had previously been created by students, was selected for use in the lab study and was represented through the newly designed visual interface. Students from the course were invited to participate in this study, and were asked to interact with the content of the selected discussion that they had previously been a part of via the new visual interface. Each participant visited the same discussion that had participated in for

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the previous course – the only difference was the interface through which the discussion was presented.

These conditions facilitated a comparison of participants' reading and replying behaviour in the visual forum with that in the text-based forum originally used in the course. Since they were participating in a discussion that they had taken part in for a course assignment in the past (instead of a researcher-created one), it was expected that participants were more likely to behave as they would for a class assignment. However, this choice also limited the number of possible participants for the study to the prior students in a single course.

4.1.3. Micro-analytic case studies

In this thesis, I construct a series of micro-analytic case studies as described by Wise, Perera, Hsiao, Speer and Marbouti (2012) of how students interact with a discussion via the visual interface. This method uses temporal log-file data to understand and characterize students' behaviours in online discussion forums. For each case, data collected from the visual interface and existing data from prior participation in the course online discussion (via a linear text-based interface) were analyzed and compared to investigate how the visual interface influenced students' behaviours in the online discussion. Analysing students' interactions with the interface in detail, as well as their feedback on the user experience, helped to understand the usability, benefits and weaknesses of the visual interface, and build a deeper understanding of how students interact with it.

4.2. Selection of Course And Discussion

After deciding on the methodology of the study, a course with an online discussion component needed to be selected. In addition, the course needed to be old enough that students could not recall the content of the posts without reading them. At the same time that students needed to remember that they had created the discussion, they should not remember the specific content of posts. For this

purpose, a past offering of EDUC 899 (a pseudonym) from two years ago was selected.

EDUC 899 was a blended introductory graduate course on educational technology in which students met once a week in person and participated in online weekly discussions beforehand. Students participated in ten weeks of online discussions (weeks two to eleven) during a 13-week semester. The online discussions revolved around the assigned weekly readings for the course. Students were asked to write a "short written reaction" (approximately 200 words) to the weekly readings, such as their reasons for agreeing or disagreeing with the position taken in the reading, their related experiences, or a discussion about something exciting, confusing, or frustrating in the reading. Students were requested to make at least one post each week, with the exception of one or two weeks, if the reading did not connect to the students' interests. Thus there was no penalty for not posting in one or two weeks. Contributions to the online discussion were evaluated by a portfolio that students' created using their posts, worth 30% of the course grade.

After getting permission from the course instructor, all weekly discussions were reviewed to select one to be used in the visual discussion forum. A preferable discussion for the purpose of this thesis was a discussion with several branches (sub-threads) of different lengths. This would allow the students a chance to see different kinds of threads via the new interface and decide whether or not to read and reply to them. This would help to evaluate the benefits and weaknesses of the new interface in the presentation of different threads. It was also preferred to select a typical discussion week in the course in terms of length (not unusually short or unusually long), and one that was not at the beginning or the end of the semester.

After reviewing all ten of the online discussions in the EDUC 899, the discussion week "Re-mediating Knowledge at University" was selected. This week was selected because it met the criteria described above. It was a typical discussion in terms of length, and it was almost in the middle of the semester (week 7). This discussion also contained several threads with a varying number of posts. Some threads were well developed (several levels of replies) and some threads were short

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(one or two posts).

4.3. Participants

Participants were seven out of 15 masters students who enrolled in the 2009 offering of EDUC 899. Students were invited via email to participate in the study. During their original participation in the course, all of the participants were in their first semester of a Masters program in Education. This study took place almost two years later, when six of the participants were at the end of the program, and one of them had recently graduated. English was the first language of three of the participants. The other four were fluent in English, as they had passed university entrance language requirement to enroll in the program. Four of the participants were female, and three of them were male.

4.4. Task design

The goal of this study was to investigate how students interact with discussions via the new visual interface, and how the interface influenced students' behaviours in order to prevent unproductive behaviours such as the new post bias. In order to accomplish this, students were asked to participate in the online discussion via the visual interface in two separate sessions. When students interacted with the interface for the first time, all posts were new, thus they could only read new posts. Students' tendency to read only new posts when others are also available could only be investigated after the first session by having them engage in a second session, when they already had read posts during the previous session. Students' participation in the two sessions was separated by a short break, in which they were asked to engage in a task unrelated to the discussion in an attempt to distract them from the discussion and flush the contents of short-term memory. In this way, the second session would be "new" to them.

The researcher asked students to do the same tasks that they were expected to do when they participated in the original course discussion. After reminding them about the EDUC 899 online discussion participation guidelines (described earlier), they were asked to read (or at least skim) a two-page summary of the selected week's reading. To simulate their participation into two sessions, they were asked to (1) participate in the discussion by reading some posts (making a post was optional), (2) do an unrelated task (read a daily newspaper) and (3) participate in the discussion again, this time by reading some posts and making at least one new post of their own (if they did not create any in the previous session). The first session was designed to occur almost in the middle of the original discussion week: 24 posts (out of 39) in 9 threads were displayed to the participants. In the second session, which was designed to be at the end of the discussion week, all 39 posts were displayed to the participants. In this session, one thread and 15 posts were added to the discussion. Thus the visual location of threads was slightly changed on the screen. Figure 4.1 illustrates the discussion structure for the first and second sessions in the visual interface. In the second session the participants had the choice to select new posts to read and/or posts that they had already read in the first session.
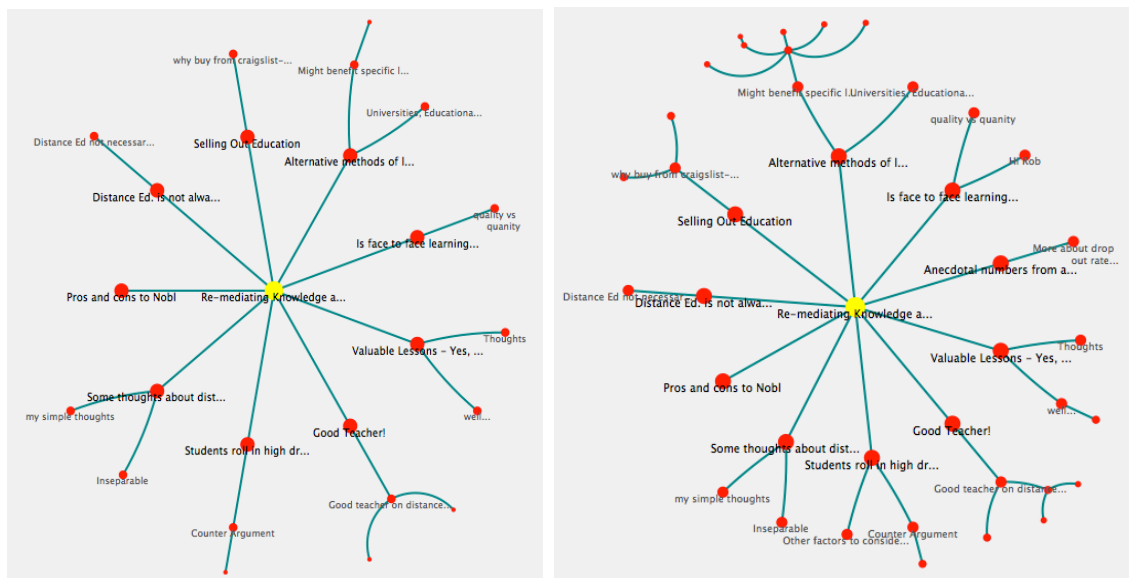
(a) *(b)*

Figure 4.1. The discussion structure used for this study. (a) discussion structure in the first session, (b) discussion structure in the second session.

4.5. Data Collection

4.5.1. Primary Data

There were three primary sources of data for this study:

1. *Clickstream data and screen capturing:* While participants were interacting with the interface, a screen capturing program recorded the content of the screen, including users' interactions with the interface. Participants' clickstream data was also recorded during their interaction with the interface. Clickstream data is a detailed log of all actions that each user takes during interacting with the interface. For each action the clickstream contains time and date of the action, type of the action (e.g. read or post), plus the subject, author, length and content of the post read or posted.

2. *Think-aloud:* Participants were asked to use a think-aloud procedure to describe what they were doing while they were interacting with the interface. They were asked to explain their decisions with regard to why they were opening, reading, or replying to a post. Each participant's voice was recorded. Think-aloud data were used in the analysis to contextualize the decisions that students made in navigating the visual interface.

3. *Survey:* At the end of each lab session, participants were asked to fill in a short survey about their experience. This survey was the System Usability Scale (Brooke, 1996) that was customized for online discussion forums. The survey included ten 6-point likert-style questions on the usability of the interface, and three open-ended questions about the features and usage of the interface. The survey data helped to examine usability of the visual interface, its weaknesses and strengths. See Appendix A for the survey questions.

4.5.2. Additional data

The tool students used for the discussions in the original 2009 course was Knowledge Forum (Scardamalia, 2004) with a standard text-based interface. The system automatically logged all students' interactions with the system. Figure 4.2

illustrates the selected week in this forum. After obtaining each participant's consent, the course instructor extracted the participants' clickstream data from the selected week during their participation in the original 2009 course.

4.6. Procedure

At the beginning of the lab session, participants were asked to read and sign a research consent form (see Appendix B). Then the researcher explained the visual interface features, and how to read and reply to posts. After answering their questions, if any, about the visual interface, the researcher introduced students to the task. They were reminded about the EDUC 899 guidelines for participation in the online discussion. In that course, students were asked to write a "short written reaction" to the weekly readings, such as their reasons for agreeing or disagreeing with the reading, their explanations, their related experience, or a discussion about something exciting, confusing, etc. They were requested to make at least one post each week (with some exceptions as described earlier). A two-page summary of the selected week's reading (the topic for the discussion) as well as the course textbook were provided to the participants. Then they were asked to participate in the discussion in two sessions as described earlier. An exact timeline was not mandated for the session lengths, but after about 15 minutes in the first session and 25 minutes the in the second session the researcher gently reminded the participants that finishing their tasks in a few minutes would leave them enough time for the tasks to follow. There was a 10-minute break between sessions, during which participants were asked to carry out an unrelated activity (e.g. read a newspaper or chat with the researcher about a topic unrelated to this study) to "wash" the contents of short-term memory. Finally, participants were asked to fill out an online survey about their experience with the interface. Each participant's entire participation in the study took no more than 75 minutes.
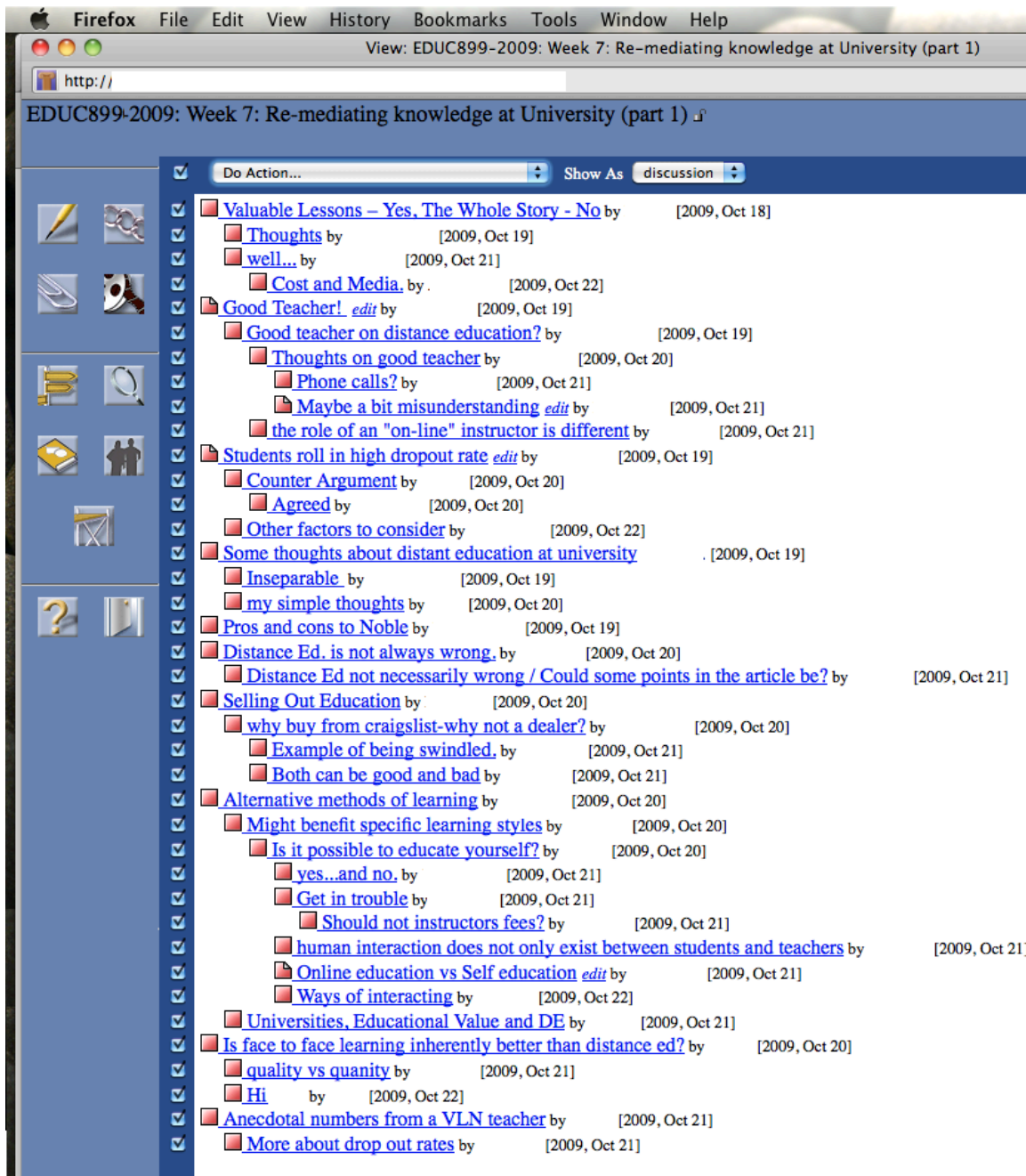
Figure 4.2. "Re-mediating knowledge at University" discussion in the text-based forum, 2009 offering of EDUC 899. Student usernames have been removed for anonymity.

4.7. Data Analysis

4.7.1. Processing of clickstream data

The goal the first step of data analysis was to provide an action-by-action list of each student's activity in both forums, containing the action type, action duration, session number, post's subject, post's author and post's length (number of words).

For the visual forum, after extracting participants' clickstream data from the visual forum database, session number and duration were calculated for each action a participant performed. Session number (one or two) was assigned to each action based on whether the action occurred before or after the 10-minute break in the lab session. The duration of each action was calculated by subtracting the timestamps of the consecutive actions. For the last action in each session, the duration was measured based on the screen capture data.

For the students' clickstream data from their prior participation in the discussion (which was extracted from the linear text-based forum), session number and duration of action were also calculated. However, because the forum had no official logout and no other data (e.g. predetermined sessions, think aloud or screen capturing data) was available, the researcher made the following adjustments to divide actions into sessions and calculate the duration of the last action in each session. First, the duration of each action was initially calculated by subtracting two consecutive times. For actions more than 60 minutes' duration it was assumed that the student had left the discussion. This was marked as the end of a session. This threshold was suggested by Wise, Speer, Marbouti, and Hsiao (in press) in studying students' behaviours in online discussion forums. In this study, 89% of students' actions and 97% of posting actions were shorter than 60 minutes. Because posting actions are expected to be longer (compared to other types of actions) and the number of actions above this point decreased drastically, Wise et al. (in press) chose 60 minutes as their cut off time. To calculate the duration of the last action in a session, the average time for that type of action (e.g. reading or posting action) was calculated and used as the action duration. Only in one case was there not enough

data to calculate an average for a posting action at the end of a session (this case will be described in the results section).

For both clickstream data from the visual interface and the text-based interface, actions were labelled as one the following types:

- Read: Opening others' post
- Post: Making a post. If the post was a reply, this action also included reading the parent post
- Review: Reading one's own post
- Edit: Editing an existing post, which also included reading one's own post.

4.7.2. Selection of sessions from the text-based forum

To evaluate the influence of the visual interface on the students reading patterns (including how they interact with the new posts), it was important to find the sessions in the two interfaces that were comparable to each other. At a student's first session in the original discussion all posts were new to them, (compared to other sessions in which only some posts were marked as new) and this might influence students' reading patterns. Thus the first session of students' participation in the visual forum was compared to the first session of the text-based forum. In one case, because the first session in the text-based forum had only one posting action and no reads, the second session was selected.

In the second session of the visual forum all posts were shown to the participants. Thus the second session of the visual forum was compared to the last session of the text-based forum in which the most number of posts were available for the student. However, in two cases the last session in the text-based forum did not include more than one reading action, thus the last session with multiple reading actions was selected as the last session.

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4.7.3. Calculating summary variables

For each participant, summary variables of overall activity, as well as for each session, were calculated for both forums they participated in.

- *Total time:* Total time spent in the system (for the focal discussion).
- *Reading time:* Time spent reading others' posts.
- *Number of unique posts read:* Total number of others' posts opened at least once.
- *Percentage of unique posts read*: Number of unique posts read, divided by total number of available posts in the session.
- *Average time reading a post*: Reading time divided by number of unique posts read.
- *Number of posts made:* Total number of posts made (including original posts and replies).

The following additional variables were also calculated for each user's last session in each forum:

- *Time rereading posts:* Time spent reading posts that had been also opened in the previous session.
- *Number of reread posts:* Number of posts opened in the last session, which also had been opened in the previous sessions at least once.
- *Time reading new posts:* Time spent only on reading new posts during the last session.
- *Number of new posts read:* Number of new posts opened during the last session.

4.7.4. Creating activity sequence diagrams

For each participant, two diagrams were created based on his or her clickstream data in the visual interface to illustrate activity in each session. To show the location and order of actions, each action was labelled as a number on the visual discussion structure. Actions were also labelled based on their type (read, post, or review). Finally the numbers were colour coded to help differentiate the chain of

actions; each time the participant visited the discussion prompt, the colour of the numbers was changed to differentiate the chain of actions.

For each participant, based on his/her clickstream data in the text-based forum, two tables were created to illustrate his/her activity in the two selected sessions. Each table was a discussion map that illustrated the discussion structure at the specific date/time the students had visited the discussion. For each session, actions were labelled as numbers. Actions were also labelled based on their type (read, post, review, or edit). For the second session, an additional column showed whether a post was created by the student in a previous session and if the student had already read the post or not (in a previous session). This column helps to understand students' reading patterns that were based on reading new or self-posts.

4.7.5. Framing the cases

For each student, the overall behaviour and reading patterns in the visual forum in both sessions were characterized and reported based on the calculated variables and activity sequence diagrams (supported by the think-aloud data). For students' past participation in the text-based forum, their overall behaviour and reading patterns were also characterized and reported based on the calculated variables and the activity sequence diagrams. At the end of each case and after reporting overall data and also reading patterns for both forums, students' activity in the visual and text-based forums were compared, to understand how the visual interface influenced students' behaviours in online discussion.

5. Results

The seven students who participated in this study will be referred to as Emily, David, Mike, Nicole, Steve, Amanda, and Christine (all names used are pseudonyms, but are gender correct). At the beginning of the chapter, survey results for all students are reported. Then for each student, interaction results are reported in three main sections. In the first section the student's activity in the visual forum is characterized and reported. This section includes an overview of his/her activity as well as a description of the student's reading patterns in both the first and second sessions. The second section for each student characterizes and reports the student's previous activity in the linear text-based forum. This section includes an overview of the student's activity in the selected discussion week, as well as a description of his/her reading patterns only in the two selected sessions (the first and last sessions, as described in the methods section). At the end of each case, a third section compares the student's reading patterns in the visual and text-based forum interfaces.

5.1. Survey Results

5.1.1. System Usability Scale

Table 5.1 summarizes participants' answers to the 10 likert-scale style questions of System Usability Scale. According to these survey results, all participants agreed that they would like to use the tool for a course. All participants found the reading and replying functions well-integrated, and everyone felt

confident using the forum. No one found the forum unnecessarily complex or felt that they needed to learn a lot of things before working with the forum. In addition, overall students found the visual forum easy to use and easy to learn. The next sections describe students' answers to the 3 open-ended survey questions.

5.1.2. What were the most useful features of this discussion forum? Why?

In answering this question, students mentioned three main factors:

1. Visual design and layout

All participants mentioned visual design and layout as one of the most useful features of the visual interface. The following quotes describe some of benefits of the visual design pointed out by participants:

Emily: "I liked being able to see quickly what threads had the most posts/activity … I imagine that when used in the classroom it would have helped link together some of those posts that were very similar, but divided into separate threads."

Mike: "The visual interface made it more intriguing to read others' posts and to be able to see how one's ideas created responses and discussions amongst the other students. Not having a linear forum forced me to read more posts and to see how opinions were formulated."

David: "Simple visual design and layout made it easy to visualize where the threads are."

2. Integrated read and reply box

Emily liked the fact that the replying function was integrated in the reading box.

3. Reset button

Amanda believed "the reset button is very useful and handy".

Table 5.1. Students' answers to the survey likert-scale style questions.

	Average	Strongly Disagree (1)	Somewhat Disagree (2)	Slightly Disagree (3)	Slightly Agree (4)	Somewhat Agree (5)	Strongly Agree (6)
I would like to use this discussion forum if I had a course with online discussion	Somewhat Agree (4.7)				4	1	2
I found this discussion forum unnecessarily complex	Somewhat Disagree (2.1)	1	4	2			
I thought this discussion forum was easy to use	Slightly Agree (4.3)			3	1	1	2
I think that I would need assistance to be able to use this discussion forum	Somewhat Disagree (2.4)	3	1	1	1	1	
I found the reading and replying functions in this discussion forum were well-integrated	Somewhat Agree (5.3)				1	3	3
I thought there was too much inconsistency in this discussion forum	Somewhat Disagree (1.9)	4	1	1	1		
I would imagine that most people would learn to use this discussion forum quickly	Somewhat Agree (4.9)		1		1	2	3
I found this discussion forum cumbersome/awkward to use	Somewhat Disagree (2.4)	3		2	2		
I felt confident using this discussion forum	Somewhat Agree (5.1)				2	2	3
I needed to learn a lot of things before I could get going with this discussion forum	Somewhat Disagree (1.9)	4		3			

5.1.3. What were the downsides of using this discussion forum? Why?

Students' answer to this question fell into three main categories:

1. Movements

Each time participants clicked on a post, the hyperbolic tree repositioned the nodes (with a smooth animation) to move the selected node to the centre of the screen and adjust other posts' position. Emily found that these movements were time-consuming. Christine, Nicole and Mike mentioned that because of the movements, it was difficult to find a specific post that they had read before.

2. Posts' Subject

Christine and Steve preferred to see the whole posts' subject (as in the text-based interface) rather than a part of it (as in the hyperbolic tree). Steve also pointed out that the subject of the lower-level posts are either not shown, or are difficult to read.

3. Authors' name

Nicole, Steve, and David mentioned that not displaying the authors' name was one of the main downsides of the visual forum.

5.1.4. How, if at all, did you find your use of this discussion forum different from your original interactions in the EDUC 899 discussion tool?

Answers to this question were different for each participant. Some students mentioned benefits of the interface from their perspective while others mentioned shortcomings. Thus in this section I report each participants' answer separately.

Emily: "I missed seeing the author's name when opening the posts. I use that information a lot when deciding which posts to open first/at all."

David: "Straightforward, short learning curve, easy to use."

Mike: "Well, I read more. I was more inclined to see how mine and others' posts lead to new ideas and clarifications. This system allowed

me to understand how my thoughts were related to others, which made me more interested in the original material."

Nicole: "Yes. I was following the sequence of the posts before but now I was more focusing on reading the threads that appears below the screen. My interactions are different."

Steve: "I like the 899 interface more because of the above mentioned reasons. Also like better the 'linear' approach of KF which in a way resembles the ToC of a book/paper."

Amanda: "It is more vivid to me, because every time when you click a node, there is a movement, it is like when your mind moves to that post, the interface will also make the that post in the centre of the screen. The mind movement and the interface movement matches."

Christine: "Yes, I found it different, and it is a new idea of the interface. It is very eye-catching and makes the forum more interesting. I may have more words to say than I used the old forum, but in terms of the functions, I prefer the old one, more clear and user friendly. This may be the downside need to be improved."

5.1.5. Summary of survey results

In summary, all students showed interest in using the visual forum for a course and no one thought it was unnecessarily complex. They also found the forum easy to use and easy to learn. In the students' opinion visual design of the interface as well as the reading and replying functions were its best features. Having difficulty in finding a post, not showing the author's name and complete posts' subject were perceived as the main downsides of the visual forum interface.

The following sections report what students actually did during their interaction with the visual interface. As described earlier, for each student his/her reading behaviours in the visual forum as well as past participation in the linear text-based forum in the selected week have been reported and compared to each

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other to understand how the visual interface influences students' reading behaviours.

5.2. Emily

5.2.1. Emily's activity in the Visual Forum

Overview

Emily spent a total of 33 minutes in the visual forum in her two sessions (see Table 5.2). In her participation in this discussion, she opened 29 posts (74% of the 39 posts available) in 23 minutes, and made three posts. In the first session, Emily opened 12 different posts in 6 threads (50% of 24 available posts in 9 threads). In the second session, Emily opened 21 different posts in 6 threads (54% of 39 available posts in 10 threads). Four of the posts she opened were ones she had opened before, and 17 were new posts. Although Emily opened more posts in the second session, on average she spent more time reading each post in the first session.

Table 5.2. Overview of Emily's activity in the visual and linear text-based forum in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:33	0:18	0:15	0:18	0:18	---
Reading Time(h:mm)	0:23	0:13	0:11	0:13	0:11	---
# of unique posts read	29	17	12	17	21	---
% of unique posts read	74%	44%	50%	74%	54%	---
Average time reading a post (m:ss)	0:48	0:46	0:55	0:46	0:34	---
# of posts made	3	1	1	1	2	---
Time of rereading posts (h:mm)	---	---	---	---	0:02	---
# reread posts	---	---	---	---	4	---
Time of reading new posts (h:mm)	---	---	---	---	0:09	---
# of reading new posts	---	---	---	---	17	---

Reading patterns

Session One

Figure 5.1(a) illustrates the sequence of Emily's activity in the first session in the visual forum. Emily's reading activity in the first session was spread among 6 threads (in different locations on the screen). For 3 of these 6 threads, she read all posts in the thread. In this session, she generally read posts in a radial pattern: reading a post, then the replies to it in sequence (e.g. actions 6-9, 12-15). Emily never read a post without reading its parent's post first. However, in some cases she did not read all posts in the thread (e.g. actions 12-15, 16-17). In addition, in a few cases (e.g. actions 4, 10), Emily reread a post after reading its reply, or an adjacent post. An example of her radial reading pattern can be seen in actions 6 to 9. In this case, she first quickly read a reply to the discussion prompt (action 6, a first level reply), then its reply (action 7, a second level reply). After reading this second level reply post, she read its two replies (actions 8, 9). After reading the whole thread, she chose where to add a post, went back to one of the posts she read before (action 10, an example of rereading a post) and created a post (action 11P).

Session Two

Figure 5.1(b) illustrates the sequence of Emily's activity in the second session in the visual forum. In the second session, she visited 6 threads and read all posts in 4 of them. Emily's reading pattern in the second session showed a radial pattern similar to that of the first session. Again she sometimes engaged in a complete radial pattern by reading all the posts in a thread (e.g. actions 20-22) and sometimes an incomplete one by leaving a thread without reading all of its posts (e.g. action 2). An example of Emily's complete radial pattern can be seen in actions 24 to 27, when she first read a reply to the discussion prompt (action 24), then she quickly read replies in that thread in order (actions 25-27, from higher level replies to lower level ones). Finally, she made a post after reading all posts in the thread (action 28P). Similar to her first session, in a few cases, she read a post more than once (e.g. actions 6, 15). She also read some posts that she had read in the first session. In reading one of the

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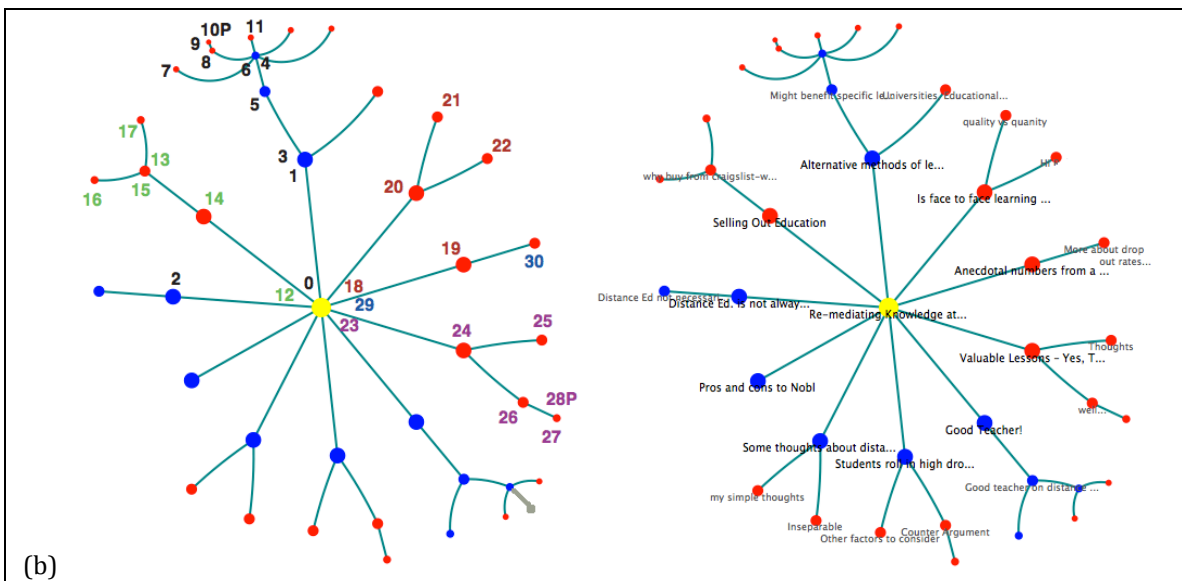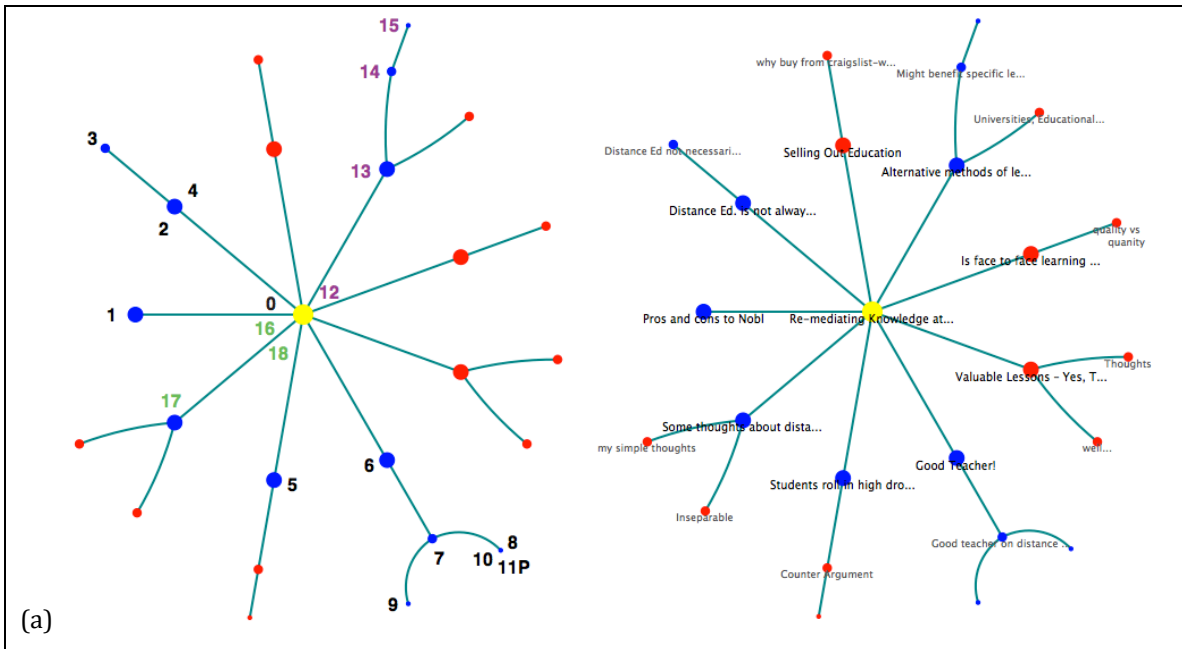
Figure 5.1. The images illustrate Emily's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of her actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

threads, she first read the posts she had read before (actions 3-5) then she read their new replies.

At the beginning of the session, Emily clicked back and forth between two threads (actions 1-3). Based on think aloud data recorded during the activity, this was because she was searching for a thread she had read in the first session. As described in the methods section, in the second session a thread and a number of posts were added to the discussion, making the visual location of threads as well as posts not exactly the same as the first session (compare Figure 5.1 a and b). This change in the location of the threads and posts caused some confusion for Emily as she tried to locate the post she was looking for.

In summary, Emily's reading pattern in the visual forum can be characterized mostly as a radial pattern. She read posts in the threads from higher-level to lower level ones. However, in some cases she did not complete the radial pattern by reading all posts in the thread. In addition, she purposefully reread some of the posts that she had read in the previous session.

5.2.2. Emily's previous activity in the linear text-based forum

Overview

In the designated week of the text-based forum, Emily had only one session lasting 18 minutes (see Table 5.2). In her participation in this discussion, she opened 17 posts (74% of available posts in the first session and 44% of all 39 posts in the discussion) in 8 threads in 13 minutes and made one post. In this week, she never read a post more than once.

Reading Patterns

Table 5.3 shows the structure of the discussion at the time Emily visited the discussion forum and the sequence of her activity in the linear text-based forum for this week. Emily entered the discussion for her only session in the middle of the week. In general, Emily read posts in threads in a linear order from top to bottom. She read all posts in the first three threads in that order (actions 1-10). She made

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her post almost at the middle of the session (action 7P) after reading the first two threads. She also visited threads from middle and bottom of the list to read posts (actions 12-13, 14-15). In one case she read the first and last posts in the threads without reading the middle ones (actions 16-17). Unlike her linear pattern at the beginning of the session (actions 1-11), the rest of her actions (actions 12-18) do not show a clear pattern based on the structure of the discussion. It is unclear if she decided to open the posts based on the subject, author or some other factors.

Table 5.3. Emily's sequence of activity in the linear text-based forum
Actions with no letter are reading actions
P represents a posting action.

Order	Post Subject			
1	Valuable Lessons - Yes, The Whole Story - No			
2		Thoughts		
3		well...		
4	Good Teacher!			
5		Good teacher on distance education?		
6, 7P			Thoughts on good teacher	
8	Students roll in high dropout rate			
9		Counter Argument		
10			Agreed	
11	Some thoughts about distant education at university			
		Inseparable		
		my simple thoughts		
	Pros and cons to Noble			
18	Distance Ed. is not always wrong.			
12	Selling Out Education			
13		why buy from craigslist-why not a dealer?		
16	Alternative methods of learning			
		Might benefit specific learning style		
			Is it possible to educate yourself?	
17				yes...and no.
	Is face to face learning inherently better than distance ed?			
14	Anecdotal numbers from a VLN teacher			
15		More about drop out rates		

5.2.3. Comparing Emily's activity in the visual and linear text-based forums

Comparability of sessions

Emily had only one session and spent less time in the text-based forum during the course, compared to the lab session using the visual forum. Because in the first lab session all posts were new and a similar number of posts were available, it is most meaningful to compare Emily's session in the text-based forum with her first session in the visual forum. In addition, Emily's reading patterns in first and second sessions of the visual forum were similar. This similarity may also be applicable to the text-based forum.

Similarities and differences

In both forums, Emily read posts in the threads from higher-level posts to the lower level ones. In general, she read a post first, then its replies. However, comparing Emily's reading patterns in the two forums suggests a higher level of attention to the structure of the discussion and selectivity in the visual forum. In the visual forum, Emily actively chose the threads from different locations on the screen and she did not just visit the threads in a specific order (e.g. circular order). In contrast, in the linear text-based forum, especially at the beginning of her participation, Emily simply opened the posts from beginning of the list to the end; by doing so she let the interface decide which posts she should open (based on the order in which they appeared on the screen). However, the second half of her actions did not continue this linear pattern, and her selections might have been based on other factors such as posts' authors or subjects, which are either not fully represented or are not represented at all in the visual interface.

In the visual forum, Emily purposefully reread some posts that she had read in the first session. Furthermore, in some cases Emily reread a post within a session, while the text-based forum Emily never reread a post. On average she spent less than a minute reading a post in both forums.

In summary, Emily's behaviour in the visual forum compared to the text-based forum was more selective in visiting threads. She also reread posts in the

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visual forum, but not in the text-based forum where she conducted all of her reading and posting activity without a break. In both forums, she read posts from higher to lower level replies.

5.3. David

5.3.1. David's activity in the Visual Forum

Overview

David spent a total of 49 minutes in the visual forum in his two sessions (see table 5.4). In his participation in this forum, he opened 23 posts (59% of the 39 posts available) in 34 minutes and made one post in each session. In the first session, David opened 11 different posts in 9 threads (46% of 25 available posts in 9 threads, at least one post from each thread). In the second session, David opened 17 different posts in 6 threads (44% of 39 available posts in 10 threads). Five of the posts he opened were ones he had opened previously, and 12 were new posts.

Table 5.4. Overview of David's activity in the visual and linear text-based forum in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:49	3:25	0:26	0:27	0:24	0:10
Reading Time (h:mm)	0:34	3:04	0:20	0:26	0:15	0:05
# of unique posts read	23	28	11	9	17	9
% of posts read	59%	72%	46%	100%	44%	24%
Average time reading a post (m:ss)	1:29	6:34	1:49	2:53	0:53	0:33
# of posts made	2	4	1	1	1	0
Time of rereading posts (h:mm)	---	---	---	---	0:04	0:00
# reread posts	---	---	---	---	5	0
Time of reading new posts (h:mm)	---	---	---	---	0:11	9
# of reading new posts	---	---	---	---	12	0:05

Reading Patterns

Session One

Figure 5.2 (a) illustrates the sequence of David's activity in the first session in the visual forum. David spread his activity among all threads. He read at least one post (the first level reply to the discussion prompt) from each thread in this session, but only in two threads did David read more than one post. After reading the discussion prompt he began by opening the replies to it in a circular pattern. He started this pattern by opening a post from the top left side of the screen (action 1) and continued opening posts at this reply level counter clockwise (actions 2-7), though he did leave one post unread at this time (see action 17). In this series of actions he opened all of the first level replies except two, which he opened later in this session before creating his post. Based on the think-aloud data in which David described each level of the replies as a circle, it seems clear that the structure and size of nodes in the visual interface was guiding him to open first-level reply posts.

After reading most of the first level reply posts in a circular order (actions 1-7), David went back to the discussion prompt (action 8), then reread a first level reply post that he had read before (action 9) and its reply (action 10). After that he went back to his circular pattern (actions 12-14) before visiting the last two threads, in which he read another lower level reply post (action 15) after reading its parent (action 14). David later made his post in this thread, one of the few in which he read more than one post (action 18P). He also reread some of the first-level reply posts (e.g. actions 21, 26).

Session Two

Figure 5.2 (b) illustrates the sequence of David's activity in the second session. In this session, he was focused on reading fewer threads but in greater depth. Based on the think-aloud data, he seemed interested to read new posts, but he scanned the first-level replies first to "refresh his memory." As described in the methods chapter, in the second session one thread (and consequently one first level reply post) was added to the discussion. David started his reading activity by

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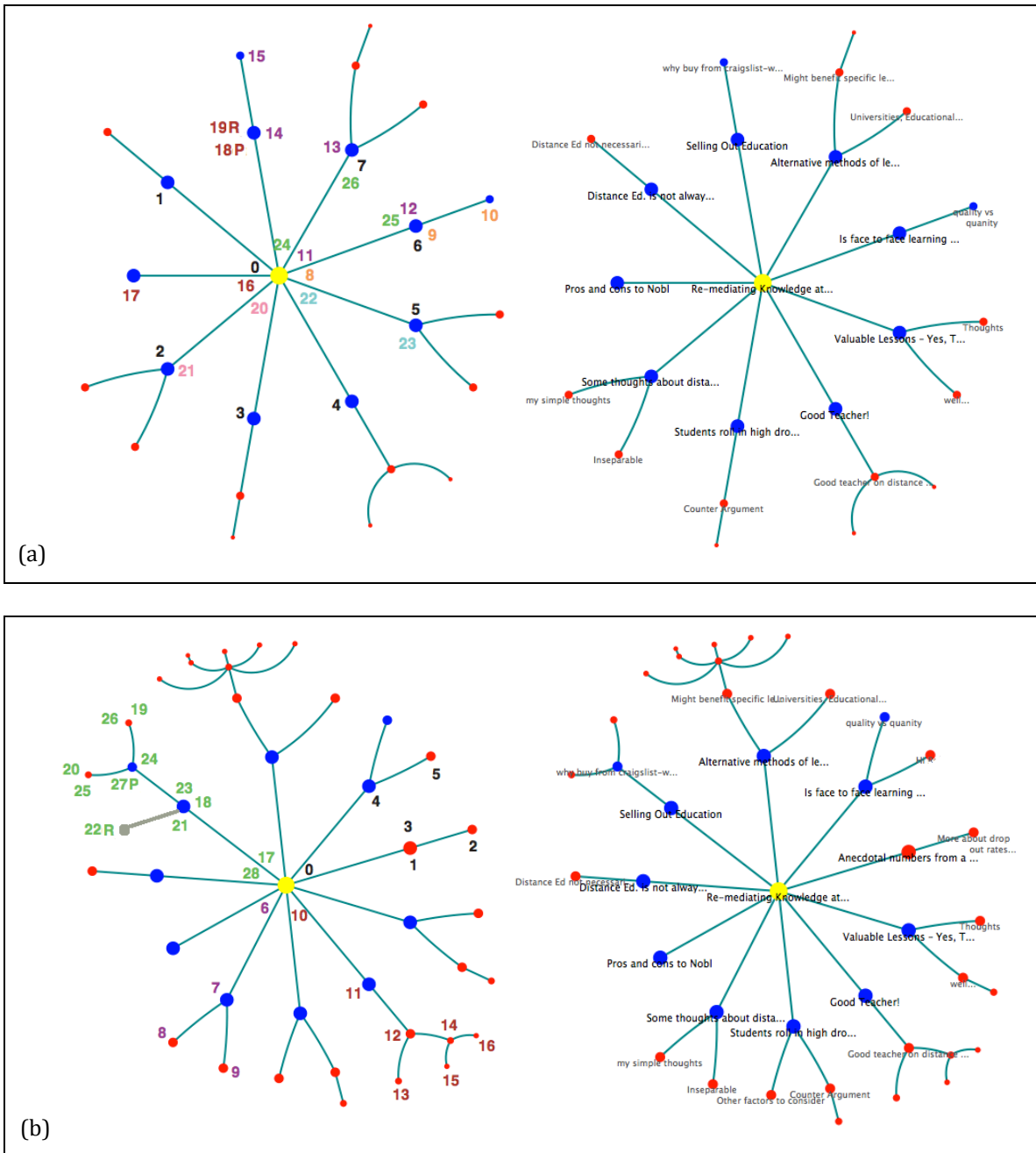
Figure 5.2. The left images illustrate David's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of his actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

reading this new post first (action 1), and then its reply (action 2). In four of the five different threads that he read, he read all posts. In the fifth thread he read all but one post (which he had read in the first session). This is similar to a "complete" version of the selective radial pattern shown by Emily. In this session, he also read some posts multiple times. At the end of the second session, after reading all posts in a thread multiple times (actions 17-26) and reviewing the post he made in the first session, David made his second post in the same thread.

David's activity during first and second sessions was different. In the first session, when all of the posts were new to him, he had a circular reading pattern and attempted to read or at least scan all of the main replies to the discussion prompt to get a sense of the discussion. In the second session, he was interested in reading new posts, which were mostly located at the lower reply level. However, he did not simply open those posts. He started opening higher level replies first, then their new "children", trying to remember the ideas in the posts he had read before. In the second session, he had a radial in-depth reading pattern. He was selective in which threads he read, and he usually read all posts from the selected threads.

5.3.2. David's previous activity in the linear text-based forum

Overview

In the linear text-based forum, David spent a total of 3 hours and 25 minutes in the focal discussion in three sessions (See Table 5.4). In total he opened 28 different posts in 10 threads (72% of 39 total posts in the discussion in 10 threads) and created 4 posts. In the first session, he opened all 9 available posts and created one post. In the last session, David opened 9 different posts in 4 threads (24% of 39 available posts in 10 threads). All posts he opened in the last session were new posts.

Reading Pattern

First Session

Table 5.5 shows the structure of the discussion at the time David visited the discussion for the first time, and the sequence of his activity in this linear text-based

forum. This visit was on the second day of the discussion. David started his activity in the discussion by creating a post (action 1P). After reviewing his post (action 2R), he started to read others' posts in a linear pattern from top of the list. After reading the first four posts (actions 3-6) and rereading one of them (action 7), he jumped to the bottom of the screen and continued to read the first level replies from bottom to top (action 8-11). After reading all of the first level replies, he read a second level post (action 12) that he had not read before. By the end of his first session, David had read all posts that were available to him.

Table 5.5. David's sequence of activity in his first session in the linear text-based forum
Actions with no letter are reading actions
P represents a posting action
R represents a reviewing action

Order	Post Subject
3	Valuable Lessons - Yes, The Whole Story - No
4	Thoughts
5,7	Good Teacher!
6	Good teacher on distance education?
11	Students roll in high dropout rate
10	Some thoughts about distant education at university
12	Inseparable
9	Pros and cons to Noble
8	Distance Ed. is not always wrong.
1P, 2R	Selling Out Education

Last Session

Table 5.6 shows the sequence of David's activity in the linear text-based forum in his last session. This visit was on the last day of the discussion. In this session, he reviewed one of his own posts (action 1R) and read 9 posts that were made by other students (actions 2-10). All the posts David read were new posts, and with the exception of one, all of them were located at the bottom of the forum. He ignored the posts at the beginning or middle of the forum. In this session, David was only interested in reading new posts. Unlike the visual forum in which he (re)read the parent posts before reading their new children, in the text-based forum he skipped the parent posts (if he had read them before) but he did read their new children (e.g. 7, 8 and 9).

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Table 5.6. David's sequence of activity in the linear text-based forum in his last session. Actions with no letter are reading actions. N- New (unread) post at the beginning of the session. O- Learners own post, made in an earlier session. R- Reviewing action

Order	Status	Post Subject
		Valuable Lessons - Yes, The Whole Story - No
		Thoughts
		well...
	N	Cost and Media.
		Good Teacher!
		Good teacher on distance education?
	N	Thoughts on good teacher
	N	Phone calls?
	N	Maybe a bit misunderstanding
	N	the role of an "on-line" instructor is different
		Students roll in high dropout rate
		Counter Argument
	N	Agreed
10	N	Other factors to consider
		Some thoughts about distant education at university
		Inseparable
		my simple thoughts
		Pros and cons to Noble
		Distance Ed. is not always wrong.
	N	Distance Ed not necessarily wrong / Could some points in the article be?
	O	Selling Out Education
		why buy from craigslist-why not a dealer?
	O	Example of being swindled.
	O	Both can be good and bad
		Alternative methods of learning
		Might benefit specific learning style
		Is it possible to educate yourself?
		yes...and no.
1R	O	Get in trouble
2	N	Should not instructors fees?
4	N	human interaction does not only exist between students and teachers
3	N	Online education vs Self education
5	N	Ways of interacting
6	N	Universities, Educational Value and DE
		Is face to face learning inherently better than distance ed?
8	N	Quality vs quanity
9	N	Hi ...
		Anecdotal numbers from a VLN teacher
7	N	More about drop out rates

5.3.3. Comparing David's activity in the visual and linear text-based forums

Comparability of sessions

Compared to the visual forum David spent a longer amount of time in the designated discussion using the text-based forum. Thus, the overall average time reading each post was lower for the visual forum. However, the times for the two selected sessions (especially the first sessions) are similar. In addition, the number of posts in the second session of the visual forum and the last session of the text-based forum are the same. Thus the reading patterns in the selected sessions can reasonably be compared to each other.

Similarities and differences

In his first session with the visual forum, when all posts were new, David paid more attention to higher-level replies than he did in his first session of the text-based forum, possibly trying to get an overall sense of the discussion. In this regard, David's activity in the visual forum was more selective compared to the text-based forum in choosing which posts to read. He read about half of the available posts in the visual forum, while in the linear text-based forum he read all posts. This might be due the fact that the number of posts in the visual forum was more than the text-based forum. In the first session of the visual forum he did not actively select which threads to visit, instead letting the interface decide for him (he visited the threads in a counter clockwise order). However, in the second session of the visual forum he did actively choose which thread to visit.

In the last session in both forums, David's activity in the forums and his own explanation suggested that he was interested in reading new posts. While in the visual forum, David read or scanned the higher-level reply in each thread before reading the new lower-level replies (trying to remember the idea in the posts and thus possibly connecting old and new ideas in a thread), in the linear text-based forum he read only new posts at the bottom of the screen without reading the higher level replies if he had read them in a previous session, or reading new posts

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in the middle of the list. He also reread posts in the visual forum more often, even within a single session.

In summary, David's behaviour in reading threads was more selective in the second session of the visual forum compared to the text-based forum. In addition, while in both forums he was interested in reading new posts, in the visual forum he read the higher level posts first before reading their new replies. In contrast, in the text-based forum, David simply ignored the posts he had read before, and those which were not located at the bottom of the forum.

5.4. Mike

5.4.1. Mike's activity in the Visual Forum

Overview

Mike spent a total of 48 minutes in the visual forum in his two sessions (see table 5.7). In his participation in this forum, he opened 34 posts (87% of the 39 posts available) in 35 minutes and made one post in each session. In the first session, Mike opened 11 different posts in 6 threads (46% of 24 available posts in 9 threads). In the second session, Mike opened 24 different posts in 6 threads (62% of 39 available posts in 10 threads). Only one of the posts he opened was ones he had opened before, and 23 were new posts.

Table 5.7. Overview of Mike's activity in the visual and linear text-based forum in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:48	1:55	0:23	1:22	0:25	0:10
Reading Time (h:mm)	0:35	0:19	0:13	0:15	0:22	0:04
# of unique posts read	34	12	11	8	24	4
% of posts read	87%	31%	46%	36%	62%	12%
Average time reading a post (m:ss)	1:02	1:35	1:11	1:53	0:55	1:00
# of posts made	2	3	1	3	1	0
Time of rereading posts (h:mm)	---	---	---	---	0:01	0:00
# reread posts	---	---	---	---	1	0
Time of reading new posts (h:mm)	---	---	---	---	0:21	0:04
# of reading new posts	---	---	---	---	23	4

Reading Patterns

Session One

Figure 5.3 (a) illustrates the sequence of Mike's activity in his first session in the visual forum. Mike spread his activity in the first session among 6 threads, and read all posts in 3 of them. Although he started this session by selecting a thread at the top left of the screen (based on the think aloud data, this was because in reading text he started from top left of the page), unlike David he did not use a circular pattern in selecting which threads to visit. In general, Mike had a radial pattern in reading posts. His radial pattern was sometimes complete (when he read all the posts in the thread in order, e.g. actions 3-5, 9-12), and sometimes incomplete (when he didn't read all posts in the thread, e.g. actions 14,15). In this regard, Mike's reading pattern was similar to Emily's. In addition, in some cases in the first session Mike reread posts and sometimes an entire thread that he had read before in the session (e.g., action 13, 20-22). Mike made his post (18P) in this session, as a reply to a post that he had read more than once, almost at the end of the session.

Session Two

Figure 5.3 (b) illustrates the sequence of Mike's activity in his second session in the visual forum. In this session, Mike read all new first-level reply posts, as he thought the presentation (the larger size of the first-level nodes) made them important. However the smaller new (red) posts at the lower level attracted his attention less, and he did not feel he needed to read them. Mike's reading pattern in the second session was similar to that in his first session. Overall he had a radial pattern, mostly complete (reading all posts in the thread, e.g. actions 0-6, 36-40) but in some cases incomplete (he didn't read all posts in the thread, actions 26-27). He also read some of the posts multiple times (e.g. 12, 32, 41).
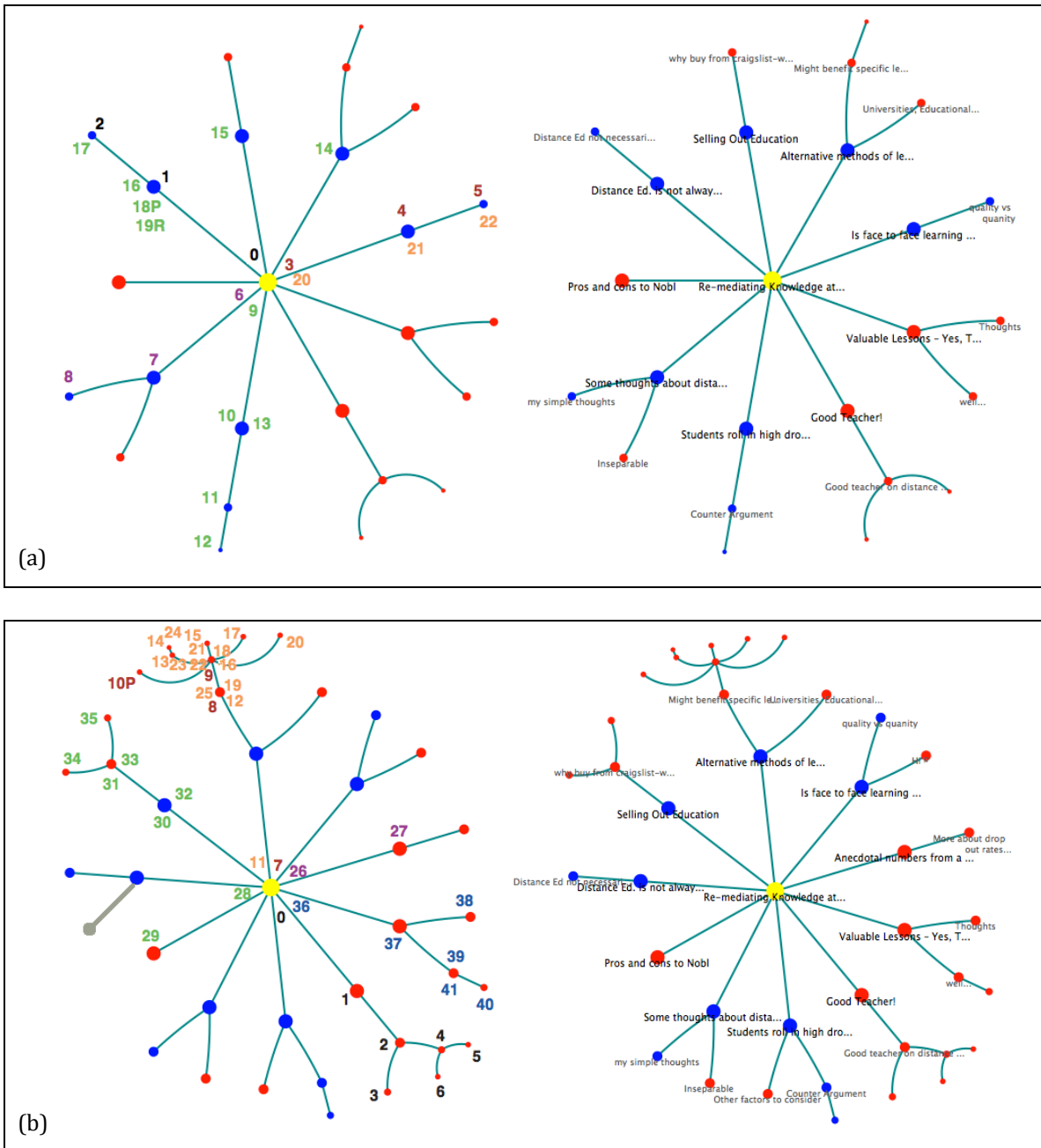
Figure 5.3. The left images illustrate Mike's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of his actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

Mike's pattern in reading one of the threads (7-25) stood out. Based on the think aloud data, although he was interested to read posts in that thread because a number of posts had been added from the previous session, he did not open the first-level post in that thread (which he had read in the first session). After reading two posts in one of the branches in this thread (8-9) he made a post (10P) and went back to the discussion prompt. But he came back to the same sub-thread and started reading posts multiple times. Based on the think aloud data, after action 17 he was looking for a particular post he had read before, and in actions 18 to 25 he was trying to find that post. This brought some frustration for Mike, as he found the visual structure (compared to the linear structure) made it more difficult to locate a specific post.

5.4.2. Mike's previous activity in the linear text-based forum

Overview

In the linear text-based forum, Mike spent a total of 2 hours in the focal discussion in three sessions (see Table 5.7). However, he spent most of this time creating posts and reviewing them; in total he only spent 19 minutes reading others' posts. Additionally, in his third and last session, he only reviewed his own posts without reading or creating any other posts. Thus the last session with a reading action was his second session. This second session in the text-based forum was selected as his last session for comparison with his second session in the visual forum. In total in the discussion, Mike opened 12 different posts in 10 threads (31% of 39 total posts in the discussion in 10 threads) and created 3 posts. In the first session, he opened 8 posts in 7 threads (36% of 22 available posts in 10 threads) and created all of his three posts. In the last session, Mike opened 4 different posts in 3 threads (12% of 33 available posts in 10 threads). All posts he opened in the second session were new posts.

Reading Pattern

First Session

Table 5.8 shows the structure of the discussion at the time Mike visited the discussion for the first time, and the sequence of his activity in the linear text-based forum. Mike visited the discussion on the third day. In this session he chose which posts to read within a thread based on the structure of the discussion, mostly opening higher-level posts. Of the 8 different posts Mike opened, six of them were first-level reply posts. He also read some of the posts multiple times. However, he did not visit all first level replies, and it is not clear how he decided which threads to visit. His decision might have been based on the subject, author or other factors. He created all of his 3 posts for this week in this first session. However, he didn't always

Table 5.8. Mike's sequence of activity in his first session in the linear text-based forum Actions with no letter are reading actions. P represents a posting action. R represents a reviewing action

Order	Post Subject
7, 11, 12P	Valuable Lessons - Yes, The Whole Story - No
	Thoughts
8	Good Teacher!
	Good teacher on distance education?
	Thoughts on good teacher
14	Students roll in high dropout rate
15	Counter Argument
	Agreed
	Some thoughts about distant education at university
	Inseparable
	my simple thoughts
	Pros and cons to Noble
	Distance Ed. is not always wrong.
1, 6, 2P, 3R, 5R, 9R	Selling Out Education
	Alternative methods of learning
	Might benefit specific learning style
16, 17P	Is it possible to educate yourself?
4, 13	Is face to face learning inherently better than distance ed?
10	Anecdotal numbers from a VLN teacher

read all posts in the thread before he made his own post. For example, in creating his third post (17P) he only read the third level reply post (16) in the thread, without reading the first and second level posts.

Last Session

Table 5.9 shows the structure of the discussion at the time Mike visited the discussion for the last time, and the sequence of his activity in the linear text-based forum. In this session, Mike reviewed the posts he had made in the first session and only opened the replies to them, without reading any other posts. In this session he did not open posts based on the structure of the discussion (for example higher- or lower-level posts), nor others' posts (except the ones related to his own posts).

5.4.3. Comparing Mike's activity in the visual and linear text-based forums

Comparability of sessions

While Mike spent less time in the visual forum compared to the text-based forum, the reading times in both forums are similar. In addition, the number of available posts in the sessions are similar in both sessions. Thus, Mike's reading patterns in both sessions can reasonably be compared to each other.

Similarities and differences

Despite the shorter time Mike spent in the visual forum, he spent more time reading posts, and he also read a larger number of posts. Most of Mike's activity in the text-based interface was self-focused. He spent only one sixth of his time in the forum reading others' posts. While in the visual interface Mike read all posts in at least half of the threads he visited, in the text-based forum Mike never read all posts in a thread in a session (with the exception of threads with only one post). In the visual forum, Mike also read a number of posts (and sometimes the entire thread) multiple times. In contrast in the text-based interface, in the first session he read a few posts and also created three posts; in another session he only reviewed his own posts and read the replies to them. Because no replies were added to Mike's posts before the second session of the visual forum, his behaviour in the two sessions

cannot be compared in this aspect. However it can be noted that in the visual forum he did not spend as much time as the text-based interface creating and reviewing his

Table 5.9. Mike's sequence of activity in the linear text-based forum in his last session Actions with no letter are reading actions. N- New (unread) post at the beginning of the session. O- Learners own post, made in an earlier session. R-Reviewing action

Order	New	Post Subject
		Valuable Lessons - Yes, The Whole Story - No
	N	Thoughts
1R	O	well...
		Good Teacher!
	N	Good teacher on distance education?
	N	Thoughts on good teacher
	N	Phone calls?
	N	the role of an "on-line" instructor is different
		Students roll in high dropout rate
		Counter Argument
	N	Agreed
	N	Some thoughts about distant education at university
	N	Inseparable
	N	my simple thoughts
	N	Pros and cons to Noble
	N	Distance Ed. is not always wrong.
	N	Distance Ed not necessarily wrong / Could some points in the article be?
		Selling Out Education
2R, 8R	O	why buy from craigslist-why not a dealer?
3	N	Example of being swindled.
4	N	Both can be good and bad
	N	Alternative methods of learning
	N	Might benefit specific learning style
		Is it possible to educate yourself?
7R	O	yes...and no.
5	N	Get in trouble
6	N	Should not instructors fees?
	N	human interaction does not only exist between students and teachers
	N	Universities, Educational Value and DE
		Is face to face learning inherently better than distance ed?
	N	quality vs quanity
		Anecdotal numbers from a VLN teacher
	N	More about drop out rates

own posts.

In summary, in the visual interface Mike had a selective radial pattern. His activity in the text-based forum was also selective but self-focused (this may not be related to the interface). His reading pattern in the visual forum shows interest in reading others' posts (especially the higher-level replies) and attention to the structure of the discussion in selecting which posts to read.

5.5. Nicole

5.5.1. Nicole's activity in the Visual Forum

Overview

Nicole spent a total of 37 minutes in the visual forum in her two sessions (see table 5.10). In her participation in this forum, she opened 22 posts (56% of all 39 posts) in 23 minutes and made three posts. In the first session, Nicole opened 10 different posts in 4 threads (42% of 24 available posts in 9 threads). In the second session, she opened 12 different posts in 2 threads (31% of 39 available posts in 10 threads). All 12 posts she opened were new posts.

Table 5.10. Overview of Nicole's activity in the visual and linear text-based forum in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:37	0:38	0:18	0:21	0:19	0:17
Reading Time (h:mm)	0:23	0:18	0:12	0:02	0:11	0:17
# of unique posts read	22	9	10	4	12	5
% of posts read	56%	23%	42%	100%	31%	13%
Average time reading a post (m:ss)	1:03	2:00	1:12	0:30	0:55	3:24
# of posts made	3	4	1	4	2	0
Time of rereading posts (h:mm)	---	---	---	---	0:00	0:00
# reread posts	---	---	---	---	0	0
Time of reading new posts (h:mm)	---	---	---	---	0:09	0:17
# of reading new posts	---	---	---	---	12	5

Reading Patterns

Session One

Figure 5.4 (a) illustrates the sequence of Nicole's activity in her first session in the visual forum. In this session Nicole visited four threads and read all of their posts, sometimes multiple times. All threads were located at the bottom of the screen but she did not visit them in a specific pattern (e.g. circular). In the first session, she had a complete radial reading pattern. For each thread she first read the higher-level reply post, then the replies to it (e.g. actions 2-5, 7-9). In some cases she reread some of the posts in the thread (e.g. actions 14-15). On average she spent just over one minute reading a post. She made her own new post at the end of the session, in the last thread in which she read all of the posts.

Session Two

Figure 5.4 (b) illustrates the sequence of Nicole's activity in her second session in the visual forum. In this session Nicole only visited two threads, in a mostly complete radial reading pattern. It seems, based on the think aloud data, that at the beginning of the second session she was interested to read one of the new posts at the second reply level (because of its title), but she decided to read its parent post first (action 1) to get a sense of the thread before reading the reply post (action 2). After reading all the posts in this thread, she made a new post (action 4P). At this point she started to visit another thread, the one that had the largest number of posts in it. She read all posts in this thread except one in a radial pattern, reading the higher posts then the replies to them (actions 5-15). She made her second post in this sub-thread after reading all of its posts (action 15P).
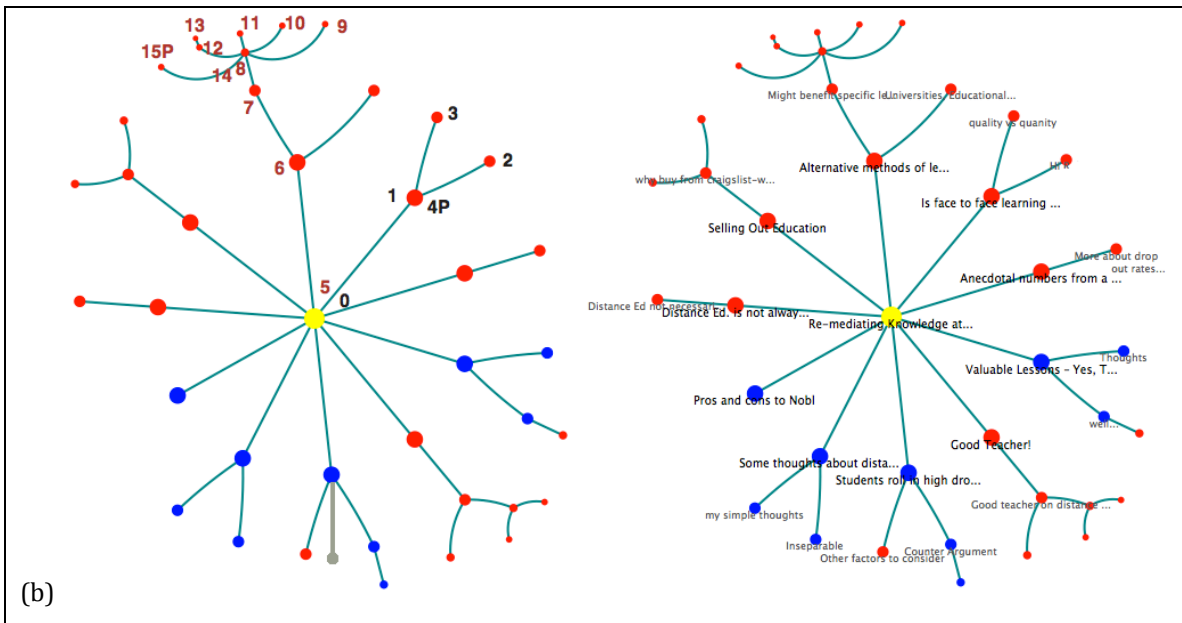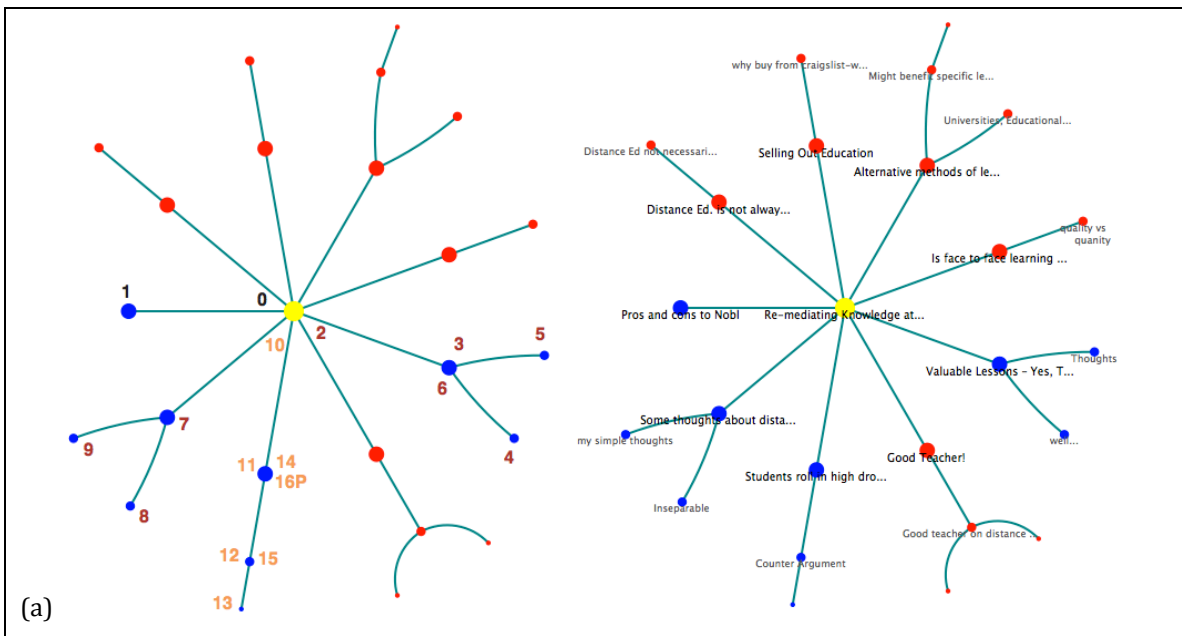
Figure 5.4. The left images illustrate Nicole's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of her actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

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5.5.2. Nicole's previous activity in the linear text-based forum

Overview

In the linear text-based forum, Nicole spent a total of 38 minutes in the focal discussion in two sessions (see Table 5.10). In total she opened 9 different posts (23% of 39 total posts in the discussion) and created four posts. In the first session Nicole opened all 4 available posts in 4 threads. In the last session, she opened 5 different posts in 2 threads (13% of 39 available posts in 10 threads). All of the posts Nicole opened in the second session were new posts.

Reading Pattern

First Session

Table 5.11 shows the structure of the discussion at the time Nicole visited the discussion for the first time, and the sequence of her activity in the linear text-based forum. Nicole visited the discussion on the first day of the discussion, when only four posts were available, and read in a linear pattern. She started this session by making a new post (action 1P). Then, she read all 4 existing posts in a linear order from top to bottom, and replied to three of them.

Table 5.11. Nicole's sequence of activity in her first session in the linear text-based forum. Actions with no letter are reading actions. P represents a posting action R represents a reviewing action

Order	Post Subject
2, 3P, 4R	Valuable Lessons - Yes, The Whole Story – No
5, 6P, 7R	Good Teacher!
8	Students roll in high dropout rate
9, 10P	Some thoughts about distant education at university
1P	Pros and cons to Noble

Last Session

Table 5.12 shows the structure of the discussion in the linear text-based forum at the time Nicole visited the discussion for the last time, and the sequence of

her activity. In this session she only read the replies to her own posts, with the exception of one post, which was adjacent to one of her posts (action 5). Overall she did not read posts based on the structure of the discussion, or posts other than ones that were related to her own. First, Nicole read in linear order all four replies to one of the posts that she made in the first session (actions 1-4). Then she read a post that was adjacent to one of her posts in another thread (action 5) and left the discussion. On average she spent more than three minutes reading a post. She did not reread any posts.

5.5.3. Comparing Nicole's activity in the visual and linear text-based forums

Comparability of sessions

Because Nicole's visited the discussion in the text-based interface early in the week, the number of posts available for her to read in the first session of the text-based forum was lower than the number of posts available in the first session of the visual interface. The lower number of posts in the text-based interface may have influenced Nicole's reading pattern in this session. The number of posts was exactly the same for the last sessions in both forums.

Similarities and differences

In her first session in the visual forum, Nicole displayed a radial reading pattern but visited less than half of the threads, while in the text-based interface she opened all 4 existing posts in a linear pattern and replied to 3 of them. The reading pattern was repeated in the last session for the visual forum, but not the text-based forum. In her second session in the visual forum, Nicole visited a limited number of threads but read all of their posts (with the exception of one) in a radial pattern. In the visual forum, in general Nicole read the posts in the threads in their reply order; even when she was interested in the lower level posts she read the parent post first. In contrast, Nicole's reading pattern in her second session in the text-based forum was self-focused; she only opened the posts that were related to her own posts. Similar to Mike, because there were no replies to the Nicole's posts in the second

Table 5.12. Nicole's sequence of activity in the linear text-based forum in her last session. Actions with no letter are reading actions. N- New (unread) post at the beginning of the session. O- Learners own post, made in an earlier session

Order	New	Post Subject
		Valuable Lessons - Yes, The Whole Story - No
	O	Thoughts
5	N	well...
	N	Cost and Media.
		Good Teacher!
	O	Good teacher on distance education?
1	N	Thoughts on good teacher
2	N	Phone calls?
3	N	Maybe a bit misunderstanding
4	N	the role of an "on-line" instructor is different
		Students roll in high dropout rate
	N	Counter Argument
	N	Agreed
	N	Other factors to consider
		Some thoughts about distant education at university
	O	Inseparable
	N	my simple thoughts
	O	Pros and cons to Noble
	N	Distance Ed. is not always wrong.
	N	Distance Ed not necessarily wrong / Could some points in the article be?
	N	Selling Out Education
	N	why buy from craigslist-why not a dealer?
	N	Example of being swindled.
	N	Both can be good and bad
	N	Alternative methods of learning
	N	Might benefit specific learning style
	N	Is it possible to educate yourself?
	N	yes...and no.
	N	Get in trouble
	N	Should not instructors fees?
	N	human interaction does not only exist between students and teachers
	N	Online education vs Self education
	N	Ways of interacting
	N	Universities, Educational Value and DE
	N	Is face to face learning inherently better than distance ed?
	N	Quality vs quanity
	N	Hi ...
	N	Anecdotal numbers from a VLN teacher
	N	More about drop out rates

session of the visual interface, his behaviour in the two sessions cannot be compared in this aspect.

In summary, Nicole's reading pattern in the visual forum was a complete radial pattern. She was also selective in choosing which threads to read. In contrast, Nicole's displayed a linear reading pattern in the text-based forum. Even though she was interested in reading new lower-level posts in the visual forum, she read their parents first. In addition, in the visual forum, she also reread some posts in the same session.

5.6. Steve

5.6.1. Steve's activity in the Visual Forum

Overview

Steve spent a total of 21 minutes in the visual forum in his two sessions (see table 5.13). In his participation in this forum, he opened 16 posts (41% of 39 total posts) in 14 minutes and made one post. In the first session, Steve opened 7 different posts in 3 threads (29% of 24 available posts in 9 threads). In the second session, Steve opened 10 different posts in 5 threads (26% of 39 available posts in 10 threads). Only one of the posts he opened was one he had opened before, and 9 were new ones.

Table 5.13. Overview of Steve's activity in the visual and linear text-based forum in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:21	0:37	0:10	0:03	0:11	0:15
Reading Time (h:mm)	0:14	0:32	0:10	0:03	0:04	0:11
# of unique posts read	16	17	7	3	10	6
% of posts read	41%	44%	29%	38%	26%	26%
Average time reading a post (m:ss)	0:53	1:53	1:26	1:00	0:24	1:50
# of posts made	1	1	0	0	1	1
Time of rereading posts (h:mm)	---	---	---	---	0:01	0:08
# reread posts	---	---	---	---	1	4
Time of reading new posts (h:mm)	---	---	---	---	0:03	0:03
# of reading new posts	---	---	---	---	9	1

Reading Patterns

Session One

Figure 5.5 (a) illustrates the sequence of Steve's activity in his first session in the visual forum. Steve displayed a radial pattern in reading posts in the threads; he read higher-level replies first, then their replies (actions 1-4, 5-6). Steve only opened posts from 3 adjacent threads. For two of the threads Steve read all posts in the thread, and for one he read only one post. He also reread some of the posts from one of the threads at the end of the session (actions 10-12). However, Steve left many of the posts unread. Based on the think aloud data, he chose threads based on a clock metaphor (he was seeing the visual structure as a clock), starting from one o'clock and continuing clockwise.

Session Two

Figure 5.5 (b) illustrates the sequence of Steve's activity in his second session in the visual forum. Steve started where he left off in the first session and continued his clockwise radial reading pattern in the second session (e.g. actions 1-3, 4-6). However, in this session he read all the posts in only one of the threads (actions 7-10), and did not re-read any posts. In this session, Steve only spent 4 minutes reading others' posts. On average he spent less than 30 seconds on each post, possibly because he was focused on looking for a place to make a new post. At the end of the session he reread a post that he had read in the first session, and made a new post.
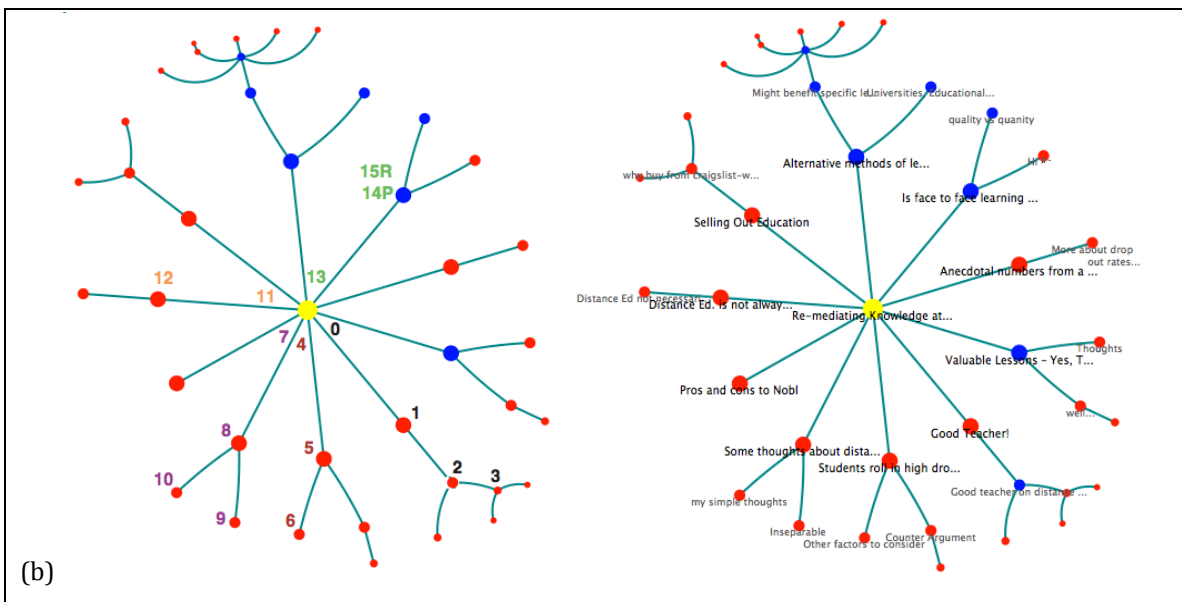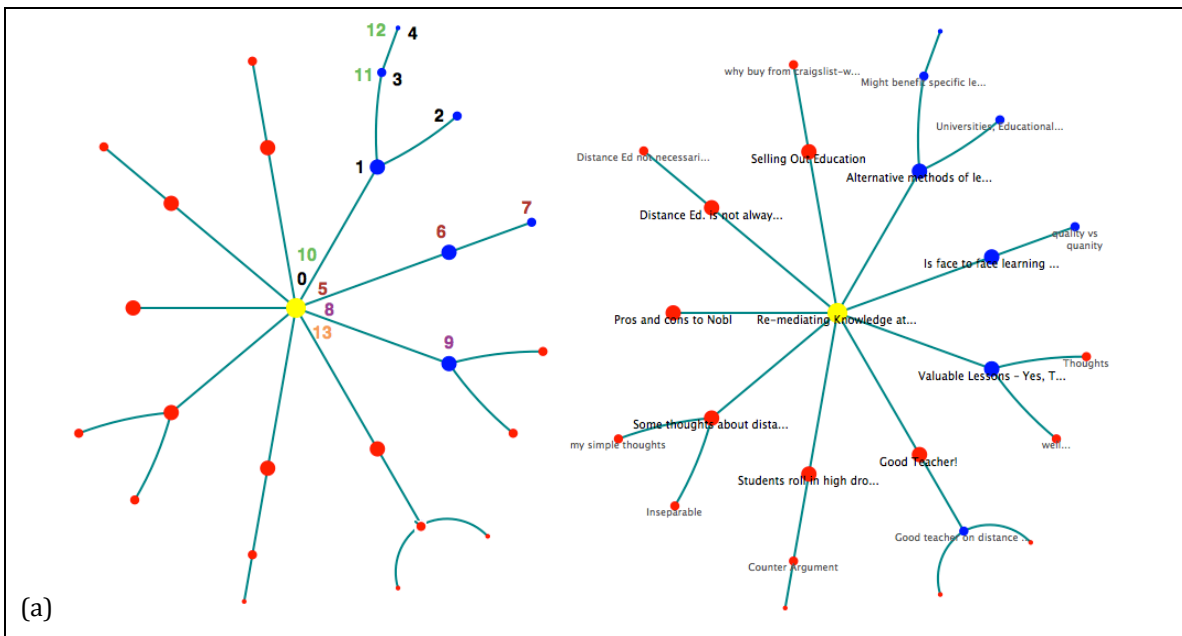
Figure 5.5. The left images illustrate Steve's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of his actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

5.6.2. Steve's previous activity in the linear text-based forum

Overview

In the linear text-based forum, Steve spent a total of 37 minutes in the focal discussion in four sessions (see Table 5.9). In total he opened 17 different posts (44% of 39 total posts) and created one post. In the first session, he opened 3 posts in 3 threads (38% of 8 available posts in 5 threads). In the last session, Steve opened 6 different posts in 6 threads (26% of 23 available posts in 10 threads). Four of the posts Steve opened in this session were the posts that he had opened in the previous sessions, and two of them were new posts.

Reading Pattern

First Session

Table 5.14 shows the structure of the discussion at the time Steve visited the discussion for the first time, and the sequence of his activity in the linear text-based forum. Steve visited the discussion in the second day. He visited the threads in a linear pattern (from top to bottom) but he only read first-level posts. In this short session, Steve only read three first-level posts from the top of the screen, in order, in three minutes (actions 1-3).

Table 5.14. Steve's sequence of activity in his first session in the linear text-based forum Actions with no letter are reading actions.

Order	Post Subject
1	Valuable Lessons - Yes, The Whole Story - No
	Thoughts
2	Good Teacher!
	Good teacher on distance education?
3	Students roll in high dropout rate
	Some thoughts about distant education at university
	Inseparable
	Pros and cons to Noble

Last Session

Table 5.15 shows the structure of the discussion in the linear text-based forum at the time Steve visited the discussion for the last time, and the sequence of

his activity. He read posts from different reply levels and different locations on the screen without a clear pattern based on the structure of the discussion. Because he mostly opened posts that he had read in the previous sessions, and he made his posts at the end of the session after reading them, it is possible that he was looking for a specific post he had read previously to reply to.

Table 5.15. Steve's sequence of activity in the linear text-based forum in his last session Actions with no letter are reading actions. N- New (unread) post at the beginning of the session. O- Learners own post, made in an earlier session. P- Posting action. R-Reviewing action

Order	New	Post Subject
		Valuable Lessons - Yes, The Whole Story - No
		Thoughts
	N	well...
		Good Teacher!
		Good teacher on distance education?
	N	Thoughts on good teacher
		Students roll in high dropout rate
2	N	Counter Argument
	N	Agreed
		Some thoughts about distant education at university
		Inseparable
	N	my simple thoughts
		Pros and cons to Noble
3		Distance Ed. is not always wrong.
		Selling Out Education
	N	why buy from craigslist-why not a dealer?
1		Alternative methods of learning
		Might benefit specific learning style
		Is it possible to educate yourself?
8	N	yes...and no.
4		Is face to face learning inherently better than distance ed?
5, 6P, 7R		Anecdotal numbers from a VLN teacher

5.6.3. Comparing Steve's activity in the visual and linear text-based forums

Comparability of sessions

Because Steve started and finished his participation early in the discussion in the text-based forum, the number of available posts in each text-based forum

session was lower compared to the equivalent sessions in the visual forums. However, he opened a similar percentage of posts in the first sessions and the same percentage of posts in the last sessions.

Similarities and differences

Overall, Steve opened less than half of the posts in both forums. In his first session in the visual forum, Steve tried to find an order in reading threads (clockwise); in the text-based forum he only read higher-level posts from the top of the screen. Thus in both forums he did not actively choose the threads to read. In the visual interface, Steve's reading pattern in the second session was somewhat similar to the first session. In general he chose threads clockwise and read posts in the threads from higher-level replies to lower-level ones. However, in the last session of the text-based interface he did not pay attention to the structure of the discussion and presumably opened posts based on other factors. In addition, in the visual forum Steve mostly opened new posts, while in the text-based forum he did not read many new posts, but primarily ones he had read before.

In summary, in both forums Steve visited the threads in a predetermined order that was displayed by the interface, and did not actively choose which threads to visit. While he read only new posts in his second session of the visual interface, he mostly reread posts in his last session of the text-based forum.

5.7. Amanda

5.7.1. Amanda's activity in the Visual Forum

Overview

Amanda spent a total of 49 minutes in the visual forum in her two sessions (see table 5.16). In her participation in this forum, she opened 14 posts (36% of all 39 posts) in 27 minutes and made three posts. In the first session, Amanda opened 6 different posts in 5 threads (25% of 24 available posts in 9 threads). In the second session, Amanda opened 9 different posts in 3 threads (23% of 39 available posts in

10 threads). Only one of the posts she opened a post she had opened before, and 8 were new ones.

Table 5.16. Overview of Amanda's activity in the visual and linear text-based forum in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:49	7:01	0:23	1:37	0:26	0:12
Reading Time (h:mm)	0:27	2:27	0:10	0:45	0:17	0:12
# of unique posts read	14	35	6	8	9	14
% of posts read	36%	90%	25%	57%	23%	36%
Average time reading a post (m:ss)	1:56	4.12	1:40	5:38	1:53	0:52
# of posts made	3	2	2	1	1	1
Time of rereading posts (h:mm)	---	---	---	---	0:02	0:00
# reread posts	---	---	---	---	1	0
Time of reading new posts (h:mm)	---	---	---	---	0:15	0:12
# of reading new posts	---	---	---	---	8	14

Reading Patterns

Session One

Figure 5.6 (a) illustrates the sequence of Amanda's activity in her first session in the visual forum. According to think aloud data, Amanda chose which threads to visit mostly based on the title of the first level reply post in the thread. However, her reading patterns also show some attention to the order of the threads on the screen. Amanda's reading pattern was a mixture of circular and radial patterns. She visited 4 of the threads in a counter-clockwise direction (actions 2-9). However, she did not visit all threads in order, and did not complete the circle. In this session she only read the first level reply post in each thread, with the exception of one thread in which she read two posts (actions 5-6) in a radial pattern. She never reread a post in this session. On average she spent about 2 minutes reading each post. Amanda made two posts, one almost at the beginning (action 2P) and one at the end (action 9P) of the session.
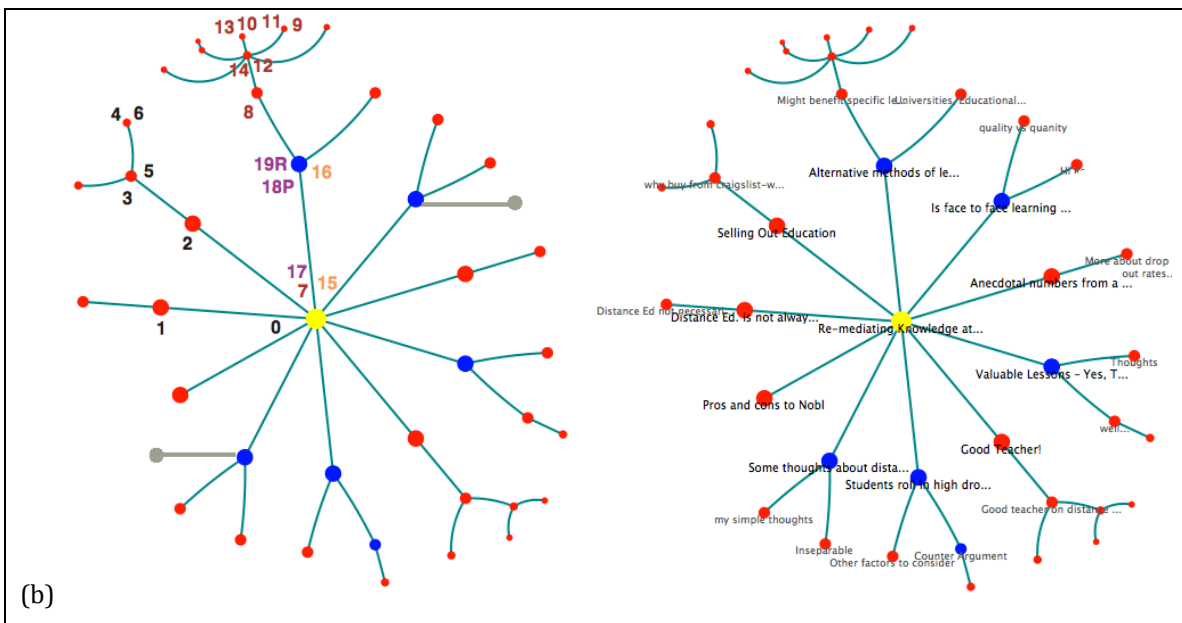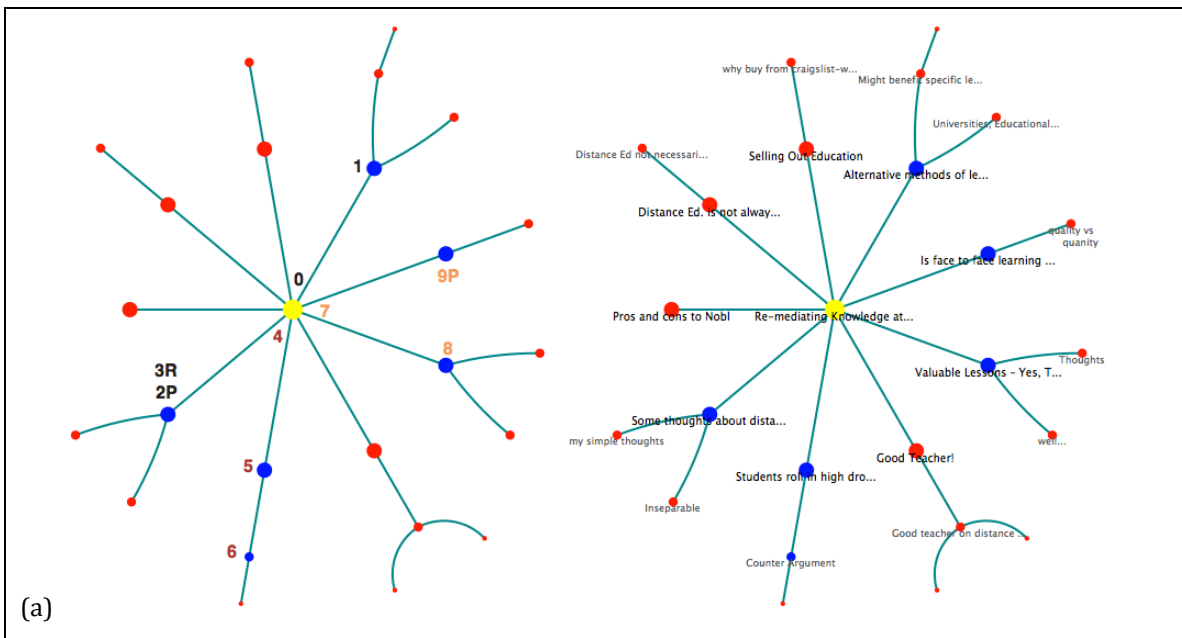
Figure 5.6. The left images illustrate Amanda's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of her actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

Session Two

Figure 5.6 (b) illustrates the sequence of Amanda's activity in her second session in the visual forum. Amanda visited three adjacent threads in this session. Her reading pattern was different for each of the threads. Based on the think aloud data, she again chose posts based on their titles, rather than the structure of the discussion. Unlike the first session, she read multiple posts from two of the threads (actions 2-4, 8-16). She also read some of the posts more than once (e.g. actions 5-6, 11-14). In one of the threads, she read the posts in their reply order first (actions 2-4), then reread two of the posts. In another thread, Amanda did not seem to pay much attention to the structure of the discussion (actions 7-14). At first she did not read the first-level post in this thread (which she had read in the first session). Instead, she read the second-level reply post first (action 8). Then, without reading the reply to that post, she read two of the reply posts at a lower level (actions 9,10). After that, she went back and read the reply to the action 8 post that she had skipped before (action 14). She eventually read the first level reply post in this thread and made a reply to it (action 19P). Even though Amanda opened more lower level reply posts in this session than her first session (e.g. actions 4, 9, 10), she did not read all posts in any of the threads. She made her own post at the end of the session (action 19P).

5.7.2. Amanda's previous activity in the linear text-based forum

Overview

In the linear text-based forum, Amanda spent an extensive amount of time (7 hours) in the focal discussion in three sessions (see Table 5.16). In total she opened 35 different posts (90% of 39 total posts in the discussion) and created two posts. In the first session, she opened 8 posts in 6 threads (57% of 14 available posts in 8 threads). In the last session, Amanda opened 14 different posts in 4 threads (36% of 39 available posts in 10 threads). All of the posts Amanda opened in the second session were new posts.

Reading Pattern

First Session

Table 5.17 shows the structure of the discussion in the linear text-based forum at the time Amanda visited the discussion for the first time, and the sequence of her activity. Amanda opened posts in this session in a linear pattern (from top to bottom). For the first two threads, she only read the first level posts (actions 1-2). After that, she read posts in a linear order (actions 3-8). On average she spent more than 5 minutes reading a post. She made her own post at the end of the session (action 9P).

Table 5.17. Amanda's sequence of activity in her first session in the linear text-based forum
Actions with no letter are reading actions. P represents a posting action. R represents a reviewing action. E represents an editing action

Order	Post Subject
1	Valuable Lessons - Yes, The Whole Story - No
	Thoughts
2	Good Teacher!
	Good teacher on distance education?
3	Students roll in high dropout rate
4	Counter Argument
5, 9P, 10R, 11E	Some thoughts about distant education at university
6	Inseparable
7	Pros and cons to Noble
8	Distance Ed. is not always wrong.
	Selling Out Education
	Alternative methods of learning
	Might benefit specific learning style
	Is it possible to educate yourself?

Last Session

Table 5.18 shows the structure of the discussion at the time Amanda visited the discussion for the last time, and the sequence of her activity in the linear text-based forum. In this session Amanda was only interested in reading new posts, and did not read any other posts. First she read all new posts at the bottom of the list in

a linear pattern (actions 1-9), then she read new posts at the top of the list (actions 10-14). By the end of this session, she had read all new posts but two. Amanda did re-read any posts, or view any posts multiple times. On average she spent less than one minute reading a post.

5.7.3. Comparing Amanda's activity in the visual and linear text-based forums

Comparability of sessions

Overall, Amanda spent much less time in the visual forum compared to the text-based forum. Thus it is not surprising that she opened fewer posts, and on average spent less time reading each post in the visual forum. However, the time she spent in her last session of the text-based interface and the second session of the visual interface were not very different. In addition, the number of posts that were available in each session and the number of actions in a session are not drastically different between the visual and text-based forums. Especially for the last sessions, the number of posts was the same. Thus the reading patterns in the two forums in both first and last sessions are reasonably comparable.

Similarities and differences

Amanda's reading pattern in the first sessions in the two forums was somewhat similar. In both forums, Amanda showed interest in reading higher-level posts, with slightly less attention to the lower-level posts in the visual forum. In the first session in the visual forum, Amanda was not selective in choosing which threads to visit. This was the same in the text-based forum where she visited the threads in a linear pattern from top to bottom. In addition, in both forums in the first sessions, Amanda did not reread any posts. In the second session in both forums Amanda mostly read new posts. While in the visual forum Amanda reread some of the posts within the same session, in the text-based forum she only read new posts once.

Table 5.18. Amanda's sequence of activity in the linear text-based forum in her last session. Actions with no letter are reading actions. N- New (unread) post at the beginning of the session. O- Learners own post, made in an earlier session

Order	New	Post Subject
		Valuable Lessons - Yes, The Whole Story - No
		Thoughts
		well...
	N	Cost and Media.
		Good Teacher!
10	N	Good teacher on distance education?
12	N	Thoughts on good teacher
11	N	Phone calls?
13	N	Maybe a bit misunderstanding
14	N	the role of an "on-line" instructor is different
		Students roll in high dropout rate
		Counter Argument
		Agreed
	N	Other factors to consider
		Some thoughts about distant education at university
		Inseparable
	O	my simple thoughts
		Pros and cons to Noble
		Distance Ed. is not always wrong.
		Distance Ed not necessarily wrong / Could some points in the article be?
		Selling Out Education
		why buy from craigslist-why not a dealer?
		Example of being swindled.
		Both can be good and bad
		Alternative methods of learning
		Might benefit specific learning style
1	N	Is it possible to educate yourself?
2	N	yes...and no.
3	N	Get in trouble
4	N	Should not instructors fees?
5	N	human interaction does not only exist between students and teachers
6	N	Online education vs Self education
7	N	Ways of interacting
8	N	Universities, Educational Value and DE
		Is face to face learning inherently better than distance ed?
		Quality vs quanity
	O	Hi ...
		Anecdotal numbers from a VLN teacher
9	N	More about drop out rates

In summary, in both forums Amanda was not very selective in deciding which thread to visit. Furthermore, Amanda's behaviour in both forums suggested interest in reading only new posts. However, in some cases in the visual forum she read the first-level posts before reading the lower level replies while in the text-based interface she ignored the first-level posts (possibly because she had read them before).

5.8. Christine

5.8.1. Christine's activity in the Visual Forum

Overview

Christine spent a total of 31 minutes in the visual forum in her two sessions (see table 5.19). In her participation in this forum, she opened 29 posts (74% of all 39 posts) in 18 minutes, and made one new post. In the first session, Christine opened 11 different posts in 4 threads (46% of 24 available posts in 9 threads). In the second session, Christine opened 20 different posts in 8 threads (51% of 39 available posts in 10 threads). Two of the posts she opened were ones she had opened before, and 18 were new posts.

Table 5.19. Overview of Christine's activity in the visual and linear text-based forums in the selected week.

	Overall		First Session		Last Session	
	Visual	Text	Visual	Text	Visual	Text
Total time (h:mm)	0:31	*	0:23	0:02	0:08	0:03
Reading Time (h:mm)	0:18	0:05	0:10	0:02	0:08	0:03
# of unique posts read	29	7	11	3	20	4
% of posts read	74%	18%	46%	9%	51%	10%
Average time reading a post (m:ss)	0:37	0:43	0:55	0:40	0:24	0:45
# of posts made	1	1	1	0	0	0
Time of rereading posts (h:mm)	---	---	---	---	0:01	0:00
# reread posts	---	---	---	---	2	0
Time of reading new posts (h:mm)	---	---	---	---	0:07	0:03
# of reading new posts	---	---	---	---	18	4

* Christine total time in the text-based forum was not available. Please see overview section of her activity in the text-based forum for more details.

Reading Patterns

Session One

Figure 5.7 (a) illustrates the sequence of Christine's activity in her first session in the visual forum. Christine had a complete radial reading pattern in this session. She visited four threads without any order (e.g. clockwise or counter clockwise) and read all of their posts in a radial pattern. For each thread, first she read higher-level posts, then their replies (e.g. actions 3-6, 7-11). On average she spent less than a minute on each post. She made her only post at the end of the session, replying to one of the posts she had read earlier in the session.

Session Two

Figure 5.7 (b) illustrates the sequence of Christine's activity in her second session in the visual forum. Christine started by visiting the new thread that was added to the discussion in this session. In general (with a few exceptions) she read the posts in a radial pattern. However, her behaviour was not as complete as in the first session. In addition she did not always read the replies in their order. Sometimes she read all posts in a thread in their reply order (e.g. actions 15-18, 24-26). In some cases, she did not read all posts in a thread (e.g. actions 19-21). In addition, in a few cases she did not read the posts in their reply order (actions 4-8).

5.8.2. Christine's previous activity in the linear text-based forum

Overview

In the linear text-based forum, Christine had three sessions in the focal discussion (see Table 5.19). In total she spent a very short amount of time (5 minutes) reading others' posts. She opened 7 different posts (18% of 39 total posts in the discussion) and created one post. In the first session, Christine made one post and left the discussion without reading any posts. As described earlier in the methods section, the duration of the last action in each session was estimated as an average for that type of action for each student. Because Christine had only one posting action and it was at the end of session (the only action in the session), there was no data to calculate the average for Christine's posting action. Thus her posting

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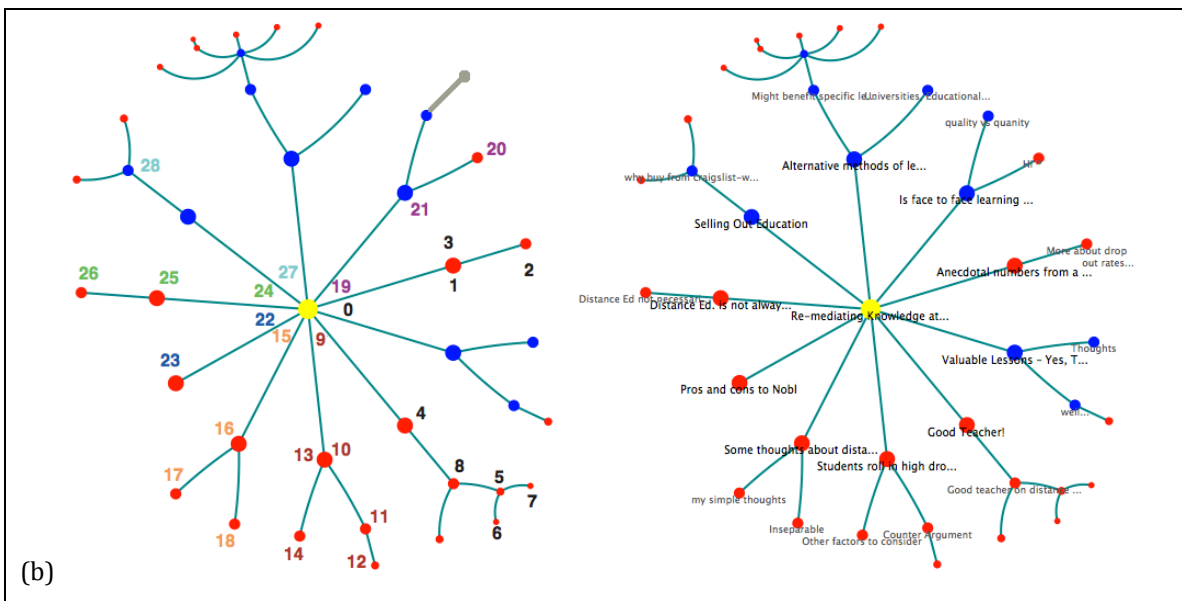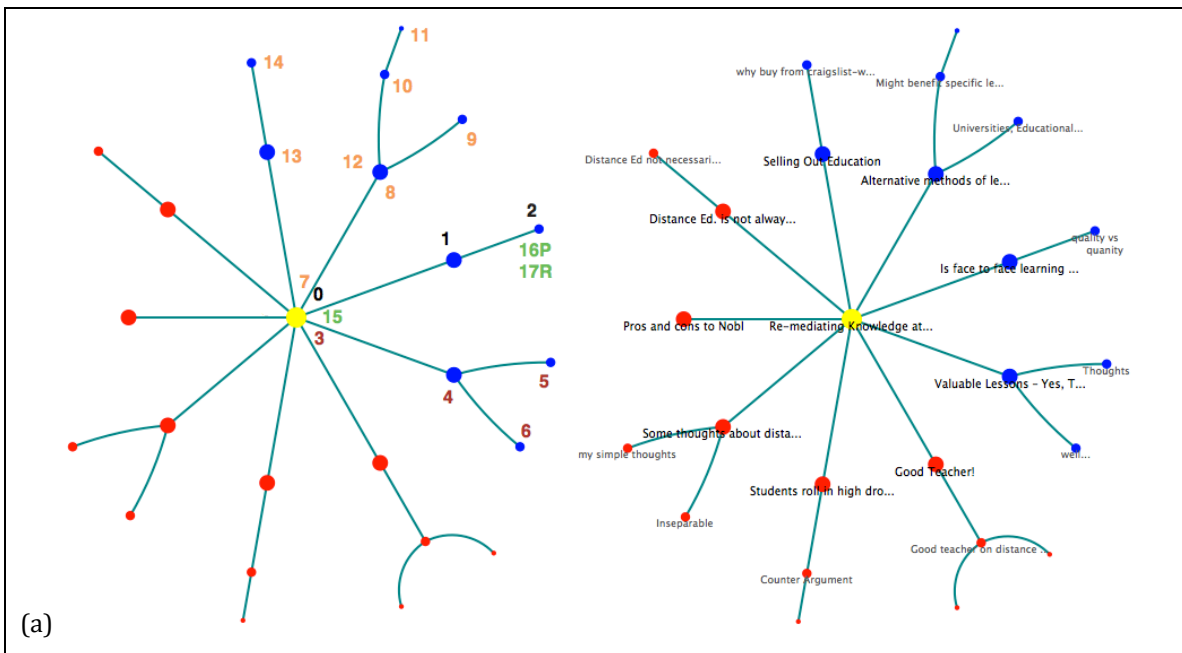
Figure 5.7. The left images illustrate Christine's activity in the visual forum (a) in the first session (b) in the second session.

The left images shows the sequence of her actions while the right images present the discussion structure including posts' subject for each session; blue nodes show posts read in the first session while red nodes indicate posts that were not read in the first session; gray nodes represent any posts made by the participant in the first session; numbers represent the sequence of actions in each session; numbers without a letter are reading actions; P represents a posting action; the colour of numbers changes each time student went back to the discussion prompt to show different segments of activity.

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time (and consequently her total time) were not calculated. As described in the methods chapter, her first session with only one posting action was not used as a comparison point. Instead her first session with more than one action is reported in this section. In this session, she opened 3 posts in 2 threads (9% of 33 available posts in 10 threads). In the last session, Christine opened 4 different posts in 3 threads (10% of 39 available posts in 10 threads). All posts Christine opened in the second session were new posts.

Reading Pattern

First Session (with more than one action)

Table 5.20 shows the structure of the discussion at the time Christine visited the linear text-based forum, and the sequence of her activity. In this session, which only lasted two minutes, she first opened the two replies to her earlier post (actions 1-2), then opened the first post in the list (action 3), and left the discussion.

Last Session

Table 5.21 shows the structure of the discussion in the linear text-based forum at the time Christine visited the discussion for the last time, and the sequence of her activity. In this short session, which lasted only 4 minutes, she opened four new posts. The first two posts were the first-level posts of the last two threads in the forum. The second two posts were a first-level post and its reply in the middle of the forum. She did not reread any posts in this session.

5.8.3. Comparing Christine's activity in the visual and linear text-based forums

Comparability of sessions

Because of the very short amount of time Christine spent in the text-based forum, she did not have a clear reading pattern in this forum. However the number of available posts in the second session in both forums was the same. Thus it might be useful to compare her reading patterns in the second sessions.

Table 5.20. Christine's sequence of activity in her first session in the linear text-based forum. Actions with no letter are reading actions.

Order	Post Subject
3	Valuable Lessons - Yes, The Whole Story - No
	Thoughts
	well...
	Good Teacher!
	Good teacher on distance education?
	Thoughts on good teacher
	Phone calls?
	the role of an "on-line" instructor is different
	Students roll in high dropout rate
	Counter Argument
	Agreed
	Some thoughts about distant education at university
1	Inseparable
2	my simple thoughts
	Pros and cons to Noble
	Distance Ed. is not always wrong.
	Distance Ed not necessarily wrong / Could some points in the article be?
	Selling Out Education
	why buy from craigslist-why not a dealer?
	Example of being swindled.
	Both can be good and bad
	Alternative methods of learning
	Might benefit specific learning style
	Is it possible to educate yourself?
	yes...and no.
	Get in trouble
	Should not instructors fees?
	human interaction does not only exist between students and teachers
	Universities, Educational Value and DE
	Is face to face learning inherently better than distance ed?
	quality vs quanity
	Anecdotal numbers from a VLN teacher
	More about drop out rates

Similarities and differences

In the visual forum, Christine generally displayed a radial reading pattern; she read the posts mostly in their reply order, and she mostly read all posts in a

Table 5.21. Christine's sequence of activity in the linear text-based forum in her last session. Actions with no letter are reading actions. N- New (unread) post at the beginning of the session. O- Learners own post, made in an earlier session

Order	New	Post Subject
		Valuable Lessons - Yes, The Whole Story - No
	N	Thoughts
	N	well...
	N	Cost and Media.
	N	Good Teacher!
	N	Good teacher on distance education?
	N	Thoughts on good teacher
	N	Phone calls?
	N	Maybe a bit misunderstanding
	N	the role of an "on-line" instructor is different
	N	Students roll in high dropout rate
	N	Counter Argument
	N	Agreed
	N	Other factors to consider
	O	Some thoughts about distant education at university
		Inseparable
		my simple thoughts
	N	Pros and cons to Noble
3	N	Distance Ed. is not always wrong.
4	N	Distance Ed not necessarily wrong / Could some points in the article be?
	N	Selling Out Education
	N	why buy from craigslist-why not a dealer?
	N	Example of being swindled.
	N	Both can be good and bad
	N	Alternative methods of learning
	N	Might benefit specific learning style
	N	Is it possible to educate yourself?
	N	yes...and no.
	N	Get in trouble
	N	Should not instructors fees?
	N	human interaction does not only exist between students and teachers
	N	Online education vs Self education
	N	Ways of interacting
	N	Universities, Educational Value and DE
2	N	Is face to face learning inherently better than distance ed?
	N	Quality vs quanity
	N	Hi ...
1	N	Anecdotal numbers from a VLN teacher
	N	More about drop out rates

thread. She did not seem to follow any particular order to decide which threads to visit. In addition, Christine reread a few posts in the visual forum even within a session. In contrast, in the text-based forum she only read new posts.

5.9.   Summary of students' reading patterns

The next sections summarize students' reading patterns in the visual and text based forums. Table 5.22 also summarizes students' reading patterns these forums.

5.9.1. Students' reading patterns in the visual forum

In the visual forum students had two general approaches to reading posts: radial and circular. In a radial pattern the student read posts in a thread from the higher-level posts to the lower-level ones. In a circular pattern the student read first-level posts in a circular pattern either clockwise or counter clockwise. All students showed some evidence of a radial reading pattern at some point in their sessions. A radial reading pattern could be either complete or incomplete. In a complete radial pattern a student read all posts in each thread they viewed, going from higher level posts to the lower level ones. For example Nicole and Christine showed a complete radial pattern. Other students such as Emily, Mike, and Steve had an incomplete radial reading pattern. In an incomplete radial pattern, students read posts in the thread in their reply order (from higher level to lower level posts), but they did not read all of the posts in the thread.

In a few cases (e.g. David's first session), students showed a circular reading pattern. In a circular reading pattern students visited the first level posts in each thread in a circular pattern (either clockwise or counter clockwise) before reading any lower level posts. For example David, read all first level replies in a counter clockwise direction but he only read two second level posts.

In deciding which threads to visit, several students were not active in choosing threads, and let the interface decide for them (based on the order that

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Table 5.22. Summary of students' reading patterns in visual and text-based forums.

Student		Visual Forum	Text-based Forum
Emily	Overall pattern	Incomplete radial reading pattern Actively chose threads to read	Mostly linear reading pattern
	New posts (last session)	Read new posts but re-read their higher level posts first	Only had one session
David	Overall pattern	Circular (1st session), complete radial (2nd session) reading patterns Actively chose threads to read (2nd session)	Mostly Linear reading pattern
	New posts (last session)	Read new posts but re-read their higher level posts first	Read only new posts located at the end of the list, ignored first level posts
Mike	Overall pattern	Incomplete radial reading pattern Actively chose threads to read	Selective reading pattern
	New posts (last session)	Read new higher level posts first then their lower level replies	Only read replies to his posts
Nicole	Overall pattern	Complete radial pattern Actively chose threads to read	Linear reading pattern
	New posts (last session)	Read new higher level posts first then their lower level replies	Only read replies to her posts
Steve	Overall pattern	Incomplete radial reading pattern Non-selective in choosing threads: used clock metaphor	Linear reading pattern, only read first level posts (1st session)
	New posts (last session)	Read new higher level posts first then their lower level replies	Mostly re-read posts
Amanda	Overall pattern	Mix of circular and radial reading patterns	Linear reading pattern
	New posts (last session)	Mostly read new posts	Only read new posts, ignored first level posts
Christine	Overall pattern	Complete radial pattern Actively chose threads to read	No clear reading pattern
	New posts (last session)	Mostly read new posts, in some cases from higher level to lower level	Only read new posts

threads appeared on the screen). Students who had a circular reading pattern (David's first session and Amanda in her both sessions) and Steve who had an incomplete radial pattern but used a clock metaphor in deciding which threads to visit fall into this category.

In contrast, some students who had a radial pattern in reading posts did not follow any clear order (e.g. clockwise or counter-clockwise) in visiting threads. Students' selections may have been based on other factors such as a post's subject, or students may have selected threads randomly. Either case suggests that students were actively (at different levels) choosing which threads to read and did not let the interface decide for them. Emily, David (in his 2nd session), Mike, Nicole, and Christine fall into this category.

In reading new posts in the second session, only two students (Emily and David) re-read higher-level posts that they had read previously before reading their new lower-level replies. Other students mostly read just new posts in the second session. While these students were interested in reading new posts, most of them (Mike, Nicole and Steve) read new first-level posts first. Thus while students showed different strategies and interest in reading new posts, most students (Emily, David, Mike, Nicole, and Steve) read higher level posts (whether new or not) before reading the new lower-level replies.

5.9.2. Students' reading patterns in the text-based forum

In the text-based interface, most students had a linear reading pattern. In general, students with a linear pattern read threads and their posts from top to bottom. Thus while students read the posts within a thread from higher-level to lower-level posts, they visited threads based on the order they appeared on the screen. This suggests they did not actively select which threads to visit or which posts to read and let the interface decide for them. The only exceptions to the linear pattern were Mike and Christine. They read threads and posts without a clear pattern, possibly based on other factors such as a post's subject or author, or perhaps randomly.

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In reading new posts in the last session, only one student (Steve) reread posts. Two students (Mike and Nicole) only read replies to their posts and other students (David, Amanda and Christine) only read new posts.

6. Discussion and Conclusion

In this chapter, I compare students' overall reading patterns in the visual and text-based forums. This comparison allows me to address the original research questions with regard to how the visual forum influences students' reading patterns in online discussion forums, first with regard to their decisions about which threads to visit and which posts to read, and second with regard to reading new posts in the discussion. Following the comparison of reading patterns, I evaluate the visual interface with respect to the thesis design goals and prior findings in the literature. I conclude with a discussion of the limitations of this study, and implications for future research and practice.

6.1. Comparing reading patterns in visual and text-based interfaces

Students' reading patterns in the visual and text-based interfaces can be compared with respect to the two research questions:

- How does the visual forum change students' reading patterns regarding which threads to visit and which posts to read?
- How does the visual forum influence students' behaviour in reading new posts?

6.1.1. Visiting threads and reading posts

Generally, in deciding which threads to visit students appeared to be more selective in the visual interface than the text-based interface. Most students in the

visual forum (Emily, David in his 2nd session, Mike, Nicole, and Christine) did not follow any clear order in visiting threads, suggesting that they actively selected which threads to visit. In contrast, in the text-based forum only a few students (Mike and possibly Christine) were selective in choosing threads, while most students displayed a non-selective linear pattern. The linear presentation of threads in the text-based forum is most likely the reason that students had a linear reading pattern; students simply read the posts from the top of the list to the bottom. They followed the order presented by the interface instead of actively choosing which threads and posts to read.

In the visual forum, only a few students (David in his 1st session and Steve in both sessions) read posts based on the presentation of the threads in the visual interface (circular pattern or clock metaphor). In contrast, most students actively chose which threads to visit. This suggests that the non-linear visual presentation of threads via hyperbolic tree, which does not have one salient order in presenting threads and posts, encourages students to find factors other than the location of posts on the screen (e.g. high-level post's subject) to decide which threads to visit.

In the text-based forum, two students (Mike and Nicole) had a different strategy in selecting which threads to visit in their last session, which was not observed in the visual interface. They only visited threads containing a reply to their own posts. Because students participated via the visual interface in a lab setting with a short break between two sessions, and no one replied to their posts between the first and second sessions, it is not possible in the current study design to investigate whether the visual interface might influence this reading behaviour or not.

6.1.2. Reading new posts

As explained in Chapter 2, it is important for students to read new posts because they are source of new information. However, if students *only* read new posts (new post bias), they may not be able to connect the ideas in the new posts to the content of the posts that they read before. Thus, re-reading or skimming the

higher level posts (even if they had read them in a previous session) before reading the new lower-level posts may help students to understand the lower level post in its context, and thus be more likely to connect the new information in the posts with the related concepts.

In general, students showed interest in reading primarily new posts in their last sessions, regardless of which interface they were using. However, their strategy in reading new posts differed between the two forums, and also between students. In the visual forum some students made an effort to re-read higher-level posts that they had read in a previous session, before reading their new replies. For example, David was interested in reading new posts; but he decided to read their higher-level parents first to refresh his memory about the posts' content before reading the new lower-level replies. David's behaviour is an example of a productive behaviour of reading new posts in their context, thus connecting the ideas between read and new posts. In contrast, in his last session in the text-based forum David only read new posts from end of the list in a linear pattern, showing a classic example of new post bias.

There were also differences between the two interfaces in students' reading patterns in the second sessions even when students only read new posts. In the visual interface, some students (Mike, Nicole and Steve) first read new first-level posts in each thread, then the lower-level replies. This suggests that even though students were interested in reading new posts, they were aware of the structure of the discussion and did not make their decision based *only* on the newness of the posts. In contrast, students who read only new posts in the text-based forum (David, Amanda and Nicole) ignored the first-level posts and started reading new posts from the lower-level reply posts. The only exception was Christine, who mostly read new first-level posts.

In the text-based interface, one student (Steve) mostly re-read posts that he had read in the previous session and ignored most of the new posts in the discussion. Thus while he did not exhibit the problem of new post bias, he ignored the new information in the discussion, which is also a problematic behaviour.

6.2. Evaluating the visual interface with respect to the design goals and prior research

Evaluation of the interface based on the students reading patterns, design goals and prior research is presented with respect to three elements: selecting threads to visit, reading posts with in a thread with respect to the new posts, and other design aspects.

6.2.1. Selecting threads to visit

One of the main differences in students' reading behaviours between the two forums was the nature of their choices about which threads to visit. In the visual interface students often actively selected which threads to visit, while in the text-based interface students often had a linear reading pattern that essentially let the interface decide for them. This suggests that students' decision in selecting which threads to visit is influenced by features of online environment (Swan, 2003; 2004), such as presentation of threads posts via the interface. This emphasizes the importance of the method of presentation of posts in the discussion.

As described in Chapter 3, one of the design goals of selecting a hyperbolic tree was to highlight the structure of the discussion. Active selection of threads in the visual forum suggests that the hyperbolic tree was successful in this respect. A hyperbolic tree displays the entire discussion on the screen, which allows learners to get an overall sense of the discussion and threads. For example, students are able to recognize threads with more posts. This can increase the learners' reviewing speed of the discussion (Kim & Johnson, 2006) and lead to better understanding of the discussion (Teplovs, 2008).

In addition, changing the presentation of threads and posts from a linear presentation with a default order to a visual presentation (hyperbolic tree) with a less salient ordering encourages students to be more active in deciding which threads to visit and decide based on other factors (e.g. post's subject, number of posts in a thread). This may be because it helped students to visualize the structure

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of the discussion and see the relationships between posts. This aligns with Kear's (2001) finding that highlighting the structure of the discussion in a visual presentation can help students have a more connected and coherent discussion.

6.2.2. Reading posts within a thread with respect to the new posts

As described earlier, in the text-based interface, which presented posts in a linear list, students often had a linear reading pattern. The same group of students in the visual forum often had a radial reading pattern. While these reading patterns may look different, in both of these patterns students read posts from higher-level to lower-level posts within a thread. This suggests in both cases students let the interface decide for them which posts to read within a thread and their decisions are influenced by features of the online environment, such as the presentation of posts via the interface (Swan, 2004). This emphasizes the importance of the method of presentation of posts in the discussion.

In the current study, students showed interest in reading new posts regardless of the interface provided. These findings confirm Hewitt's (2003; 2005) and Chan et al.'s (2009) findings that students have a tendency to read new posts. As explained earlier, reading new posts is necessary as a source of new information, but reading *only* new posts is unproductive and has negative educational consequences (Hewitt 2003; 2005). While past research has documented the new post bias problem by reporting the results in aggregate, the current study expands the understanding of this problem by showing individual reading patterns in dealing with new posts as well as implementing and evaluating a solution for this problem.

Although in the visual interface students showed interest in reading new posts, they had different strategies from the text-based forum in how they did so. Analyzing these patterns in detail revealed that despite prior findings about new post bias, reading only new posts might not be always an unproductive behaviour. For example in some cases while students read only new posts, they read new first-level reply posts first before new lower level posts. This suggests that these students are taking into account the structure of the discussion in reading new posts. While reading new and scattered posts may result in an incomplete understanding of the

discussion, reading new but connected posts (from higher level to lower level posts) may not be problematic. This behaviour may result in a reasonably comprehensive understanding of the thread, because the student reads a sequence of connected posts in their reply order. This pattern (attention to the higher level posts when reading new posts) was only observed in the visual forum. These findings indicate that the visual presentation of the discussion via hyperbolic tree led to more attention to the higher-level posts and may provide a solution to the unproductive behaviour of reading new, scattered posts in an online discussion.

As described in Chapter 3, one of the goals of selecting a hyperbolic tree interface was to highlight the structure of the discussion and attract students' attention to higher-level posts. A hyperbolic tree presents the higher-level posts with larger nodes. Higher-level posts are more likely to have logically prior ideas, and thus may be important to read before their replies. The radial reading pattern, which was the most common reading pattern in the visual interface, involves reading higher-level posts before their lower level replies.

Another design choice in constructing the hyperbolic visual interface was the use of colour to differentiate between new and read posts. Colour was used in combination with node size in the hyperbolic tree, which represented the reply level of posts. The purpose of these decisions was for students be able to find new posts as source of new information while avoiding new posts attracting too much attention (ie. more than higher-level posts). In the visual interface, even when students were interested in reading new posts, most of them read higher-level posts first. Thus the representation of higher-level posts attracted more attention to them, compared to the new posts. While the visual interface did not prevent reading new posts, the patterns of reading new posts were different between the visual and text-based interfaces. Furthermore, the fact that two sessions in the visual interface were close to each other in time may have increased reading new posts in the second session simply because the students still remembered what they had read in the first session, and did not have a strong need to re-read the posts. In future research, it would be desirable to test the current visual interface through sessions with more elapsed time between them.

In the investigation of new post bias in this thesis, another novel behaviour was observed that has not been reported in prior research. Steve, in his last session with the text-based interface, mostly re-read the posts he had read in an earlier session, while ignoring new posts. Although reading only new posts is an unproductive behaviour, ignoring new posts and only re-reading old posts is also not productive. If a student ignores new posts, his understanding of the discussion would be limited and not current with the rest of the group.

6.2.3. Other design aspects

As explained in Chapter 3, designing a forum involves more than just deciding on a method for presenting the structure of the discussion and differentiating between new and read posts. It also includes deciding what and how to display posts' attributes (e.g. date/time, author, subject), how to display the posts' content and the reply box, etc. In this section I discuss these design aspects of the visual forum examined in this thesis, based on the students' feedback.

Integrated display. In the design process I decided to integrate all components of the visual interface into one screen. Presenting the structure of the discussion, the posts' content, and the reply form in the same window allowed the learners to read and reply to the posts in the context of their connections to other posts. This feature was pointed out by students a useful feature of the visual forum. They found the reading and replying functions well-integrated. In addition, the reply box content did not change in viewing different posts. Thus, a student could start composing a post when reading one post and continue it when reading another post. However, this was not mentioned by students possibly because they did not realize or use it. The benefits of this feature can be further investigated by making students aware of it and by assigning specific tasks (e.g. summarizing).

Finding a post. One of the problems some students had with the visual interface was finding a post that they had read before. This problem may have several causes. In the non-linear presentation of the posts in the visual interface, each time students clicked on a post, that post moved to the centre of the screen. Students believed that these movements were the main reason that they couldn't

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find a particular post that they were looking for. In addition, when a thread and a few posts were added to the discussion (between the first and second sessions), the visual presentation of the hyperbolic tree changed to adjust with the new structure. This change in the location of the threads and the posts might also have caused some disorientation. The fact that all posts' subjects were not fully displayed might also have played a role. This problem might be one of the main weaknesses of this visual interface. The visual interface may have weaknesses in some respects that are offset by benefits in other areas. These task-specific benefits and weaknesses should be investigated further, and will be discussed in the section on future research.

Displaying posts' subject and author. The visual forum did not display the author's identity and full post's subject (if it was long). Some students pointed out that they preferred to see the author's name and also the complete post's subject. While there might be some benefits in not showing the post's author (e.g. students will decide which posts to read without any bias about the author), this aspect should be further investigated by comparing students' reading patterns under two conditions: one with and one without the authors' names displayed. In addition, not showing the full subject of the posts made some students curious to open the posts; once they opened the posts they would at least skim them. However, some of them preferred to see the full title before deciding to open a post. Despite the benefits or weaknesses of showing posts' full subjects and authorship, there is a visualization challenge in adding this text-based information to the hyperbolic tree. This also can be investigated in future research.

6.3. Limitations

In this section, I discuss the limitations of this study, which were mostly related to the comparability between the visual and text-based forums at different levels.

Establishing the comparability of sessions was a substantial challenge in this study. Sessions were different in number and duration between the two interfaces for each student. While students had only two sessions in the visual interface, in

most cases the number of sessions was greater in the text-based interface, which was used under naturalistic conditions. In addition, time on task for the visual and text-based interface could not be made comparable. The lab session (for the visual forum) was limited in time, but isolated from other distractions. Students' participation via the text-based forum in the course discussion was not limited and they were able to participate in more than two sessions, thus some students spent more time in the selected discussion week.

The elapsed time between different sessions was also different between forums. The two lab sessions in which students participated in the visual forum were very close to one another in time in order to avoid losing participants. If students had participated in two sessions with a longer time between them (e.g. a few days) it is possible that they would have read fewer new posts, or re-read more posts in their second session of the discussion because they would more likely have forgotten the content of the posts. In addition, because in the visual forum there was no possibility of adding replies to students' posts between the first and second sessions, it was not possible to examine the influence of replies to one's own posts.

In the text-based interface, especially in the first session, students might already have written their personal reactions to the assigned reading in an external tool (e.g. Word) before logging in to the forum. Thus, they logged in with the intention of creating a top-level post before reading any other ones. This explains why in some cases students created a top-level post in a short time without reading any other posts. However, this does not influence the rest of their reading pattern in the first session, or their behaviour in the last session.

An attempt was made to maximize the comparability of sessions, as described in the Methods section. In addition, for each student the selected sessions were evaluated to ensure that the sessions were comparable. Adjustments were made in a few cases as described in the results.

Another challenge in this study was the authenticity of the assigned task for the participants in the lab settings. I used a hybrid method and asked students to interact with a discussion that they had participated in for a course before. Although this improved the authenticity of the task, it limited the number of the students that

could be invited to participate in the study. Nielsen (1994) notes that three to five test users can provide the most useful feedback in testing a system, and that adding more users would most likely provide similar feedback. By this rubric, the number of participants (seven) in this study is not low.

With the lab sessions, I was able to record screen capture and think-aloud data. In the text-based forum, the lack of observational data (e.g. screen capturing or think aloud data) limited my interpretation of students' reading behaviours. On the other hand, while asking participants to talk while they interacted during the lab sessions added some depth to the interpretation of the clickstream data, it might also have added an extra cognitive load for them. This may have influenced their reading behaviour. However, students did not always explain the reasons behind their actions in the think aloud data as was expected.

6.4. Implications for future work

6.4.1. Design of a visual forum

This thesis took a first step in designing a visual interface to reduce new post bias in online discussion forums. While the design was successful in highlighting the structure of the discussion for participating students, their strategies in dealing with new posts and their feedback on the interface raised some concerns that require further investigation.

First, because of the lack of screen real estate in the visual representation, the identity of posts' authors was not displayed in the interface. In the design process, I was forced to choose between the post's author and the subject. Because displaying the post's subject seemed more important (it is most likely to be related to the post's content), I chose to display the subject instead of the author. I also reasoned that there could be some benefits in not displaying each post's author, because students would decide which posts to read without any bias about the author. However, several students pointed out that they were used to using the author's name to decide which posts to read.

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Due to the lack of space in the hyperbolic tree for text (especially in the lower levels), adding any kind of information requires substantial changes in the design of the visual forum. The merits of such changes can be further investigated. For example, with a limited number of discussion participants, the author's identity can be indicated visually (e.g. via different node shapes or colours). In addition, not showing the full posts' subjects (for long subjects) also created some concerns. Finding a way to represent this information and integrate it with the visual representation of threads and posts may be the next step in improving the visual interface.

A second concern in the visual interface was that several students had difficulty finding a post they had read before. While in the non-linear structure of the hyperbolic tree higher-level posts received more attention, this structure may have made it more difficult for students to re-locate particular posts. Adding some features to the hyperbolic tree (e.g. allow students to flag specific posts by changing the colour) may help students in this regard. However, the visual interface may be more useful for some purposes, and less useful for others. This suggests the need to design task-specific interfaces that can benefit the learner in specific situations. Following this idea, forums may have different interfaces (visual, text-based, or some other kind) that can be used for different tasks. Students would be able to switch between them to accomplish different objectives.

The last design suggestion is with respect to illustrating different posts. In addition to differentiating between new and read posts, other types of differentiation may be beneficial in the visual interface. For example, providing a way to display student's own posts, the instructor's posts, posts based on the content (e.g. agree or disagree), or the function of posts in the dialogue (e.g. synthesizing posts) may help students to navigate an online discussion.

6.4.2. Future Research

Although for the first examination of the visual interface it was important to record students' interactions with the interface in detail (e.g. screen capturing and think-aloud data), in order to improve the design, using the visual interface for a

real class discussion may provide more useful information about its benefits and limitations. For example, one of the limitations of this study was authenticity of the task, which would be addressed in a more naturalistic context. Furthermore, the two sessions in the visual forum were close to each other in time. Using the visual interface for a class discussion would address this issue. This would require some improvement of the technical implementation of the forum; but by using the visual interface for a class discussion, new reading patterns may be observed.

Investigating the benefits or weaknesses of displaying different information (e.g. the post's author or subject) in the visual interface in different situations is another area for research. Some of this information may be beneficial for specific tasks. In addition, asking students to perform specific tasks during data collection would help future researchers to understand the benefits and weaknesses of the visual forum in different situations. For example, while the visual interface highlights the structure of the discussion, several students had problems finding the posts they had read before. Asking students to carry out specific tasks would help to understand such problems and inform changes to the visual interface. In addition, assigning different roles in the discussion (e.g. a synthesizing role) may be investigated in the visual forum. The visual forum may be more beneficial for some roles than others.

This study was primarily focused on student reading patterns. Another aspect of students' behaviour is their replying pattern, which may be influenced by the interface. Future research should investigate the differences in student replying patterns in the visual and text-based forums. In addition, the quality of individual posts is likely to be influenced by students' reading behaviours. If students read more connected posts and gain a better understanding of the discussion, they may create better posts. Evaluating the quality of posts in the visual forum and comparing them with those produced in a text-based interface may provide insight into the question of if the visual interface can improve the quality of posts.

6.4.3. Implications for Practice

While in the visual forum some students actively chose which threads to visit, within a thread many students in both interfaces followed the interface's implicit choice in the order of reading posts (radial pattern in the visual forum, and linear pattern in the text-based forum). Thus it seems that students in general let the interface decide the order in which they will read posts.

Because the forum interface influences students' reading behaviours, it is important for instructors to choose a forum that pedagogically supports their assigned tasks. In most cases, instructors believe choosing a forum is more of a technical task than an instructional one. I speculate that they are more likely to choose the most accessible forum, and underestimate its educational consequences for students. If they were more aware of the influences of the interface on the development of online discussions, instructors might put effort into finding an appropriate forum for a class.

In addition, the fact that students are not active in deciding which posts to read makes the instructor's decisions about assigning tasks and roles in the online discussions more important. For example, simply asking students to discuss the week's topic may not be the best way to engage students in a meaningful discussion, depending on the prior preparation of the students. Assigning tasks or roles aligned with the learning goals may help students. Assigning specific roles has been shown to increase interactions between students in some settings (Hara et al., 2000; Seo, 2007), which may lead to a more meaningful discussion. For example, assigning synthesizing or summarizing tasks may encourage students to read more posts and not ignore some of them. In addition, by creating and labelling a summary post, students are more likely to read that post and get a sense of the discussion, even if they did not read some posts. For these reasons, a synthesizer role can lead to higher levels of knowledge construction in discussion forums (Wise & Chiu, 2011).

6.5. Conclusion

Drawing on the literature from both online discussions and information visualization, in this thesis I designed a visual interface for a discussion forum and studied students' reading behaviours in this visual forum as compared to a more standard text-based linear discussion forum. The design goals for the visual interface were to highlight the structure of the discussion and increase students' attention to higher-level posts. In addition, there was an attempt to prevent the unproductive behaviour of new post bias, which previous authors have argued can have negative educational consequences.

In reading posts within a thread, students in the visual forum in general showed a radial reading pattern. In the text-based forum, most students showed a linear reading pattern. This suggests that in both interfaces students were influenced by the method of presentation of posts in the interface, and within a thread essentially let the interface decide for them the order of posts to read.

Studying students' reading patterns in the visual forum and comparing them with students' past participation in the text-based forum revealed that students' reading patterns appeared to be different in the visual interface. In the visual interface students more actively selected which threads to read, as compared to the text-based interface. In addition, despite the primary design goals of preventing unproductive behaviour of new post bias, students' attention to new posts was still high in the visual forum. However, the negative consequences of reading only new posts may have been minimized by the method of visually presenting the structure of the discussion, since more students (re)read higher level posts prior to reading new ones. Thus in this regard, the hyperbolic tree design appeared to be successful in representing the structure of the discussion to participants. Students' feedback also supported this design decision, but raised concerns about some of the design features that should be investigated in future research.

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Appendices

Appendix A – Survey Questions

This survey is part of testing the visual discussion forum and asks participants about their experience with the visual interface.

Q1 .   Is English your first language? (Yes/No)

Q2 .   For each of the following statements, mark one box that best describes your reactions to the discussion forum.

	Strongly Disagree	Somewhat Disagree	Slightly Disagree	Slightly Agree	Somewhat Agree	Strongly Agree
I would like to use this discussion forum If I had a course with online discussion :						
I found this discussion forum unnecessarily complex :						
I thought this discussion forum was easy to use :						
I think that I would need assistance to be able to use this discussion forum :						
I found the reading and replying functions in this discussion forum were well integrated :						
I thought there was too much inconsistency in this discussion forum :						
I would imagine that most people would learn to use this discussion forum quickly :						
I found this discussion forum cumbersome/awkward to use :						

I felt confident using this discussion forum :					
I needed to learn a lot of things before I could get going with this discussion forum :					

Q3 . What were the most useful features of this discussion forum? Why?

Q4 . What were the downsides of using this discussion forum? Why?

Q5 . How, if at all, did you find your use of this discussion forum different from your original interactions in the EDUC 899 discussion tool?

Appendix B – Consent Form

RESEARCH CONSENT FORM (2011s0367)

Design, Implementation and Testing a Visual Discussion Forum

Investigator: Farshid Marbouti, Faculty of Education, Simon Fraser University

fmarbout@sfu.ca, (778)-882-4618

By filling out this form, I consent to participate in the study "Design, Implementation, and Testing a Visual Discussion Forum".

By consenting to participate, I agree to participate in the following activities:

- Participate in an online discussion on one the topics of EDUC 890 course by reading some existing comments and contributing at least one comment of my own
- Allow the researcher to record my activity based on my participation in the online discussion forum using screen capturing and voice recording
- Complete a short questionnaire about my experience

I also give permission to the researcher to access to my discussion clickstream data in EDUC 890 course.

I also understand that:

- The goal of the project is to design and test a new visual interface for online discussion forums.
- My participation will be no more than 75 minutes
- Any information that identifies me will be kept strictly confidential. Data will be collected and stored on a secure SFU server.
- While my identity will be hidden, the comments I make in the online discussion may be read by other participants in the study
- I will not be identified by name in any reports, publications or presentations resulting from this study and upon completion of the study and any attendant publication(s), all my data will be erased or destroyed
- The investigators foresee no risks associated with my participation in the study
- I can withdraw from this study at any time

Research results can be requested from Farshid Marbouti, Master student in the Faculty of Education at fmarbout@sfu.ca or 778-882-4618. Any concerns or complaints should be directed to Dr. Alyssa Wise at alyssa_wise@sfu.ca or 778-782-8046, or Dr. Hal Weinberg, Director, Office of Research Ethics, at hal_weinberg@sfu.ca or 778-782-6593.

To summarize, by signing this form, I will consent to the following statements:

- I agree to participate in an online discussion on one the topics of EDUC 890 course.
- I agree to allow the researcher to record my activity based on my participation in the online discussion forum using screen capturing and voice recording
- I agree to complete a short questionnaire about my experience.
- I give permission to the researcher to access to my discussion clickstream data in EDUC 899 course.

In agreement with the above, I affix my signature.

Participant name:_____

Signature:_____   Date:_____