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ABSTRACT

Online discussions provide an opportunity for collaborative construction of meaning through peer to peer dialogue. The aim of this study is to develop an understanding of cognitive load as a factor supporting or inhibiting students' participation in online asynchronous discussions. We employ cognitive load theory as a theoretical perspective, applying it not only to participants' cognitive load but also to their collaboration load. Through an experimental study, we confirm that anchoring discussion leads to more task-oriented communication and less need for social and planning comments, which leaves more time and effort for the creation of elaboration and evaluation of ideas. Furthermore, anchoring discussion leads to more efficient communication as it reduces cognitive load involved in correctly interpreting messages.

Keywords

Effective online discussion, cognitive load, anchoring technology, elaboration of ideas, and evaluation of reasoning processes.

1. Introduction

Asking questions, sharing ideas, elaborating, arguing, and reaching consensus on new knowledge are all essential activities for enriching conceptual understanding of a topic in the socio-constructivist perspective on learning. As an asynchronous computer supported collaborative learning environment, online discussion allows students to gain new insights and perspectives on a topic by reading each other's ideas and by collaboratively expanding and deepening their understanding of the subject matter (DeWert et al., 2003; Mitchell, 2003; Gunawardena, 1998; Kanuka et al., 1996). Furthermore, writing messages in online discussions forces the sustained externalization of one's thoughts helping to achieve proper reflection on a topic (Dillenbourg, 1999). Therefore, online discussion forums have been argued to foster collaborative knowledge construction. However, the pressing problem in online discussions is that students often do not naturally engage in constructive interactions that are productive for learning (Guzdial, 1997; Guzdial et al., 2000; Hewitt et al., 1999; Lipponen, 1999). First, students rarely explain or elaborate on their own or others' contributions (Kanuka et al., 1996; Curtis et al., 2001; Pawan et al., 2003). Second, students are reluctant to evaluate others' ideas (Andriessen, 2006; Koschmann, 2003). Third, discussions tend to consist mostly of independent monologues instead of true knowledge construction dialogues (Pawan et al., 2003). To address this problem in the literature, we draw on cognitive load theory to develop a research model which suggests that anchoring online discussion will influence the division of learners' perception of collaboration load as well as their perceived cognitive load when working in a community of inquiry.

In the proposal under consideration, in line with Suthers (2006), we approach collaborative knowledge construction as the composition of interpretations which serve to create and modify ideational entities. The research question guiding this research is: How does anchoring technology influence negotiation of ideas in online discussions? We propose that anchoring technology will lead to more task-oriented communication and less need for social comments leaves for more time and effort for the creation of elaborations and evaluations. In addition, we assume that anchoring discussion will lead to more efficient communication as it reduces cognitive load involved in correctly interpreting messages. Our research follows a quasi-experimental design involving two groups of undergraduate students, varying technology (anchoring vs. standard discussion forum).

The article is organized as follows. The second section reviews the literature on online asynchronous discussions and cognitive load. The third section describes the anchored discussion system adopted in this study. The fourth section presents the research model and the study hypotheses. The fifth section explains data analysis and results. The paper concludes with a discussion of results, limitations of the study, and implications for future research.

2. Online Asynchronous Discussions and Cognitive Load

This section clarifies some key concepts before we put forward our notions in this research, because these concepts are essential to our proposed model.

2.1 Online Asynchronous Discussions

Prior research suggests that students perceive online discussions as more equitable and democratic than face-to-face classroom discussions (Swan et al., 2005). In addition, the asynchronous nature of the medium supports a certain level of mindfulness and a culture of reflection in online discussions because collaborative learners have an opportunity to reflect on each other's contributions while creating their own (Swan et al., 2004). But, simply adding an online discussion forum in an instructional setting does not mean students will actively engage in cognitive activities such as explanations, articulations, and argumentations (Guzdial et al., 2000). According to Piccoli et al. (2001), the appropriate use of online discussions is primarily a pedagogical issue because they support a range of different pedagogies. On one hand, an instructor following an objectivist model may use online asynchronous discussions to quickly and publicly answer student questions similar to in-class lectures. On the other hand, an instructor emphasizing the constructivist model may use online discussion forums to foster students' engagement in discourse and construction of meaning. This study takes a socio-constructivist perspective because we believe that construction of meaning is fundamentally a process within an individual mind, yet this process can be improved through contacts with other minds (Suthers, 2006). In this context, we agree with Guzdial et al. (2000) that effective discussion in an instructional setting is "cognitive," "on-topic," "on-task," and "sustained."

2.2 Cognitive Load Theory

Cognitive load is a term that refers to the load on mental resources during thinking, reasoning, or problem solving. Cognitive load theory emphasizes working memory capacity and limited attention as bottlenecks for human information processing (Baddeley, 2003; Sweller, 1988; Oviatt et al, 2006; John et al., 2003). More specifically, this theory argues that traditional instructional techniques do not sufficiently consider the limitations of working memory capacity (Schnotz et al., 2007). This theory identifies three types of load: Intrinsic, germane, and extraneous. Intrinsic cognitive load depends on the difficulty level of the instructional material which may not be altered. Germane cognitive load is associated with processing, construction, and automation of schemas. Extraneous cognitive load results from the way in which information to be learned is presented. This particular load could be reduced by mindful organization and presentation of instructional material to learners. Cognitive load theory can be understood in the following way. If intrinsic load and extraneous load are high, then total load will exceed mental resources and desired instructional activities may fail to occur. Thus, cognitive load theory has stimulated research on designing educational interfaces in order to minimize students' intrinsic and extraneous load but to maximize the germane load which is the effort that leads to learning (Oviatt et al, 2006; Paas et al., 2003; van Merriënboer et al., 2005).

At the heart of determining the level of cognitive load for performing a particular task, Paas & Van Merriënboer (1994) distinguished causal and assessment factors. Causal factors include a subject's cognitive abilities, task complexity, environment, and their mutual relations. Assessment factors consist of three measureable dimensions of cognitive load: Mental load, mental effort, and performance. Mental load focuses on the portion of cognition load that a task and environment demands. Mental effort is the cognitive capacity an individual can allocate to a task. A subject's performance is a reflection of mental demand, mental effort, and aforementioned factors.

3. Anchored Discussion System

The anchoring technology adopted in this paper for online asynchronous discussion was developed by J. van der Pol at University of Utrecht. As defined by Guzdial et al. (2000), "an anchor is a topic that students find worthy of discussion and a successful anchor is one that engenders a sustained discussion in the collaboration forum" (p. 443). Anchored forums differ from standard forums because anchored forums visually place discussions near the topic being discussed and make the connection between them explicit. The rationale for anchored forums in educational settings could be explained through situated action theory which suggests that if a student cannot communicate easily during an instructional communication, the possibility of collaborative knowledge construction will be hindered (Van der Pol, 2009).

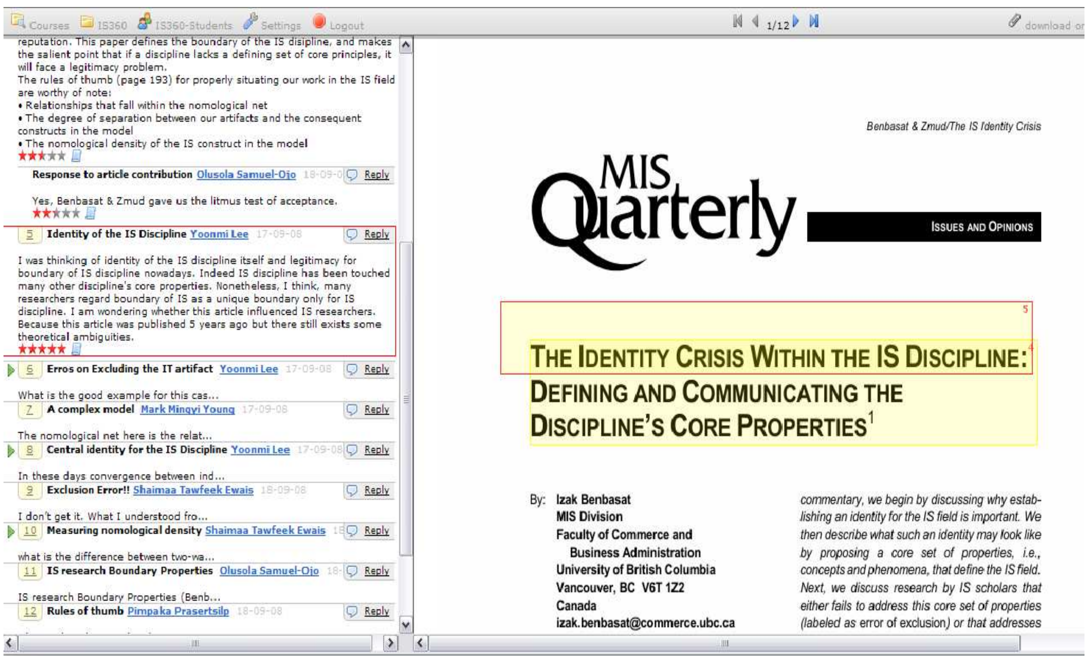

Figure 1. Adopted version of the PDF Annotation Engine (see http://www.annotatiesysteem.nl)

Several studies have shown that the anchoring technology leads to significantly longer threads than regular forum discussions (Guzdial et al., 2000; Brush et al., 2002). When investigating the underlying mechanism, Abowd et al. (1999) indicated that anchored discussions tend to be more sustained because the anchoring of collaboration to material useful to students makes the discussion more relevant to students' activities. A more recent study argued common ground, mutual understanding, and grounding as basic elements of conversation in general, and examined the functional characteristics of the adopted tool to facilitate and stimulate rich and constructive interactions Van der Pol (2009). The first element, common ground, refers to the meaning shared by communicating entities. A high degree of common ground makes a conversation flow more smoothly because it allows participating entities to assign the same meaning to a certain statement. The second element, mutual understanding, is the level of understanding that an entity has on another entity's message when replying to it. Mutual understanding is a pre-condition for effective feedback because it helps the feedback to be relevant. The third element, grounding, is the process of enhancing mutual understanding between two or more entities in a dialogue. Depending on the degree of initial common ground, the ease and success of this process can either increase or decrease. Van der Pol et al., (2006) postulated that the specialized design of the tool facilitates grounding because the on-screen presence of learning material allows students to re-read relevant sections of a document before replying to a message, and providing messages with a frame of reference assists students to interpret messages correctly.

When examining the interactions in anchored forums, Van der Pol et al., (2006) reported an increased communicative efficiency due to briefer referrals and messages containing fewer self clarifications on contextual information. Hence, Van der Pol et al. (2006) posits anchored discussion as a more useful tool than regular online discussion when used for a deep processing of literature.

A related line of research has characterized anchored discussion as artifact centered discourse. Based on Suthers (2001) anchors are shared, learner-constructed contextual representations. Suthers et al. (2003) argued that complex ideas could be explained more easily to peers through anchors. Suthers et al. (2008) pointed out that anchoring technology could improve coherence of messages by clarifying the contextual relevance of each contribution and convergence of messages by collecting together contributions referencing a given topic.

4. The Research Model and Hypotheses

Our approach is analogous to that of Van der Pol (2009) because we seek discussions focus on processing the meaning of academic text through negotiation of ideas in order to deepen students' understanding of instructional material. Figure 2 depicts our research model. Subjective cognitive load for correct message interpretation, elaboration of ideas, and evaluation of reasoning processes in online asynchronous discussions are our primary outcomes of interest.

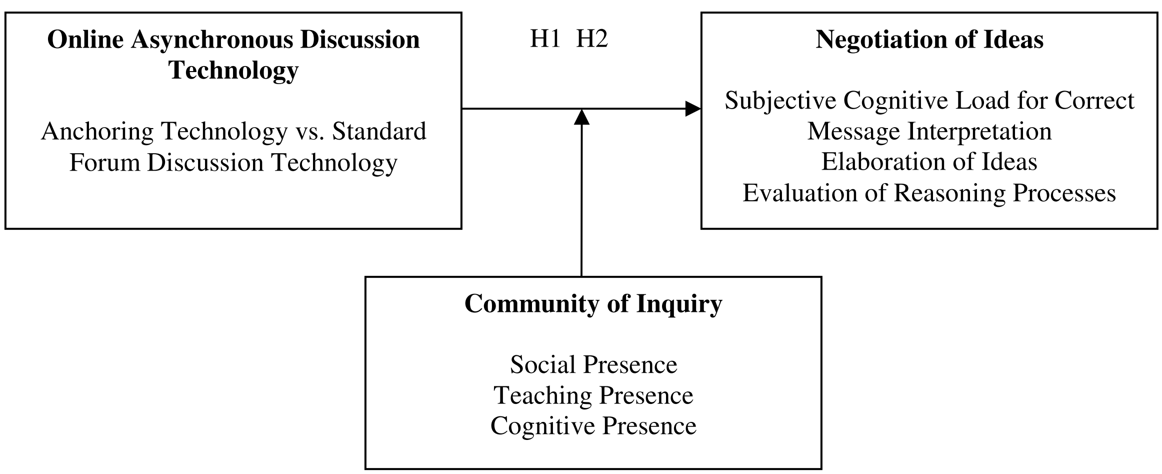

Figure 2. Research Model

Swan (2003) conceives that three types of presence as mediated through online interface are essential for negotiation of ideas within threaded discussions. Social presence refers to students' ability to represent themselves affectively. Based on Preece (2000), a lack of social presence in an online discussion can cause impersonal behaviors and hinder collaboration. Teaching presence considers design and facilitation of an online discussion by an instructor (Lui et al., 2007). Cognitive presence indicates construction of knowledge and meaning through sustained discussion by students. The primary research issue on cognitive presence is the progressive development of discussion because prior research consistently mentions that online discussions have great difficulty moving beyond simple information exchange (Garrison et al., 2007; Celetin et al., 2007; Luebeck et al., 2005). Therefore, we hypothesize:

H1: Anchoring discussion leads to more task-oriented communication and less need for social and planning comments leaves more time and effort for the creation of elaboration of ideas and evaluations of reasoning processes.

The method used to assess these activities is content analysis, which Borg and Gall (1989) described as "a research technique for the objective, systematic, and quantitative description of the manifest content of communication" (p. 357). The particular content analysis model we adopted is developed by Veerman & Veldhuis-Diermanse (2001) and validated by Schellens, T. & Valckle, M. (2005) to investigate academic discourse. This content analysis model uses messages as the unit of analysis, and it considers two types of communication in an online discussion: non-task-oriented and task-oriented. Non-task-oriented communication consists of four categories. The first category, planning, contains information about planning a task. The second category, technical, is about the technical issues related to a computer supported collaborative learning system. The third category, social, does not involve a reasoning process or justification when writing a message. The last category, nonsense, involves messages that are not related to relevant subject. Task-oriented communication includes three cognitive processing activities. The first cognitive processing activity, presentation of new information, focuses on learners presenting new ideas relevant to a discussion topic. A new idea could be about facts, experiences/opinions, or theory. The second cognitive processing activity, explanation, refers to further elaboration of earlier ideas to reflect self-explanation of learning material. The last cognitive processing activity, evaluation, reflects argumentations on reasoning processes and justifications to identify opportunities for enhancing development of elaborations.

H2: Anchoring discussion leads to more efficient communication as it reduces cognitive load involved in correctly interpreting messages.

The current research uses two rating scale assessment techniques to determine the cognitive load. Both are built on the assumption that subjects are able to reflect on their cognitive processes and to report the amount of mental effort expended (Paas et al., 2003). Short self-report instrument is a single question of overall mental load with seven point mental effort rating scale developed and refined by (Paas et al., 2003). NASA Task Load Index (TLX) builds on NASA Bipolar Rating Scale with nine subscales. NASA-TLX measures workload via six subscales because the developers considered that nine were too many (Hart et al., 1988). Each subscale is associated with different source of workload: Mental demand, physical demand, temporal demand, performance, effort, and frustration level. Research on cognitive load measurement reports that these instruments are consistent with each other, but NASA-TLX is more sensitive to changes in extraneous load than short self-report instrument (Windell, 2007).

5. Data Analysis and Results

This study was piloted with seven doctoral students attending to an introduction to research methods course. In this course, the subjects were assigned weekly journal and book readings. The journal reading discussion based on the anchored discussion system. The book reading discussion based on a non-standard traditional discussion system (Claremont Conversation). The purpose of the pilot study was to assess the usability of the anchored discussion system, familiarize researchers with the content analysis method, and test cognitive load measurement instruments. We identified the following in the pilot. First, the tool allowed making postings without using the anchoring feature. Anchoring is at the heart of this technology therefore we disabled that feature. Second, interviews revealed that students found it hard to read the articles from the interface due to double column format of the journal readings and document resolution which required up-down scrolling. Third, some students reported receiving errors and getting multiple post when making a comment. This was an email server related issue and we tried to address it. Upon addressing the usability issues, we picked two discussions on journal article readings recommended by the instructor for content analysis. The pilot study content analysis is reported in Table 1. Through interviews, we discovered a student who reported low subjective cognitive load value on anchored discussion system was familiar with the journal readings from prior experience. Thus, we excluded this student from the pilot. We found that subjective cognitive load for correctly interpreting social comments was low and the distinction between the tools was negligibly small. This also applied to comments focusing on the parts of the readings which subjects thought too easy. Additionally, subjects indicated fairly high cognitive load in both tools when interpreting a comment focusing on the parts of readings which they did not understand. However, we discovered that anchoring made it easy to create talking points for in-class discussion on difficult parts of readings. Figure 3 illustrates pilot study cognitive load results. These results were motivating, but non-significant.

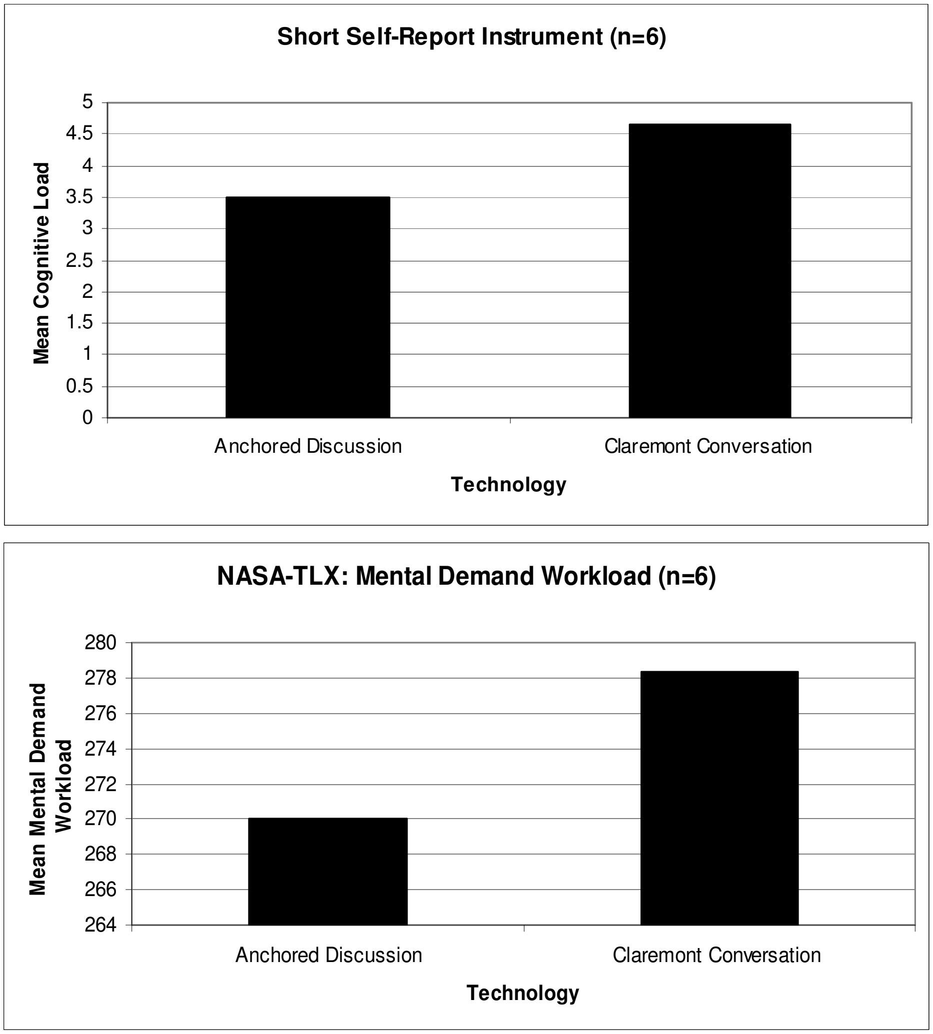

Figure 3. Pilot Study Cognitive Load Results

The main study had 78 junior level undergraduate students enrolled to two sessions of an introduction to statistics course. Both sessions had 39 students. The control group used Blackboard as a forum discussion and the treatment group used anchored discussion system. In order to understand our targeted population, we conducted a preliminary survey prior to online discussions to measure social presence, teaching presence, and cognitive presence between the groups. All surveys are pre-validated (Swan et al., 2005; Arnold et al., 2006; Shea et al., 2003). A series of t-tests revealed no significant difference between the groups on these dimensions. Table 1 gives a summary of the distribution of the types of communication as categorized by Veerman & Veldhuis (2001). Three researchers coded all the messages. The quality of the coding is assessed by determining Cronbach's alpha (α). The recommended setting is $\alpha > 0.8$ to assume inter-rater reliability. After negotiations, a value of 0.87 is computed for 693 messages.

There were significantly more task-oriented messages in the treatment group compared to the control group, χ^2 (1) = 30.95, $p < 0.01$. Furthermore, the proportion of messages in the explanation category was significantly greater for the treatment group compared to the control, $t(618) = 3.33$, $p < 0.001$. Lastly, the proportion of messages in the evaluation category was significantly greater for the treatment group compared to the control group, $t(618) = 3.70$, $p<0.001$. These results provide support for H1.

	Initial Pilot		Main Study-Control		Main Study-Treatment	
	Number	Percentage	Number	Percentage	Number	Percentage
Non-Task Related Communication						
Planning	0	0%	9	5%	11	3%
Technical	0	0%	0	0%	0	0%
Social	1	1%	41	21%	30	7%
Nonsense	0	0%	1	1%	0	0%
Task Related Communication						
New Idea						
Facts	7	9%	10	5%	31	7%
Experience /Opinions	38	51%	86	45%	147	34%
Theory	1	1%	0	0%	4	1%
Explanation	14	19%	28	15%	115	27%
Evaluation	14	19%	15	8%	90	21%
Total	75	100%	190	100%	428	100%

Table 1. Distribution of messages and percentages

The second hypothesis is tested using independent samples-t-test. Table 2 reports the findings on short self-report instrument.

Short Self-Report Instrument (n=39)						
	Group	Mean	SD	*t*	*df*	*p*
Subjective Cognitive Load	Treatment	2.82	1.27	-1.83	76	0.04
	Control	3.36	1.32			

* p<0.05, one tailed.

Table 2. Results from short self-report instrument

When examining NASA-TLX results, we focused on students who thought selected articles were challenging, but not too difficult to put effort for collaborative knowledge construction. We identified 27 students in this category for each group by examining students' self-reported mental demand workload, effort, and performance measures. We validated these students by comparing their self-reported measures with their posting quality. Also, we noticed that five students did not fill out the survey instrument correctly. Thus, we excluded them. Table 3 shows results from NASA-TLX. Our findings provide support for H2.

NASA-TLX (n=27)						
	Group	Mean	SD	*t*	*df*	*P*
Mental Demand Workload (Perceptual Activity)	Treatment	199.81	90.68	-1.92	52	0.03 *
	Control	250.00	100.66			
Mental Effort	Treatment	220.93	67.11	1.17	52	0.12
	Control	195.19	92.45			
Performance	Treatment	280.74	121.60	1.22	52	0.11
	Control	240.56	120.64			

* p<0.05, one tailed.

Table 3. Results from NASA-TLX

6. Conclusion

The results of this research confirm the findings of an earlier study on anchoring technology (Van der Pol., 2006), and strengthen the findings by showing greater proportions of elaborations of ideas and evaluations of reasoning processes in collaborative knowledge construction when the adopted tool is used for deep processing of literature. From the lens of cognitive load theory, anchoring technology may be particularly beneficial for efficient communication as it reduces cognitive load involved in correctly interpreting messages. Both Paas' single question measure and NASA-TLX showed results consistent with each other suggesting that design features of an online discussion forum may reduce the risk of misinterpretations when negotiating ideas in a community of inquiry to construct shared meaning. The experimental results revealed that anchoring technology has the most significant effect on cognitive load for students who perceive selected online discussion articles challenging, but not too difficult to give up collaborative knowledge construction in frustration. Furthermore, although not statistically significant, we found that students in this category reported more mental effort and performance with the adopted tool. We think that these measures could be improved with the further development of this tool. For instance, pilot study subjects recommended that the future version of the tool might link different anchors to one comment. However, anchoring appears to be less effective for interpreting social comments and messages that address the parts of a reading which subjects find either too easy or too difficult to understand.

We believe our findings are important insights for instructional implementation of technology because while anchoring discussion does not determine learning outcomes, the adopted tool differs significantly from standard forum discussion with respect to subjective cognitive load and to the quality of discourse it fosters. While the results offer interesting insights into the pressing problem in online asynchronous discussions, a number of limitations must be considered. First, the measure of cognitive load used in this study is subjective. Thus, future work might investigate the validity of those subjective evaluations. Second, replications with other populations in different subject areas are required to generalize our findings to other learning contexts.

Although content analysis techniques are useful to identify message categories and measure the frequency of messages observed in each category, they provide little information to explain or predict the relationship between threaded messages and how message sequence and group processes affect subsequent discussion and cognitive outcomes (Jeong, 2003). Therefore, in our ongoing research, we are interested in examining how the patterns of interaction relate to knowledge construction process between anchored discussion and standard forum discussion. Moreover, we are investigating the functional difference of the anchored discussion tool to another tool that places threaded discussion near an academic text without connecting messages to specific sections of an academic text.

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