Anchored Annotations to Support Collaborative Knowledge Construction

Justin Plevinski, Jennifer Weible, and Michael DeSchryver,
plevi1js@cmich.edu, j.weible@cmich.edu, desch2m@cmich.edu
Central Michigan University

Abstract: Online discussion forums have been shown to support collaborative reflection, critique, and construction of knowledge. However, when these discussions are reading-centered and hosted in traditional threaded discussion forums, it is often difficult to maintain focus on the readings themselves, as well as navigating the difficulty of attributing ideas to just one discussion post within a thread. This study demonstrates how an anchored annotation system was used in a first semester online, asynchronous doctoral course to support more effective reading-centered knowledge construction. We investigated the discussion activities of 12 online doctoral students as they explored seven articles during two non-consecutive weeks. Through analysis of 591 student comments and replies, we examined how students used the anchoring system as a support to help make sense of the articles. We found that using anchored annotation reduced coordination activities and supported knowledge construction, particularly interpretation and elaboration of ideas.

Introduction

Asynchronous discussion is a common collaborative activity in both undergraduate and graduate online courses. These discussion forums are useful for reflection, communication, and knowledge construction (Gao, Zhang, & Franklin, 2013). They may also facilitate deeper understanding of concepts (Gilbert & Dabbagh, 2005). Concerns with the quality of interactions have been related to the design of typical threaded forums, leading to development of innovative environments intended to support more effective discussions (van der Pol, Admiraal, & Simons, 2006). To better support online doctoral students' construction of knowledge, we explored a tool, Framebench (Agarwal, 2015) that allowed for online, collaborative annotations to be anchored within the text of assigned readings.

In this paper, we synthesize contributions from previous work in computer supported collaborative learning to frame our study. Then, we describe Framebench (Agarwal, 2015), an anchored system that we used in the context of reading-centered academic discussion, and explore its affordances as compared to prior research on linked annotation systems. Thereafter, we present findings regarding the knowledge building patterns of 12 online doctoral students over the course of first semester readings using this anchored system as the underlying tool to support asynchronous discussion focused on the text. Finally, we discuss the implications of these findings for future research and practice.

Conceptual framework

Readings, and discussion about them, are a common activity in most graduate seminars. In its simplest form, such conversation involves teacher-asked questions, followed by student answers, followed by teacher feedback or responses. However, this linear, teacher-directed model does not reflect the generative discourse patterns in effective knowledge building communities (Scardamlia & Bereiter, 1994). In this way, knowledge building results from collective understanding through interaction, often supported by technology within the learning environment. As such, students must articulate their ideas, questions, and responses to demonstrate insights and understandings about the text in online discussions focused on course readings (Gao, Zhang, & Franklin, 2013). In online classes, studies of this type of socially constructed knowledge have often focused on discussion forums, or threaded discussions (e.g., Hew & Cheung, 2010). The content of these discussion forums may center on various intellectual artifacts such as topics, problems, or case studies drawn from the readings. However, because of the various affordances and constraints of systems designed to support these discussions, the actual dialogue within the forum is typically physically separated from the text of interest. For instance, a common method utilized when engaging students in a browser-based threaded discussion is to open one browser window for the threaded discussion while a PDF of the reading is available in another window or tab. In this way, the reading itself is distal to the related discussion. Eryilmaz et al. (2013) found that this distance may increase coordination efforts (cognitive expenditures needed to align the text and the discussion) and decrease energy and effort available for knowledge construction as students navigate back and forth between the reading and the

forum discussion. This leads to lower numbers of references to the related readings and reduced understanding of the content. As such, many threaded forum discussion posts do not demonstrate a rich understanding of content, nor do they fully integrate the key ideas from the related readings (Hewitt, 2001).

For this study, we adopted a constructivist approach to learning in which the individual's knowledge construction is based on their individual and social practices (Pena-Shaf & Nicholls, 2004). In so doing, we mapped knowledge construction activities onto six cognitive processes including remembering, understanding, applying, analyzing, evaluating, and creating (Krathwohl, 2002). We were particularly interested in how remembering and understanding supported the comprehension of assigned readings. That is, remembering involves retrieving and recalling what a learner knows, and understanding is the act of "[d]etermining the meaning of instructional messages" (Krathwohl, pp. 215). Included in the understanding category are cognitive actions of interpreting, classifying, summarizing, inferring, comparing, and explaining (Krathwohl).

We also situated this study in the computer supported collaborative learning environment (CSCL) of anchored discussions, which emphasize social interaction (Gao, Zhang, & Franklin, 2013) and "offer creative activities of intellectual exploration" (Stahl, Koschman, and Suthers, 2006, p. 410). Using a collaborative, computer-based environment encourages students to make their thinking visible to others by articulating their learning socially (Chu & Kennedy, 2011). These visible demonstrations help students expose their understanding to other students, explore different views, and contribute to shared understanding, which may deepen learning processes (Stahl, Koschman, and Suthers).

Previously Guzdial and Turns (2000) used an anchoring system called CaMILE as a way of improving online course discussions. They anchored specific notes onto web pages that were linked to the CaMILE system. By clicking on a note anchored within a web page, threaded discussion comments appeared on a different web page. Although the notes and discussion comments were connected, they were linked on two separate web pages. Using the CaMILE system, Guzdial and Turns' research focused on improved sustained on-topic forum discussions. Other authors have used more advanced features of the web for different types of anchored discussions in order to reduce the cognitive load due to distance between the reading and the discussion. One way of reducing the distance between readings and discussion is the use of linked discussions; to integrate the discussion forum and reading together in an environment and "link" them to each other (e.g., Eryilmaz et al., 2013; van der Pol et al., 2006). These previous studies of "anchored" discussion systems explore what are termed "parallel linked systems" where the discussion forum and artifact are presented side-by-side on the screen, and then linked visually via hyperlink. In these parallel linked systems, the distance between discussion and text is less than in traditional threaded discussion forums, but coordination activities that represent extraneous cognitive load still exist. However, using document-mediated systems such as linked discussions may provide a stronger collaborative context and "direct users' collaborative intentions towards the processing of that text" (van der Pol et al., p. 344), while reducing the need for coordination of the collaborative process.

Building on linked discussions, other formats supporting collaborative discussion from the anchored perspective also exist. These systems have been studied through the lenses of constrained environments, visualized environments, and anchored arguments (e.g., Gao, Zhang, & Franklin, 2013). The latter demonstrate truly anchored discussions through online annotation systems that allow for questions, comments, and replies to be embedded directly on the text of readings, which may reduce cognitive load and related coordinative activity (e.g., Annotate, Hypothesis, Diigo). However, across the annotation systems currently available, many do not cleanly accommodate the discussion and interaction patterns desired for academic discussion of the text. For instance, some systems allow for anchored comments within the text, but multiple replies to that comment result in a long window on the screen that extends on to the next page, rendering the anchoring more distal and less useful. Some other systems allow anchoring, but the notes cannot be collapsed. As such, students who encounter the reading after other classmates have annotated the document find a document covered with notes, disrupting their ability to read the original text. All of these activities may have an "interaction cost" that is either social or coordinative (van der Pol et al., 2006), and may reduce the effectiveness of a CSCL environment if the costs are too high. Coordinative costs (mental capacity used to reference evidence) are particularly persistent in traditional asynchronous text based online discussions (Eryilmaz et al., 2013). For instance, some systems leave too much coordination and structuring to the students, particularly for maintaining a shared frame of reference (Häkkinen & Järvelä, 2006). This is often in the form of specific references to the learning artifact from within the discussion contributions (Herrmann & Kienle, 2008).

Because of this problem, Eryilmaz et al. (2013) explored the coordination costs of establishing and maintaining shared focus in proximal online readings using a linked artifact-centered discourse system, finding that decreasing the need for coordination costs in an online discussion environment increased knowledge construction potential. They utilized the Annotation Tool (Van der Pol et al, 2006), which presents both discussion threads and the readings in the same window in two separate frames, using links between the image

of a text page and the discussion threads for two-way reference between them. Previous research indicated this sort of "anchoring" may stimulate sustained on-topic conversations (Guzidal & Turns, 2000), encourage messages on specific points in the reading (Häkkinen, et al. 2002), and help students better engage with complex ideas (Suthers, et al., 2006). Eryilmaz et al. found participants demonstrated less coordination activities and increased knowledge construction activities. However, although linked artifact systems like the Annotation Tool significantly reduce the navigational distance between discussion and artifact, they do still demonstrate spatial distance across the screen and window.

Framebench software (Agarwal, 2015) uses a more advanced anchoring system whereby the annotation system is integrated directly within pdf documents. The threaded discussions appear as a collapsible floating window on the pdf document itself rather than being linked through a separate webpage. We focused on the students' collaborative knowledge construction through threaded discussions anchored directly at the point of reference within the pdf document text. As such, given that linking discussion and text across the screen reduced coordination activity, we explored whether proximally anchored annotations might reduce it even more, leaving greater energy and effort to expend in knowledge construction activities.

Methodology

Research questions

The goal of this research was to examine the affordances of anchored annotations for both reducing coordination activities and supporting construction of knowledge. In this analysis, we answer the questions: (1) How do anchored annotations support student coordination activities?, and (2) How does using anchored annotations in a learning environment support student collaborative knowledge construction activities?

Selection of the online system

We evaluated options for anchored discussion that connect the discussion in even closer proximity or directly on the text itself than linked systems. The tool used for this study was Framebench (Agarwal, 2015) that afforded two features integral to supporting the proximal anchoring. First, initial comments are embedded with only a small icon so that the text is "clean" when readers return to it, but comments are readily available with a single click. Second, Framebench uniquely encapsulates comments and replies in a single window where readers can scroll through them, still anchored to the text, using very little screen real estate. In most other systems, the four replies demonstrated by the open comment window (See Figure 1) would extend on to the next page. Therefore, this environment provided several key affordances of anchored discussion to support reading-focused knowledge construction that are not available in other currently available tools.

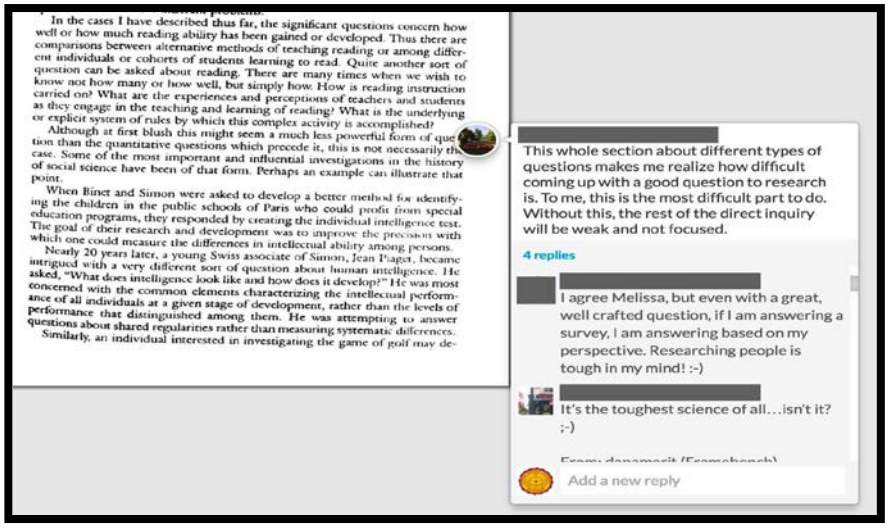

Figure 1. Screenshot of a comment and responses encapsulated within Framebench's anchored annotation format.

Participants and settings

For this study, participants (n=12) were students enrolled in an entirely online doctoral program in educational technology. Ten were from states within the United States, and two were international students. The setting for this study was a first semester course intended to provide an overview of educational technology research and the scope of the field. Students were assigned four sets of readings to be discussed in Framebench (Agarwal , 2015) during weeks two, six, ten, and 14 (other synchronous and asynchronous options were utilized in the remaining weeks of the course for weekly discussion), of which we selected week six and fourteen for analysis. Week six was chosen to ensure that all students were already familiar with the Framebench system and were able to access it without difficulty, and week 14 was chosen to analyze for changes in interaction patterns across the semester.

Data, findings, and analysis

Data examined for this analysis were 591 anchored annotations (both initial posts and replies) written by participants across nine articles assigned during the two selected weeks. Each comment and all replies were logged into a spreadsheet in their entirety, as well as word counts, number of comments and replies, and number of highlights and other written annotations from within the documents. Each comment and reply were segmented into activities (Erilmaz et al, 2013), which were coded based on *a priori* codes for coordination (Erlimaz et al.) and knowledge construction activities (Krathwohl, 2002; Pena-Shaff & Nicholls, 2004). We also allowed for emerging codes (see Table 1). These emergent codes were developed, identified, and defined by all researchers before being utilized within the coding scheme. In particular, we modified the framework of Pena-Shaff & Nicholls to include a more nuanced understanding of clarification, interpretation, and elaboration that incorporated ideas from Krathwohl. Clarification was used to denote when ideas and thoughts were identified, while elaboration was added to differentiate between clarification and allow for coding of other activities (see Table 1 for definitions and examples). Interpretation was defined as "inferences, conclusions, summaries, generalizations, problem solution suggestions, or hypotheses" and elaboration was defined as expanding the scope of the current discussion by adding additional information or examples (Pena-Schaff & Nichols, pp. 257). Aligning with Krathwohl, elaboration as a cognitive skill falls into both the remembering and understanding categories: elaboration relies on long-term knowledge (remembering) to provide relevant, related examples that demonstrate understanding the content of the text. The cognitive actions in understanding, according to Krathwohl, are the same cognitive actions used to define interpretation. Descriptive statistics for each code category as well as percentages of the coded activities were calculated. Two researchers coded all segmented annotations separately and discussed differences to reach consensus to provide validity.

Table 1: Conceptual Framework, Definitions, Examples, and Percentage

Categories	***Operationalization***	***Example of the applied code***	***Percent***
Knowledge Construction Activities			
Interpretation	Inferences, conclusions, summaries, generalizations, problem solution suggestions, hypotheses	*"This supports the idea that active learning is beneficial to students"*	***21%***
Question	Seeking to find additional information pertaining to the discussion; prompt further discussion about the current topic; a question that reflects upon the current discussion	*Are there other content areas that may benefit also, why science (other than the video was available)?* *Couldn't there be an option to learn from books, videos, games, whatever best matches the student with perhaps formative assessments along the way for students to see if they are learning?*	*14%*
Conflict	Disagreeing with another student; mentioning a different point of view in direct reply	*"Perhaps I misread this first sentence, but I'm not sure I agree with this statement"*	*2.5%*
Consensus Building	Discussion of misunderstandings; reaching an	*"I too believe that these assumptions are more vital than just to label them "assumptions.""*	*6%*

	agreement on an idea, fact, or interpretation; negotiating the definition, interpretation, or truthfulness of a claim or fact		
Support	Empathizing; statements of acknowledgement; providing direct feedback	*Tammi, I also see a big problem here*	*12.4%*
Clarification	Listing main ideas, facts from the reading, assumptions	*"aka - a student-teacher scenario."*	*1.8%*
Elaboration	Connecting ideas with examples, defining terms, causes or consequences, listing advantages or disadvantages, using analogies to explore ideas, making connections, comparing and contrasting	*"Gee's background in sociolinguistics is shining through here in this section. :)"* *"This happens with adult learners who tend to be focused on learning just what is needed to achieve the task at hand"*	***21%***
Coordination Activities			
Distal	References to information outside of the text.	*"I think it's in Steinkuelher's article that she questions why relate gaming to TV or radio, etc."*	*5.9%*
Proximal/Far Proximal	References to information either within the same paragraph or within the text.	*"This paragraph rings a bell about student empowerment & motivation that comes when students can take control of their learning-actively."*	*1.43%*
Other Emerging Codes/categories			
Social Interactions	Comments directed at participants but not at the task at hand.	*"Also, it's my 3 year old who watches Caillou. My daughter would be mortified if she knew I mixed that up :-)"*	*2%*
Tangential	Comments peripherally related to the topic.	*"J---, I read a great article this week, also by Gee, talking about games and libraries."*	*3 %*
Directions	Directions or guidance from the instructor.	*"This is the kind of annotation that is helpful to everyone else, and demonstrates the kind of reading I'd like to see you all practice. If you don't know something, it can be easily explored by our friend Google.."*	*.23%*
Confusing	Comments that did not make sense within the context.	*"My english-speaking peer mentoring partnership based on the research findings, recommendation of need and lack of english-speaking and transitioning support for Domestic students and recommendations."*	*.3%*

Table 2: Data Grouped by Category

Activities by Category	***Week 6***	***Week 14***	***Total***	***Percentage***
Coordinating (focusing on shared topic of discourse)	**40**	**39**	**79**	**6.7%**
Knowledge construction (interpretation and elaboration)	**221.5**	**234.5**	**456**	**38.6%**
Knowledge construction (other)	284.5	290.5	575	48.6%

Other	26	26	52	4.4%
Total number	578	604	1182	100%

Discussion

Anchored annotation reduces coordination activities

Within our study, coordination activities accounted for 6.7% of the overall activities (see Table 2). Considering that Erilmaz et al. (2013) found that between 17% and 26% of all activities were considered to be coordination activities in a parallel linked annotation system, our findings indicate that a within-text anchored annotation system (such as Framebench) may decrease coordination effort and allow more focus on construction of knowledge. This may have resulted from the proximal nature of the anchored comment. That is, when a comment is embedded in the text of a reading, the content of the comment is clearly referencing the text near or on which the comment is connected. For instance, a student comments "Summative assessment (or summative evaluation) refers to the assessment of participants where the focus is on the outcome of a program. This contrasts with formative assessment..." (see Figure 2). Another student replies, "Sort of - the critical piece of formative assessment that makes it formative…" Due to the proximity of the user's icon to this paragraph, and even more precisely, aligning with the first two sentences of the paragraph, there is a seamless discussion of the authors' contentions about summative evaluations in a research context. As indicated, there is little need for specific references to the text on the part of the initial commenter, and subsequent repliers need not search for intended references.

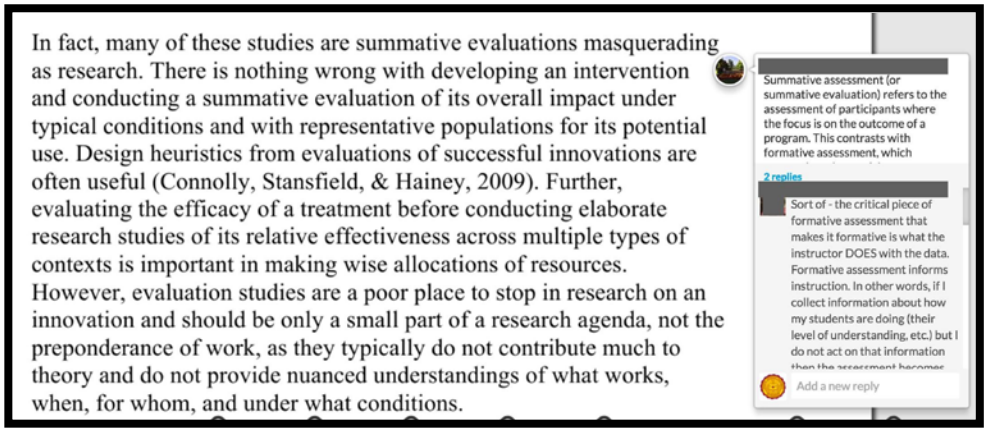

Figure 2. Screenshot of anchored annotation of student discussion in Framebench in which they are developing collaborative understanding of summative vs. formative evaluations.

In Eryilmaz et al., participants used specific coordinative references such as "the author's argument on page 8" six percent of the time, and another 11% of comments were used to maintain that focus. We propose two possibilities for why the anchored system within Framebench (Agarwal, 2015) may reduce such references in comparison to the linked system. First, the anchored annotations are located immediately within the text, whereas in the linked system, the screen is covered in multiple threaded comments on the left side of the browser and the document itself can be covered in several colored highlights. Within the threaded systems, students may find that in spite of all of these cues connected across the document and browser, references to the text are still necessary or useful.

Second, instructions provided to the learners in each context may have primed them for the functionality of the system. That is, in this study, given that the students were doctoral students, the instructor, was transparent upon introducing Framebench about the apparent and intended affordances of the system. Students were told that they were using a discussion system that might help them closely explore the text of assigned readings with embedded comments. Specific language in those instructions may have indicated, explicitly or implicitly, that the proximity of the comments reduced the need to make specific reference to the related text. Eryilmaz et al. indicated that students were "briefed about the functionality of the utilized

interaction environment" (p. 125). But, it is unclear if this briefing may have underrepresented the connective affordances of the systems, or if identical instructions were given to the treatment and control groups, which would not have highlighted the potential benefits of linked-parallel artifact systems.

Anchoring annotation supports remembering and understanding of text

In our study, anchoring annotations within the text supported multiple types of knowledge construction activities, primarily elaboration and interpretation. The number of activities within our data set coded as elaboration and interpretation statements within the anchored annotations accounted for 42% of all comments or replies (21% of comments coded elaboration and 21 % of comments coded interpretation). Finding that the use of anchored annotations may foster knowledge construction activities that align with remembering and understanding (Krathwohl, 2002) more than other types of knowledge construction activities, such as consensus building and synthesis, may be due to the manner in which the tool handles instances of annotations. Each annotation can be anchored immediately beside the text referenced, and each article contains numerous opportunities for threaded annotated discussions near the text that spurred the initial comment for the threaded discussion. In alignment with Gao, Zhang, and Franklin (2013) who found that anchoring annotations reduced the localization effect (the given distance of text's proximity to the location of the annotation is low, thus moving from one space to another changes the qualitative nature of the annotation), our students changed focus with every post. Within our study, students created multiple, shorter length comments and replies, often within the same paragraph, that focused on a small portion of the text instead of constructing a longer post that synthesized across several paragraphs or ideas. We posit that this ease of "targeted" annotations facilitated students' remembering and understanding of the content, but hindered synthesis across texts and consensus building activities between the students.

Furthermore, the way in which Framebench (Agarwal, 2015) was implemented within the course may support the knowledge construction activities of remembering and understanding moreso than other knowledge construction activities because of the length and the number of readings. Each week there were four to five scholarly readings of extended length (well over 100 pages per week), and students could annotate anywhere in the documents. That is, in addition to the focused nature of the annotations within Framebench, the sheer volume of pages to read and annotate may have encouraged the knowledge construction activities of understanding and remembering, key steps for comprehending the assigned readings, in place of synthesis or evaluation.

Conclusion and implications

This study explored how first semester, online doctoral students utilized a text anchored annotation system to make sense of and discuss their weekly readings. Just above, we outlined how our data indicated that coordination activities were relatively minimal and that this system supported knowledge construction activities closely aligned with the cognitive processes of remembering and understanding. Some might interpret these findings to be disconcerting in the context of knowledge construction. That is, given remembering and understanding are often considered "lower-order" skills in the context of Krathwohl's (2002) presentation of cognitive processes, it would be easy to dismiss the value of in-text anchored annotation systems, since the current study did not promote the more generative "higher-order" processes often associated with knowledge construction. In practical terms, however, the online students used the affordances of Framebench's in-text, anchored annotation system as a support while they processed broad, foundational readings needed to make sense of the field. As such, using anchored annotations in online learning environments may have positive implications for providing students with a social method to explore and understand complex readings.

This being the case, it is also important to emphasize the specific goals of the course in which this study was conducted. Situated in the first semester of an online doctoral program, the primary objective in this survey course was to ensure that students absorbed the key ideas in the assigned readings from across 14 different genres of education and educational technology research. Absent the more traditional conversational style of a face-to-face doctoral survey course that affords the instructor ample opportunities to assess the extent to which students are internalizing assigned readings, we specifically endeavored to find a system that would support such discussions and assessment in an asynchronous manner. Given the tendency of threaded discussion to stray away from the readings, we utilized Framebench as a way to focus students on the specific text elements within the readings through visible discussion anchored at that point.

There are currently several styles of systems available to support discussion in online learning: embedded anchors, standard threaded discussion forums, and parallel linked anchors. We posit that in choosing a discussion system for online learning, it is important to consider (a) the goals of the online discussion (e.g. understanding vs. knowledge construction), and (b) the design affordances that undergird the system (e.g.

reducing coordination costs vs. creating connections). Future research may provide continued exploration of the tradeoffs between and among these considerations. Furthermore, this study may also inform design principles for the creation of additional systems that utilize anchored annotation within text.

References

Agarwal, R. (2015). Framebench.com [computer software]. India.

Chu, S. K-W., & Kennedy, D. M. (2011). Using online collaborative tools for groups to co- construct knowledge. *Online Information Review, 35(*4), 581-597.

Eryilmaz, E., van der Pol, J., Ryan, T., Clark, P. M., & Mary, J. (2013). Enhancing student knowledge acquisition from online learning conversations. *Journal of Computer-Supported Collaborative Learning, 8,* 113-144.

Gao, F., Zhang, T., & Franklin, T. (2013). Designing asynchronous online discussion environments: Recent progress and possible future directions. *British Journal of Educational Technology, 44*(3), 469-483.

Gilbert, P. K. & Dabbagh, N. (2005). How to structure online discussions for meaningful discourse: A case study. *British Journal of Educational Technology, 36*(1), 5-18.

Häkkinen, P., & Järvelä, S. (2006). Sharing and constructing perspectives in web-based conferencing. *Computers & Education*, *47*(4), 433-447.

Herrmann, T., & Kienle, A. (2008). Context-oriented communication and the design of computer-supported discursive learning. *International Journal of Computer-Supported Collaborative Learning*, *3*(3), 273-299.

Hew, K.F., & Cheung, W.S. (2010). Fostering higher knowledge construction levels in online discussion forums: An exploratory case study. *International Journal of Web-Based Learning and Teaching Technologies, 5*(4), 44-55.

Hewitt, J. (2001). Beyond threaded discourse. *International Journal of Educational Telecommunications*, 7, 207-221.

Jonassen, D., Davidson, M., Collins, M., Campbell, J., & Haag, B. B. (1995). Constructivism and computer-mediated communication in distance education. *The American Journal of Distance Education, 9*(2), 7-26.

Krathwohl, D. R. (2002). A revision of Bloom's Taxonomy: An overview. *Theory Into Practice, 41*(4), 212-218.

McGinley, W. (1992). The role of reading and writing while composing from sources. *Reading Research Quarterly, 27*(3), 226-248.

Pena-Shaff, J. B. & Nicholls, C. (2004). Analyzing student interactions and meaning construction in computer bulletin board discussions. *Computers & Education*, 42 (3), 243- 265.

Scardamalia, M., & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York: Cambridge Press.

Stahl, G., Koschmann, T., & Suthers, D. D. (2006). Computer-supported collaborative learning. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 409-425). New York: Cambridge Press.

van der Pol, J., Admiraal, W., & Simons, P. R. J. (2006). The affordance of anchored discussion for the collaborative processing of academic texts. *International Journal of Computer-Supported Collaborative Learning*, 1(3), 339-357.