The Role of Anchoring Discussion in Mediating Effective Online Interaction for Collaborative Knowledge Construction

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Abstract

This paper reports a quasi-experimental study carried out with two social technologies in order to support and enhance collaborative knowledge construction among doctoral students discussing research papers. We conducted a fine-grained investigation of discourse in both systems by using three coherent theories of collaborative learning to guide three different methods of analysis. We started our investigation by analyzing the content of discussions in search for active meaning making. Then, we examined the interaction processes to identify new cognitions emerged from interacting individuals. We completed our investigation by evaluating the positive interdependence of distributed competencies in each group. Results indicate that the anchored discussion system seems to be particularly suited for theory-oriented collaborative processing of research papers.

1. Introduction

A knowledge building community is a group of learners who engage in collaborative construction of meaningful and worthwhile knowledge. Such a knowledge construction process involves continuous reciprocal engagement in knowledge internalization (absorbing knowledge created within a community) and externalization (articulating knowledge meaningfully in a community) [1,2]. Dialogue serves as an instrument for collaborative knowledge construction because different perspectives are incorporated in the process of explaining, clarifying, elaborating, and defending ideas [3,4]. Dialogue affects not only a learner’s cognition but also a community’s distributed cognitions as participants express, negotiate, and transform their ideas to create new knowledge [5]. This process has been recognized as more powerful for communication in written form because the successful conveyance of meaning requires a fuller elaboration when done without immediate feedback from a colleague as in oral communication [6].

We can regard an asynchronous discussion forum supporting a knowledge building community as a distributed cognition system. Knowledge is not only distributed among learners, but it also exists in text-based cognitive artifacts which make thinking and reasoning visible [7,8]. For such systems, online dialogue is often referred to as immediacy of peer interaction, which emphasizes reciprocal communication events between at least two objects and two actions [9]. In classroom settings, interaction becomes a genuine effort at reflecting together on what students know and do not know, to build deeper understanding of course content rather than by posting messages reflecting one’s experience without taking into account others’ opinions.

Many researchers have concluded that asynchronous computer supported collaborative learning environments, such as discussion boards, facilitate cognitive activities which can foster higher level processes of inquiry based interaction [10,11]. Despite the benefits of asynchronous discussion forums, recent findings have also shown that students who seem to have the same educational background and prior knowledge do not, as is often assumed, construct knowledge together easily [12,13,14,15]. The observed problems in generating coherent and interactive dialogue necessary for conversational modes of learning are similar. Discussion threads are short and participation rates are low [16]. Consequently, discussions tend to have “one-way” interactions which hinder collaborative construction of meaning [17]. Moreover, “two-way” interactions deal with surface-level knowledge instead of deeper explanations of the phenomena under study [10,18]. In response to these problems, the present study
compares the design of an anchored discussion system with a non-standard discussion system to promote rich and constructive interactions in two small groups of doctoral students learning how to conduct academic research and report it effectively. This study examines two different asynchronous discussion systems whose goals are to foster a collaborative process in which meaning is negotiated and knowledge is constructed collaboratively. Our investigation relies on three quantitative methodologies for an in-depth examination of two small groups of doctoral students using an anchored discussion system and a non-standard discussion system. We employ a multidimensional content analysis model to examine the quality of online discussions for collaborative knowledge construction, a sequential analysis of content to identify how patterns of interaction relate to collaborative knowledge construction processes within each group, and a social network analysis approach to analyze the quantity of messages between peers and strength of overall network connection among doctoral students.

This paper is organized into six sections. Section two overviews three complementing theories and relate them to three perspectives of analysis for collaborative knowledge construction. Section three focuses on central differences in between the online discussion systems adopted in our study. Section four presents the research questions and hypotheses. Section five describes research design, data collection, and methods of data analysis. Section six explains findings. The last section summarizes the study’s contributions.

2. Theoretical Background

Learning is a complex phenomenon. Assessing the extent to which learning occurs from participating in online asynchronous discussion is not simple. According to Rourke and Anderson [19], many studies do not have a clear epistemological stance on what constitutes learning and how researchers might examine it. We concur with Dennen that learning in a collaborative setting is “demonstrated through conversation, in which learners reflect upon what they currently know and negotiate new meaning and knowledge creation with others through conversation” [20, p.97]. Due to this phenomenon’s complexity, several studies have recommended an eclectic approach that triangulates multiple theoretical perspectives [21,22]. This paper takes such an approach. We start with the socio-constructivist theory for the notion that meaning arises as students actively create interpretations of learning material. Then, we employ distributed cognition theory which puts forward the importance of new cognitions originating during interaction among learners through cognitive artifacts with which they interact. Finally, we explore Hatch and Gardner’s contextual influence model for a conceptual understanding of a dynamic social system.

Socio-constructivist theory, an extension of Vygotsky’s theory, focuses on active meaning making in a knowledge building community [23]. Although this theory views the context in which social interaction occurs as central to a learner’s development, it does not provide a theoretical explanation for identifying or differentiating the interactive processes that actually take place in a knowledge building community [24, 25]. Many researchers adopting the socio-constructivist perspective use content analysis schemes to measure the frequency of messages observed in each category to reveal evidence about knowledge construction from online discussions. However, content analysis methods fail to depict the interaction processes among learners [26]. Therein lies the need for conceptual understanding and examination of group interaction processes to investigate collaborative knowledge construction (see the model in Stahl [21]).

Distributed cognition elaborates on social construction of knowledge by referring to new cognitions developing through interactions with other learners and cognitive artifacts which support such interactions [25]. Therefore, distributed cognition asserts that knowledge resides in these interactions and not only in the individual [27]. From this perspective, we look for how a learner takes up another’s contribution in an online discussion and furthers it reflecting collaborative knowledge construction through interaction. In this manner, a sequential analysis examining the relations between threaded messages is the key to understanding different interactive processes in collaborative knowledge construction. The premise that cognition is distributed suggests that learning spaces are becoming more dynamic and complex and that students should put themselves in a position to extend their knowledge by forming a social system.

The contextual influence model provides a conceptual understanding of a dynamic social system by pointing out positive interdependence of distributed competencies (cognitive, social, and motivational) as a prerequisite for effective collaboration [28]. The model suggests that positive interdependence creates a shared responsibility which promotes group cohesion for collaborative knowledge construction. Moreover, the model presents individual accountability to accomplish a
group’s goals as a major indicator of positive interdependence which counters the free-rider effect [28]. The notion of social relationships is in the essence of a dynamic social system. Thus, a social network analysis approach is also suitable for our specific study to analyze the level of communication and strength of connection in a dynamic social system.

3. Computer Support for Collaborative Knowledge Construction

The problems identified at the outset of this study might result from discussion tools and more particularly from their lack of connection with learning contexts. In line with others [29, 30], we think that the separation of collaborative knowledge construction activities from the learning context is not favorable for the emergence of effective online interaction. Our job as information systems researchers is to design online discussion systems that guide and support cognitive processing and active construction of knowledge. This section describes two social technologies designed to mediate professional dialogue between peers.

3.1. Anchored Discussion System

An anchored discussion system (Figure 1) has two fundamental characteristics. The first characteristic is the online presence of the learning material which serves as a context for collaboration and strengthens the link between discussion and study material [31]. The second characteristic is the potential to hypertextually annotate every fragment of the learning material to clarify the conceptual relevance and meaning of each contribution [32,33]. In addition, all contributions are displayed in an extra frame next to the main display area. By selecting an annotation within the document, multiple contributions referencing a given topic are collected together to improve convergence [30].

The proponents of these systems stress that the difficulty of finding relevant contributions in an online discussion and placing one’s own contribution in the relevant context inhibit online collaborative knowledge construction [30,34,35]. The use of an anchored discussion system in an educational setting could be rationalized with situated action theory which indicates that each action in computer-mediated communication closely depends on a particular context. Specifically, when learner constructed annotations become part of the collaborators shared context, these annotations may stimulate the production of rich and constructive interactions for negotiations of meaning [29].

This study adopts the anchored discussion system developed by J. van der Pol at the University of Utrecht, who demonstrated that the first fundamental characteristic’s context-creating effect directed students’ attention to a more meaning-oriented processing of literature as students reported more frequent referring to content and a higher frequency of rereading referenced sections of a document. The second fundamental characteristic’s context-creating effect showed an increase in communicative efficiency due to briefer referrals and messages containing fewer self clarifications than the system for regular forum discussion. Combined, both effects are postulated to make anchored discussion a more effective tool for conducting theory-oriented online learning conversations [29].

3.2. Stakeholder-Controlled Networking System

The stakeholder-controlled networking system (Figure 2) builds on an action and design research to enhance scholarly community and conversation in our university. The application utilizes the Elgg open source social networking software. This system is distinguished from a standard course management system in its orientation towards individuals who can grant access to their own contributions to an online discussion on a number of levels including individual, community, logged in users or wider audiences including the Internet [36]. This feature serves to promote an exchange of ideas with students in different courses and disciplines in our university.
and possibly offers interactions with students from other universities.

The forum functionality of the stakeholder-controlled networking system centers on individuals and on individual messages reflecting a student’s understanding of one or more important points related to the learning material. Taking this perspective, the forum within the stakeholder-controlled networking system collates a series of thoughtful opinion pieces with the option for comment on each of them. Accordingly, the genre of writing encouraged in this system is more like individual knowledge pieces shared with a learning community. The use of comments then supports interaction within each course or beyond depending on the level access assigned to a message by its owner.

Several studies investigated the forum functionality of the stakeholder-controlled networking system found that individuals perceived high levels of value from it regarding a sense of ownership over their posted content, deepening peer relationships, and collaborative knowledge construction [36, 37].

4. Research Questions and Hypotheses

Doctoral students frequently have difficulty defining, developing, and resolving research problems. An important method to cultivate research skills involves engaging in professional dialogue focusing on high quality research papers. We aspire to investigate the role of technology to facilitate a natural setting for cognitively demanding activities such as knowledge articulation, explanation, and argumentation that can foster higher level processes of inquiry-based interaction. Consequently, we ask:

I. How will the two systems affect the quality of discussions for collaborative knowledge construction?

According to socio-constructivist theory, meaning arises as students actively create interpretations of learning material. With respect to doctoral students, when discussing a high quality research paper, developing arguments to explain understanding of theoretical principles and describing how those principles lead to the development of hypotheses are often difficult activities. In this sense, discussion boards as a computer supported collaborative learning environment should provide opportunities for students to articulate and reflect on the content under study, to negotiate meaning with the self (reflective activity) and with others [6]. Recent research suggests that complex ideas can be explained more efficiently through the existence of a shared frame of reference which clarifies the contextual relevance of each contribution [29, 38]. This leads to the first hypothesis.

H1. Anchoring discussion will foster theory-oriented discourse with greater emphasis on grounded claims.

II. How will the patterns of interaction relate to collaborative knowledge construction processes between the two systems?

Distributed cognition in computer supported collaborative learning refers to new cognitions that arise as a result of interaction processes across learners through cognitive artifacts with which they interact [27]. In an online discussion forum, messages can be viewed as cognitive artifacts because they make learners’ thinking and reasoning visible. Under the distributed cognition perspective, we expect that interaction with a large number of converged postings explaining theoretical principles will provide sufficient information and adequate deduction to enhance students’ ability to articulate how those
principles lead to formulation of testable hypotheses in a research paper. A related study suggests that anchoring discussion may improve convergence of postings by collecting together contributions referencing a given topic [30]. This leads to the second hypothesis.

**H2.** Anchoring discussion will produce higher mean number of responses emphasizing logical connections between theoretical principles and hypotheses.

**III.** How will the two systems affect the social network structure of a small group of doctoral students learning to conduct academic research and report it effectively?

Based on the contextual influence model, individual accountability to participate in a group discourse focusing on a shared meaning making process is a major indicator of positive interdependence which counters the free-rider effect [28]. In this sense, each student is responsible for contributing to discourse in order to sustain a democratic professional dialogue. Prior research provides empirical evidence that anchoring discussion leads to more extensive participation than non-anchored forum discussion because anchoring feature makes messages shorter and more “to-the-point” leading to a greater number of messages [29]. Thus, we hypothesize:

**H3a.** The anchored discussion system group will have higher number of messages between peers than the stakeholder system group.

The contextual influence model underlines positive interdependence of distributed competencies (cognitive, social, and motivational) as the key to effective collaboration [40]. From the standpoint of cognitive competency, the model emphasizes learners’ awareness of what peers know about learning material as a prerequisite to connect group members together for construction of shared meaning [40]. We expect that the more learners communicate to each other for processing the meaning of learning material, the better they will understand each other’s cognitive competencies. An early analysis indicates that the context-creating effect of anchoring discussion turns students’ experience-oriented exchange of ideas into a more meaning-oriented processing of learning material [29]. Therefore, we hypothesize:

**H3b.** The anchored discussion system group will have stronger overall network connection than the stakeholder system group.

**5. Research Design**

We employed a quasi-experimental design with two participant groups defined by the software they used: anchored discussion system and stakeholder-controlled networking system. The participants in this study were 14 first year international students who spoke fluent English and enrolled in two sessions of the principles of information systems and technology research seminar. Each session had 7 students and was held for 14 weeks in a traditional classroom setting to sharpen students’ critical thinking and writing skills for scientific inquiry. During the seminar, the students had to read 12 high quality research papers and discuss them online. In order to interact via discussion systems, students were asked to post a message on the weekly research paper reading and react to at least two fellow students’ messages for that reading. The instructor told participants that their online discussion forum postings should provide talking points for in-class discussions. We had no reason to expect initially relevant difference between the groups. The primary data collected was the discussion transcripts from each participant group, totaling 12 discussions. In order to analyze the primary data, we used three methods of analysis described below.

**5.1 Content Analysis**

We focused on the epistemic and argument dimensions of the content analysis instrument developed by Weinberger and Fischer [39] to test the first hypothesis. The epistemic dimension is divided into off-task and on-task discourse to determine what learners contribute to collaborative knowledge construction. The former is divided into two categories: non-epistemic activities and construction of relations between prior knowledge and problem space. This hinges on the idea of preventing students from digressing. The latter is subdivided into three categories. The first category, construction of problem space, serves to communicate an understanding of the concrete problem space learners are supposed to work on. The second category, construction of conceptual space, comprises discussion on theoretical principles. The last category, construction of relations between conceptual and problem space, indicates the extent to which learners are able to establish logical connections between theoretical principles and
hypotheses which can be regarded as the main task for doctoral students engaging in academic research. The argument dimension is divided into micro and macro level representations to describe how learners construct arguments. The micro-level encompasses claims, grounds with warrants (“since”, “because”) or qualifiers that limit the claims (“maybe”, “could be”). The macro-level includes argument, counterargument, integration (reply), and non-argumentative moves.

5.2 Sequence Analysis

We utilized Jeong’s [40] Discussion Analysis Tool (DAT) to test the second hypothesis. The DAT assumes that meaning and critical thinking are produced not by examining any one message by itself, but by examining the relationship between a message and replies to it. The tool offers two metrics to analyze and identify patterns in message response sequences. The first metric, transitional probability, is based on the frequency of a particular response posted as a reply to a specific message type. The DAT represents the transitional probabilities in a sequence diagram to demonstrate likelihood of particular interaction types. The second metric, the mean number of specific responses elicited per message category, determines how many times a given type of message is able to produce a particular type of response.

5.3 Social Network Analysis

We used Social Network Analysis (SNA) to test the last two hypotheses. We analyzed the number of messages between peers through in-degree and out-degree measures [41]. In-degree is the number of messages an individual receives from other group members. A high average in-degree for a group indicates that students are frequently building on each other’s contributions, which is a hallmark of collaborative knowledge construction. A large network in-degree variance suggests that some participants’ contributions may be neglected by others because certain participants have more popular contributions. Out-degree is the number of messages an individual sends to others in a social system. A high out-degree of a social network shows that participants are able to exchange their opinions with many others. A large network out-degree variance may reflect different levels of commitment to collaborative knowledge construction.

We examined the strength of overall network connection through a network density measure which indicates how connected individuals are to others in a group [41]. The notion of network density is that a higher degree of connection is a positive sign of a collaborative knowledge construction community. The measure of density is sensitive to the size of a network because larger groups are likely to exhibit lower density ratios than smaller groups.

6. Findings

This section has three subsections relating to three major methods of analysis.

6.1 Content Analysis Findings

Table 1 presents content analysis results. Two researchers independently coded a total of 600 messages. The Cohen’s kappa inter-rater reliability figures for the coding of transcripts in the epistemic dimension were 0.87 in the anchored discussion system group and 0.84 in the stakeholder-controlled networking system group. For the argument dimension, the Cohen’s kappa was 0.92 in the anchored discussion group and 0.90 in the stakeholder-controlled networking system group.

The first hypothesis investigated the proportion of grounded claims and theory-oriented messages. The two systems showed significant differences on epistemic and argument dimensions of the content analysis instrument. In the epistemic dimension, the anchored discussion system had greater proportions of messages for construction of conceptual space and construction of adequate relations between conceptual and problem space (Z=4.16, p<0.001; Z=2.78, p<0.01, respectively). However, messages in the stakeholder system directed more towards construction of relations between prior knowledge and problem space (Z=4.59, p<0.01). With respect to the argument dimension, the anchored discussion system showed significantly more grounded claims (Z=5.16, p<0.001). Although the messages in the stakeholder system contained more qualified claims and grounded claims with qualifiers (Z=3.06, p<0.01; Z=2.65, p<0.01, respectively), there are certainly fewer messages in the stakeholder system for the epistemic dimension focusing on construction of conceptual space and construction of adequate relations between conceptual and problem space as illustrated in Table 1. These results provide support for H1.

6.2 Sequence Analysis Results

Figure 3 depicts transitional state diagrams for a visual illustration of sequence analysis results.
### Table 1. Content Analysis Results

<table>
<thead>
<tr>
<th>Categories of Epistemic Dimension of Argumentative Knowledge Construction</th>
<th>Anchored Discussion System Group</th>
<th>Stakeholder-Controlled Networking System Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of problem space</td>
<td>173</td>
<td>40%</td>
</tr>
<tr>
<td>Construction of conceptual space</td>
<td>95</td>
<td>22%</td>
</tr>
<tr>
<td>Construction of adequate relations between conceptual and problem space</td>
<td>62</td>
<td>14%</td>
</tr>
<tr>
<td>Construction of inadequate relations between conceptual and problem space</td>
<td>30</td>
<td>7%</td>
</tr>
<tr>
<td>Construction of relations between prior knowledge and problem space</td>
<td>57</td>
<td>13%</td>
</tr>
<tr>
<td>Non-epistemic activities</td>
<td>20</td>
<td>5%</td>
</tr>
</tbody>
</table>

### Categories of Micro-level of Formal Dimension of Argumentative Knowledge Construction

<table>
<thead>
<tr>
<th></th>
<th>Anchored Discussion System Group</th>
<th>Stakeholder-Controlled Networking System Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple Claim</td>
<td>195</td>
<td>45%</td>
</tr>
<tr>
<td>Qualified Claim</td>
<td>64</td>
<td>15%</td>
</tr>
<tr>
<td>Grounded Claim</td>
<td>108</td>
<td>25%</td>
</tr>
<tr>
<td>Grounded and Qualified Claim</td>
<td>50</td>
<td>11%</td>
</tr>
<tr>
<td>Non-argumentative Moves</td>
<td>20</td>
<td>5%</td>
</tr>
</tbody>
</table>

### Categories of Macro-level of Formal Dimension of Argumentative Knowledge Construction

<table>
<thead>
<tr>
<th></th>
<th>Anchored Discussion System Group</th>
<th>Stakeholder-Controlled Networking System Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argument</td>
<td>143</td>
<td>33%</td>
</tr>
<tr>
<td>Counterargument</td>
<td>81</td>
<td>19%</td>
</tr>
<tr>
<td>Integration (Reply)</td>
<td>193</td>
<td>44%</td>
</tr>
<tr>
<td>Non-argumentative Moves</td>
<td>20</td>
<td>5%</td>
</tr>
</tbody>
</table>

**Total**

<table>
<thead>
<tr>
<th></th>
<th>Anchored Discussion System Group</th>
<th>Stakeholder-Controlled Networking System Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>437</td>
<td>100%</td>
</tr>
<tr>
<td>Percentage</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

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**Figure 3. Transitional State Diagrams**
To ease readability, transitional probabilities less than 0.04 were omitted in the diagrams. The second hypothesis predicted that a large number of converged postings explaining theoretical principles would provide sufficient information and adequate deduction to enhance students’ ability to articulate how those principles lead to formulation of testable hypotheses in a research paper. On one hand, the diagram for the anchored discussion system shows that a message on construction of conceptual space was most often followed by a response on construction of adequate relations between conceptual and problem space and that response was then followed by a posting on construction of relations between prior knowledge and problem space. On the other hand, the diagram for the stakeholder system indicates that a message on construction of conceptual space was more likely to be followed by a response on construction of conceptual space, construction of inadequate relations between conceptual and problem space, or construction of relations between prior knowledge and problem space. Moreover, in the process of strengthening inadequate relations between conceptual and problem space, students used the anchored discussion system to refer back to both conceptual and problem spaces, whereas in the stakeholder system we only found referrals back to problem space.

To determine whether the transitional probability of the particular interaction type is significantly higher in the anchored discussion system, we examined the sequence analysis data derived from the DAT which tallied the number of replies elicited by each construction of conceptual space message.

Table 2. Message Response Sequence Data

<table>
<thead>
<tr>
<th>Message Response Sequence</th>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction of conceptual space</td>
<td>Anchored Discussion System</td>
<td>0.38</td>
<td>0.59</td>
<td>95</td>
</tr>
<tr>
<td>Construction of adequate relations between conceptual and problem space</td>
<td>Stakeholder-Controlled Networking System</td>
<td>0.09</td>
<td>0.30</td>
<td>11</td>
</tr>
</tbody>
</table>

The second hypothesis was supported because comments on theoretical principles produced a significantly higher mean number of responses on adequate relations between conceptual and problem space in the anchored discussion system, \( t(20)=2.67, p<0.01 \), one tailed.

6.3 Social Network Analysis Results

Table 3 summarizes the social network analysis results. We created spreadsheets that showed which participants responded to others’ posts and how often they did so. The initial posts that started the threads were not considered interaction and were not counted. We imported the spreadsheets into the UCINET software to examine the different SNA measures.

The last two hypotheses predicted that the anchored discussion system group would have higher number of messages between peers and stronger overall network connection than the stakeholder system group. We employed Freeman’s in and out-degree measures to determine the communication among individuals in each group. Since the messages used for SNA were directed, the mean values of in-degree and out-degree centralities were the same for each group. We found that the average in and out-degree measures for the anchored discussion system group were higher than the stakeholder system as illustrated in Table 3. This indicates that a higher number of messages were sent between peers in the anchored discussion system. However, we have to be aware of the larger in and out-degree variances in the anchored discussion system group. Clearly the stakeholder system group was more homogeneous with regard to in and out-degree measures, but the fact is that both measures were fewer in the stakeholder system group. Therefore, we can conclude that anchored discussion system group had higher communication, but the group was more heterogeneous with respect to in and out-degree measures providing support for H3a.

We looked at network density measure to investigate the strength of overall network connection in each group. We saw that students used the anchored discussion system had higher degree of connection to others in the group, thus supporting H3b.

Table 3. Social Network Analysis Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Anchored Discussion System Group</th>
<th>Stakeholder-Controlled Networking System Group</th>
<th>( t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-degree Centrality</td>
<td>Mean 35.86</td>
<td>10.71</td>
<td>4.97***</td>
</tr>
<tr>
<td></td>
<td>SD 12.86</td>
<td>3.77</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COV 35.86%</td>
<td>35.20%</td>
<td></td>
</tr>
<tr>
<td>Out-degree Centrality</td>
<td>Mean 35.86</td>
<td>10.71</td>
<td>3.95**</td>
</tr>
<tr>
<td></td>
<td>SD 16.30</td>
<td>4.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>COV 45.45%</td>
<td>39.21%</td>
<td></td>
</tr>
<tr>
<td>Network Density</td>
<td>Mean 0.98</td>
<td>0.85</td>
<td>2.00*</td>
</tr>
<tr>
<td></td>
<td>SD 0.07</td>
<td>0.09</td>
<td></td>
</tr>
</tbody>
</table>

Significance: * \( p<0.05 \), ** \( p<0.01 \), *** \( p<0.001 \), one tailed
7. Conclusion

The premise of this study is centered on a fine-grained investigation of the discourse in each system. We used three coherent theories of collaborative learning to guide three different methods for data analysis. From a socio-constructivist perspective, a high quality discourse of scientific inquiry means that collaborative learners actively construct arguments to reason scientifically while jointly working on a learning task. While the arguments in the stakeholder system contained more qualified claims and grounded claims with qualifiers, the discourse was directed more towards construction of relations between prior knowledge and problem space. However, the discourse in the anchored discussion system had more grounded claims and greater emphasis on creating interpretations of theoretical principles as well as establishing logical connections between those principles and hypotheses.

Based on a distributed cognition perspective, we looked at new cognitions that emerged from interacting individuals. We found that students in the anchored discussion system had more opportunity to take up contributions reflecting understanding of theoretical principles and further them by articulating how those principles lead to formulation of testable hypotheses in a research paper. The cause for this enhanced link might be that the students in the anchored discussion system began collaborative knowledge construction with more contributions explaining understanding of theoretical principles. From observing the sequential patterns discovered, we saw that students in both systems carried out brief and prior knowledge related discussions after establishing logical connections between theoretical principles and hypotheses.

By examining the quantity of the directed messages from a contextual influence model perspective, we demonstrated that individual accountability to participate in a group discourse was homogeneous but limited to class participation requirements for the stakeholder system. On the other hand, the anchored discussion system group had higher but more heterogeneous communication because two participants in this group just met the participation requirement. Furthermore, we revealed that the overall network connection in the anchored discussion system group was stronger suggesting that students used each others’ cognitive competencies more effectively for collaborative knowledge construction.

Results suggest that the anchored discussion system seems to be particularly suited for collaborative processing of research papers because it naturally directs students’ efforts towards theory oriented discussion of research papers, whereas the stakeholder system seems to be better suited to facilitate more individual oriented processing of research papers based on one’s prior knowledge as it helps individuals to organize their thoughts.

8. Acknowledgment

The first author would like thank to Catherine Wagley for her critical comments that have improved the readability of the paper.

9. References