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Designing Support for Productive Social Interaction and Knowledge Co-Construction in Collaborative Annotation

Xinran ZHU*, Hong SHUI & Bodong CHEN
Department of Curriculum and Instruction, University of Minnesota, U.S.A
*zhu00323@umn.edu

Abstract: This paper introduces a generic scaffolding framework of participation roles that was co-designed by instructors and researchers to support collaborative learning activities in online classes. Informed by the CSCL literature, the framework specifies three participation roles – *facilitator*, *synthesizer*, and *summarizer* – that play distinct roles in each week's collaborative activities. Using a web annotation tool named Hypothes.is, we piloted the framework in a fully online undergraduate course in Fall 2020. To examine how the framework facilitated social interaction and knowledge co-construction in the class, we conducted social network analysis and content analysis on students' annotation data generated from their engagement with 18 readings. Results indicated the participation roles were enacted properly to a great extent and knowledge co-construction was facilitated when role-takers made high-level contributions. This study has practical implications for online teaching and collaborative learning.

Keywords: Collaborative annotation, participation roles, social interaction, knowledge co-construction

1. Introduction

The COVID-19 pandemic has forced instructors around the globe to seek ways to engage learners in disciplinary learning and peer interaction. While some instructors focused on replicating models of face-to-face (F2F) teaching, others took this opportunity to explore affordances provided by web technologies for new models of instruction. Take seminar courses for example, where critical reading and classroom dialogues are often important means to achieve higher-order competencies such as critical thinking, communication, and collaboration. While it is often believed that in-depth dialogues could only take place in a F2F setting, we can also argue that F2F communication in a fixed amount of time poses serious constraints for classroom dialogues, limiting the amount of speaking opportunities and favoring learners who are more outspoken in a F2F environment. In contrast, web technologies, such as web annotation and video conferencing, offer opportunities for learners to participate in different ways than being in a F2F setting.

This paper reports on a pilot study conducted at a large public university in the US in Fall 2020, when the university campus was shut down due to COVID-19 and many instructors pivoted to online instruction. To engage students in reading and discussing course materials in three liberal-arts classes, we collaborated with instructors to integrate a web annotation technology, *Hypothes.is*, in their online teaching. While the extant literature has investigated various usages of web annotation tools in classrooms (Zhu et al., 2020), studies that incorporate computer-supported collaborative learning (CSCL) ideas in the design of social annotation activities remain rare. In this study, we designed a scaffolding framework comprising three predefined participation roles for learners to participate in weekly collaborative reading and annotation activities. This study advances CSCL and online learning research by generating a design framework of collaborative annotation and testing it in online courses. For the remainder of this paper, we first introduce key perspectives informing this study. We then describe the study context and research methods. After reporting the main findings, we discuss implications and future directions.

2. Related Literature

2.1 Using Web Annotation in Education

Annotation, be it online or paper-based, is an important part of human cognition. Making annotations is a highly developed activity, one that represents an important part of reading, writing, and scholarship (Marshall, 1997). For example, readers annotate printed books as a routine part of their engagement with the materials, with annotations serving a multitude of functions: procedural signals, placemarks, an in-situ way of working problems, interpretive activity, a visible trace of a reader's attention, and so on (Marshall, 1997; O'Hara & Sellen, 1997). While annotations are generally considered marginal, peripheral, and secondary, in-depth analysis of annotations in used books has revealed their added value to the "primary" content and their influence on later book users (Liu, 2005).

Web annotation is a genre of information technology that allows a user to annotate information in a shared web document and hereby anchor a discussion to the annotated information. Similar to annotations in paper-based documents, web annotations are extra pieces of information associated with existing, "first-order" web resources (Haslhofer et al., 2011). According to a systematic literature review, web annotation has been used across different education levels to help students process domain-specific knowledge, promote argumentation and inquiry, improve literacy skills, support instructor and peer assessment, and connect online learning spaces (Zhu et al., 2020). While some use cases of web annotation involve students reading and annotating in groups, there remains untapped potential in web annotation to promote collaborative learning through sophisticated CSCL designs.

2.2 Designing Participation Roles in CSCL

CSCL has a long-standing interest in designing sophisticated social configurations, such as participation roles and classroom discourse, for collaborative learning. This interest is grounded in CSCL's recognition of social interaction as an important factor of learning along with cognitive factors such as knowledge construction (Dillenbourg et al., 2009). In CSCL research, roles have been recognized as a fundamental aspect of group dynamics essential for collaborative knowledge construction (Heinimäki et al., 2020; Ouyang & Chang, 2019). Prior work has explicated two types of roles: *emerging roles* that participants develop naturally and spontaneously in their collaborative learning; and *scripted/assigned roles* that are usually pre-defined by the instructor or instructional designer to facilitate collaboration (Kollar et al., 2006; Strijbos & Weinberger, 2010).

The notion of emerging roles highlights learners' agency in structuring and regulating their collaborative processes. Emerging roles are dynamic over time in relation to learners' cognitive and social engagement (Strijbos & Weinberger, 2010). Reflecting CSCL's interest in scaffolding collaboration, participation roles are also designed to meet instructional goals (Strijbos & Weinberger, 2010). These roles can be designed in response to learner characteristics and curriculum objectives. One premise of this work is that students can meaningfully engage with content and with each other by assuming their assigned roles. Prior work has demonstrated by carefully assigning roles – either contented-oriented roles (e.g., summarizer) or activity-oriented roles (e.g., project planner) (Wise et al., 2012) – learners could harness productive interdependence to reach higher levels of knowledge construction, learner responsibility, and collaboration (Strijbos & Weinberger, 2010).

2.3 The Present Study

The study aims to support collaborative web annotation in college classrooms by designing sophisticated participation roles. Following a co-design approach, we worked closely with three instructors from a large public university in the U.S. to design a generic scaffolding framework for collaborative annotation activities and supported each of them to implement the framework in their classes, with course-specific customization. This study was conducted when the university pivoted to online/distance teaching in Fall 2020 and instructors were looking for ways to meet their teaching needs. At that time, the instructors were participating in a college-level pilot of a web annotation tool named Hypothes.is that was integrated in Canvas to support social reading and annotation among students.

In the design phase, we designed a generic scaffolding framework comprising three scripted participation roles based on the CSCL literature (Strijbos & Weinberger, 2010; Wise et al., 2012). These roles are: a *facilitator* responsible for stimulating conversations by finding connections, seeking clarifications, and encouraging their peers to consistently tag their annotations for an entire week; a *synthesizer* who synthesizes the initial ideas, highlights agreement/disagreement, and suggests directions of further discussions in the middle of the week; and a *summarizer* who summarizes group conversations at the end of the week for the whole class.

In the implementation phase, each instructor further customized the participation roles based on the class they taught. Figure 1 presents an example design from one class, which is the focus of this paper. In this class, each week, the instructor assigned readings and the participation roles to students. The students annotated the course readings and interacted with each other by replying to the annotations. The *facilitator* was responsible for catalyzing productive conversations throughout the week. Under facilitation, students negotiated the meaning of key terms from different perspectives. Figure 2 shows an example interface of the activity (Student B was the facilitator). The *synthesizer* collected students' different perspectives and reflected on their initial thoughts in the middle of the week before their class meeting on Zoom. During the class meeting, students discussed their annotations to address problems of understanding based on multiple perspectives. After the class discussion, the *summarizer* summarized the entire week's activities before each student wrote their individual reflection.

Figure 1. The Scaffolding Framework of Participation Roles.

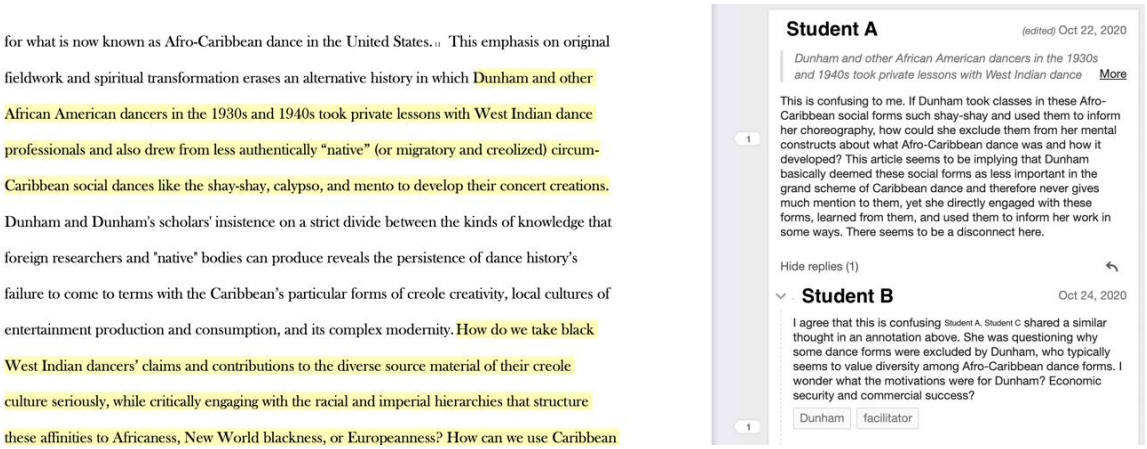

Figure 2. An Example of the Collaborative Annotation Interface.

We proposed the following research questions to guide our investigation of the enacted participation roles strategy:

1. How did the activity design facilitate social interaction? In particular: What were the participation patterns for different participation roles? What were the participation patterns for the whole class and how were they related to patterns of participation roles?
2. How did the activity design facilitate knowledge co-construction? In particular: How were the levels of knowledge co-construction reflected in contributions made by different participation roles? How were the levels of knowledge co-construction reflected in contributions made by the whole class each week and how were they related to knowledge co-construction levels of participation roles?

3. Methods

3.1 Context and Participants

This study was conducted in a fully online undergraduate course at a large public university taught by one instructor and a teaching assistant in Fall 2020. In this liberal-arts class, students (*n*=13) were engaged in reading course materials, participating in weekly online meetings, and writing reflective essays. For the reading tasks, students were required to read 1-2 readings each week, post annotations on Hypothes.is, and reply to each other's annotations. Following the designed scaffolding framework, the instructor assigned the participation roles – i.e., *facilitator*, *synthesizer*, and *summarizer* – to three students each week from Week 1 to Week 11. Students rotated across weeks and had the opportunity to assume different roles.

3.2 Data Source

The main data source included 482 Hypothes.is annotations and 492 replies created by students in 18 readings across 11 weeks.

3.3 Data Analysis

To answer our research questions concerning the social and cognitive aspects of collaborative annotation, we analyzed social interaction and knowledge construction from a socio-cognitive perspective.

3.3.1 Social Network Analysis

To answer the first research question, Social Network Analysis (SNA) was applied to analyze participation patterns in the collaborative annotation activity. SNA as a methodology is interested in capturing and characterizing social positions, structures, and processes. It can capture the structure of a complete network as well as an individual's positions and behaviors in a network. For example, Dowel and Poquet (2021) used SNA measures such as *degree centrality* and *positional dominance* to capture learners' positions in massive open online courses (MOOCs). Such SNA measures could be further combined with other analytical methods (such as content analysis) to examine online communication. In this study, we conducted both whole-network and ego-network analysis to examine the role takers' positions and interaction patterns and their association with features of the full network. We first constructed interaction networks for the whole class, treating each student as a *node* and their interaction/reply events as *edges*; this network was temporal (sliced by week), directed (following the direction of replies), and weighted (based on the number of ties in a particular week). Network measures including *degree centralization*, *density*, *reciprocity*, and *transitivity* were calculated to characterize interaction patterns among students. From the full networks, we also extracted one-step ego networks for individual students and calculated ego-network measures including ego-network *size*, *centrality*, and *constraint* (Burt, 1992) to characterize each student's local situation. Explanations of these network analysis techniques are beyond the scope of this paper and can be found in texts such as Carolan (2014).

3.3.2 *Content Analysis*

To answer the second research question, we conducted content analysis using a coding scheme we developed for the social annotation context based on Gunawardena's Interaction Analysis Model (IAM) (1997) and Onrubia & Engel's model of collaborative knowledge construction (2009).

IAM divides knowledge construction into five phases: (1) Sharing and comparing information; (2) Discovering and exploration of dissonance or inconsistency among ideas, concepts or statements; (3) Negotiation of meaning/co-construction of knowledge; (4) Testing and modification if proposed synthesis or co-construction; and (5) Agreement statements/application of newly constructed meaning. One limitation of this model is that the highest level is rarely achieved. Research suggests that the scope of higher levels of knowledge construction needs to be reconsidered (Lucas et al., 2014). Besides, the

discussion of dissonance as described in the IAM model may not be a necessary condition for higher levels of knowledge construction in certain contexts (Lucas et al., 2014). To address the limitations, we also referenced Onrubia & Engel (2009)'s model which identified four phases of collaborative knowledge construction: (1) Initiation; (2) Exploration; (3) Negotiation; and (4) Co-construction. This model is similar to IAM in terms of the typology of collaborative knowledge construction processes but merges IAM's 4th and 5th phases into one single phase (Lucas et al., 2014). In our study, we did not directly use the four-phase model developed by Onrubia & Engel (2009) because it is designed for collaborative writing activities that require student groups to negotiate dissonance and build consensus in order to to generate a shared writing document. In our context of collaborative reading and social annotation, consensus building was less of a concern as more emphasis was placed on the sensemaking and negotiation of ideas in the readings. Therefore, we developed a revised interaction analysis model (see Table 1). We adopted the levels from the four-phase model by Onrubia & Engel (2009) but revised the indicators by addressing the tasks of collaborative reading and social annotation.

Using this coding scheme, two researchers independently coded student annotation data from Week 1, compared the coding results (Cohen's *kappa* = .90), and addressed disagreements through discussion. After establishing a shared understanding of the coding scheme, each researcher coded half of the remaining data.

To investigate the extent to which participation roles facilitated knowledge co-construction, we first calculated knowledge co-construction levels for roles takers across readings to describe their level of knowledge co-construction in general. Then we zoomed into each reading to count the number of posts in each level contributed by non-role participants. By revealing the knowledge co-construction level of role takers and investigating their associations with the whole class's annotations, we explored how role takers were linked with the knowledge co-construction levels of their peers.

Table 1. *Revised IAM of Collaborative Annotation*

Level	Definition	Examples
Level-1: Initiation	a) Share initial understandings b) Ask questions and share resources without elaboration or critical examination	"Does this sound similar to what is happening in our society today? "
Level-2: Exploration	a) Elaborate on the texts b) Provide additional evidence/information to an argument without critical examination c) Make connections without critical examination	"Do you think this definition of social dance is accurate? What examples of social dance do we see today? How do these dances impact culture?"
Level-3: Negotiation	a) Response to questions through critical reasoning b) Negotiate disagreement c) Connect readings with critical reasoning d) Synthesize meanings e) Create new supporting statements by building on a previous conversation	"This also reminded me of the readings ... This approach to viewing performances seems desirable because it's often nice to just be able to watch a piece for the art that it is, but it is also important not to settle into this mindset and block out the intentions and messages behind a staged performance as well."
Level-4: Co-construction	a) Reach a consensus on a previous question b) Apply the knowledge or way of thinking gained through the activity c) Make a metacognitive statement illustrating their learning outcome	"… before this class began, I only thought of the first description when I considered diaspora. I viewed it as a lonely and isolating thing where people are forced from their homelands and lose all connection with their culture. However, these articles are broadening my view and allowing me to appreciate the connective power of diaspora, which I think is perfectly alluded to in this quote."

4. Results

4.1 How Did the Activity Design Facilitate Social Interaction?

4.1.1 Node-level Measures for Role Takers and Non-Role Takers

The mean and standard deviation of the SNA measures for different role takers suggested that the role takers, especially the *facilitators* and *synthesizers*, varied in the SNA measures which implies they may take different strategies when completing their tasks. The Analysis of variance (ANOVA) to determine if there are statistical differences between mean SNA measures among the four groups (non-role takers, *facilitators*, *synthesizers* and *summarizers*) suggested that the differences are significant in in-degree ($F(3, 211) = 3.48$, $p < .05$), out-degree ($F(3, 211) = 21.92$, $p < .05$), betweenness ($F(3, 211) = 5.67$, $p < .05$), positional dominance ($F(3, 211) = 6.16$, $p < .05$), and ego size ($F(3, 211) = 4.56$, $p < .05$). The constraint was not significantly different among groups.

A post hoc comparison using the *Tukey* test was also conducted to further examine the differences between each group (see Table 2). The results revealed that the *facilitators* were significantly different from non-role takers in all SNA measures except constraint. Also, the *facilitators* were significantly different from the *summarizers* in betweenness. The *synthesizers* were significantly different from non-role takers and *summarizers* in out-degree. The *summarizers* did not show significant difference with non-role takers in all measures.

The results aligned with the design that *facilitators* tended to facilitate the social interaction by sending out more replies and reaching out to more peers, resulting in receiving more replies and being influential in the collaborative annotation activities. The *synthesizers* also participated more than non-role takers in terms of the numbers of posts they sent out (out-degree), but not as much as the *facilitators* did in facilitating the interaction since they tended to focus more on synthesizing the readings and annotations. The *summarizers* participated the same as non-role takers since their responsibility was to write the weekly summary independently after class meetings.

Table 2. *Pairwise Comparisons among Groups*

		Mean Differences (A-B)					
Group A	Group B	In Degree	Out Degree	Betweenness	Constraint	Dominance	Ego Size
Facilitator	Synthesizer	0.11	0.03	5.21	-0.07	0.09	0.76
	Summarizers	0.07	0.14	10.13*	-0.05	0.14	1.24
	Non-role	0.11*	0.13*	9.75*	-0.08	0.16*	1.37*
Synthesizer	Facilitator	-0.11	-0.03	-5.21	0.07	-0.09	-0.76
	Summarizers	-0.04	0.11*	4.92	0.02	0.05	0.47
	Non-role	0.00	0.10*	4.55	-0.01	0.07	0.61
Summarizers	Facilitator	-0.07	-0.14*	-10.13*	0.05	-0.14	-1.24
	Synthesizer	0.04	-0.11*	-4.92	-0.02	-0.05	-0.47
	Non-role	0.04	-0.01	-0.38	-0.03	0.02	0.13

Note. * indicates the mean difference is significant at the .05 level.

4.1.2 Network-Level SNA Measures Across 11 Weeks

Whole-network SNA was conducted for each reading across 11 weeks. The results do not show discernible trends across weeks. For example, Reading 3a has the highest transitivity but relatively lower scores in the other network measures, while Reading 4 has relatively high scores among all four network measures. Readings 3b, 5, and 9b show a big drop in the SNA measures in comparison with previous weeks/readings, especially in degree centralization, transitivity, and reciprocity.

To further explore the explanations of the variance of the social interaction patterns across weeks/readings, a Pearson correlation test between *facilitators* and *synthesizers*' node-level measures and the network-level measures was conducted. As shown in Table 3, the network-level measures (except reciprocity) are significantly correlated with *facilitators* and *synthesizers*' node-level measures to some extent. It is worth noting that the positional dominance and the ego size of *facilitators* and all

measures of *synthesizers* are linked to the network transitivity, e.g., the *synthesizers'* sending out more annotations (higher out-degree) is linked to a more transactive network (higher transitivity), meaning that students are more likely to develop different perspectives by interacting with multiple peers. The results suggested that these role takers' participation is associated with the interaction patterns for the whole class. Hence, when different role takers took different strategies to play their roles and interact with peers, it may lead to the variance of interaction patterns across the whole class.

Table 3. *Pearson Correlations between Facilitators and Synthesizers' Node-level Measures and Network-level Measures*

		Density	Reciprocity	Transitivity	Centralization
Facilitator	In-degree	0.32	0.34	0.33	0.68*
	Out-degree	0.83*	-0.02	0.47	0.74*
	Betweenness	0.57*	0.26	0.12	0.53*
	Constraint	-0.45	-0.19	-0.04	-0.28
	Dominance	0.43	0.31	0.50*	0.86*
	Ego size	0.60*	0.18	0.49*	0.67
Synthesizer	In-degree	0.57*	-0.18	0.64*	0.65*
	Out-degree	0.77*	0.13	0.62*	0.53*
	Betweenness	0.64*	-0.08	0.58*	0.45
	Constraint	-0.48	0.27	-0.55*	-0.05
	Dominance	0.48	0.27	0.57*	0.81*
	Ego size	0.75*	-0.13	0.77*	0.53*

Note. * indicates the correlation is significant at the .05 level.

4.2 How Did the Activity Design Facilitate Knowledge Co-Construction?

4.2.1 Knowledge Co-Construction Levels of Participation Roles in General

According to Table 4, the great numbers of Level-2 and Level-3 posts of the *facilitators* revealed that the *facilitators* generally asked questions or provided answers with elaboration, examples, critical reasoning, etc. to launch and advance the discussion. Yet the large standard deviation also suggested that the knowledge construction level varied across the *facilitators* in different weeks; some *facilitators* posted more Level-1 posts that consisted of only general questions or links to additional resources. Similarly, the *synthesizers*' posts were also mostly classified into Level-2 and Level-3 posts (83 out of 93 posts). It was partly because the scripted role of the *synthesizer* requested them to synthesize the initial ideas, highlight agreement and disagreement, and suggest directions for further conversations.

The *summarizers* on average contributed much less annotations. The results were in line with the design, i.e., the *summarizer* focused on the class discussion during Zoom meetings and composed a summary that connected synchronous Zoom discussions with asynchronous web annotations.

Table 4. *Mean and Standard Deviation of Participation Roles in Four Levels*

	Level-1	Level-2	Level-3	Level-4
Facilitator	0.88 (1.65)	2.24 (1.35)	3.24 (2.17)	0.18 (0.39)
Synthesizer	0.62 (0.81)	2.00 (0.89)	3.06 (1.73)	0.12 (0.50)
Summarizer	0.29 (0.47)	2.06 (1.09)	1.29 (1.05)	0.06 (0.24)

4.2.2 Knowledge Co-Construction Levels of Non-role Participants

According to the results in Figure 3, non-role rakers demonstrated comparatively higher knowledge co-construction levels in Readings 3a, 04, 6a, 8 and 11b. These five readings showed a similar growing trend in the frequency of levels, i.e., with very few Level-1 posts, a moderate quantity of Level-2 posts,

and a great number of Level-3 posts. In addition, non-role takers in Readings 3a, 8 and 11b even contributed Level-4 posts that were rare in this dataset.

By contrast, non-role takers in Readings 2b, 3b, 6b, and 10b contributed more Level-1 posts and less Level-3 posts compared with the other readings, displaying a lower level of knowledge co-construction.

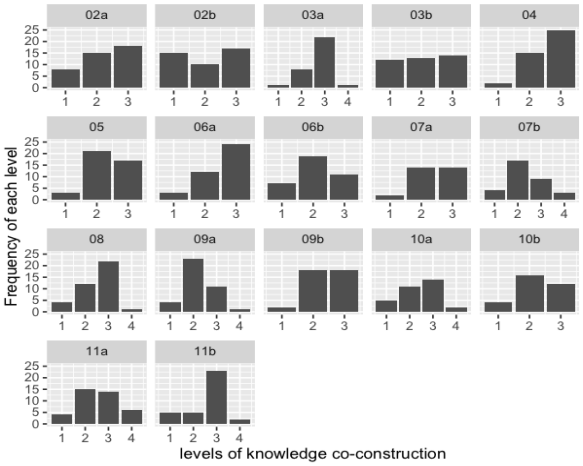

Figure 3. Level Frequency by Non-role Participants in Each Week. The first week was not measured because the instructor and TA played the participation roles as a demonstration.

4.2.4 *The Relationship between the Contributions Made by Role-takers and Non-role Takers*

Table 5. *The Percentage of Posts Contributed by the Role-takers in Each Knowledge Co-construction Level and the Average Knowledge Co-construction Levels of Non-roles*

		Readings															
		02a	02b	03a	03b	04	05	06a	06b	07a	07b	08	09a	09b	10a	10b	11a
Role	Level-1	6%	21%	5%	27%	0	0	0	43%	9%	32%	16%	13%	8%	8%	8%	0
	Level-2	56%	43%	45%	27%	30%	40%	21%	29%	35%	42%	32%	50%	58%	33%	42%	47%
	Level-3	38%	36%	35%	45%	65%	60%	79%	29%	57%	26%	53%	38%	33%	42%	50%	53%
	Level-4	0	0	15%	0	4%	0	0	0	0	0	0	0	0	17%	0	0
Non-role	average	2.24	2.05	2.72	2.05	2.55	2.34	2.54	2.11	2.40	2.33	2.51	2.21	2.42	2.41	2.18	2.56

Note. Reading 11b was excluded due to the absence of synthesizer and a very small number of posts contributed by the facilitator and summarizer. Percentages may not add up to 100 due to rounding.

Table 5 shows the percentage of posts contributed by the role takers in each knowledge construction level and the mean knowledge co-construction scores of non-role takers in each reading. In weeks when role takers posted more higher-level posts, the knowledge construction level from non-role takers tended to be high too. For example, in Readings 3a and 04 where 95% and 100% of the role takers' posts respectively were higher than Level-1, the knowledge construction levels for non-role takes were among the highest. Take the *facilitator* for example. In Reading 3a, when the *facilitator* sent out seven posts that all were above Level-2, they attracted 2 Level-2 replies and 6 Level-3 replies. To illustrate the details, below is one conversation thread demonstrating how this *facilitator* proposed specific questions to invite their peer to go deeper in this discussion.

> [Student 110]: Cultural syncretism means the blending of cultures to form something new. This can be in the form of religious practices, architecture, philosophy, recreation, food, etc. I think this back and forth Dunham was experiencing throughout her career is understandable. Was she in search of a right and a wrong answer? Or was she struggling to see how cultural syncretism preserved culture while simultaneously creating something new and different.
>
> > [Facilitator]: Student 110, this is a good thought and a new word for me, too. Student 105 student 114 talked about diaspora and assimilation a few paragraphs above. How do you think diaspora and syncretism relate, or maybe they do not relate at all? Do you think one is more beneficial than the other for preserving the culture?
> >
> > > [Student 110]: In general terms, I interpreted diaspora meaning this shift of cultures due to movement, and the intertwining of different cultures. I think syncretism focuses more on the combination of religious beliefs and an

"interfaith". I don't know if one is better than the other, there always seems to be two sides to the story. In my opinion, I think the creation and development of new cultures is beautiful, but I am also someone who likes to hold onto tradition.

In contrast, Reading 6b's *facilitator* only received two replies to their five Level-1 annotations. Because the annotations made by this *facilitator* lacked in specificity and elicitation, e.g., "Here is a video of zapateado…," they failed to elicit contributions from others or to deepen the discussion.

5. Discussion

Inspired by the use of scripted roles to facilitate collaboration in CSCL, we worked with instructors to co-design a generic scaffolding framework for collaborative annotation activities by assigning three participation roles: *facilitator*, *synthesizer*, and *summarizer*. We piloted the design in a fully online undergraduate course and answered two research questions via SNA and content analysis on student annotation data.

The first question asked: How did the activity design facilitate social interaction? The ANOVA post-hoc pairwise comparison revealed that there was a significant difference between *facilitators* and non-role takers in annotation activities. It indicated that *facilitators* were most active in fostering the social interaction of the class by initiating the conversation through proposing questions, providing answers to puzzles, sharing information, etc. Besides *facilitators*, *synthesizers* also facilitated the social interaction by connecting readings and annotations to further the negotiation. *Summarizers*' participation was similar to non-role takers. These results indicated that to a great extent the designed activity was enacted by students properly.

The second question was: How did the activity design facilitate knowledge co-construction? Generally, *facilitators* and *synthesizers* held higher knowledge co-construction levels than *summarizers*. Examining weekly contributions of participation roles and non-role participants indicated that the knowledge co-construction level of role takers was associated with the level of their peers. For instance, when a *facilitator* sent out high level posts, they were more likely to receive replies and trigger a negotiation among peers. The reason might be that the high-level posts -- which featured elaboration, connection, critical reasoning, and application -- provided more directions for peers to engage in the conversation.

This paper's contribution to the CSCL and online learning literature is three-fold. First, we proposed a scaffolding framework for collaborative annotation that is applicable to many college-level classes. This framework builds on prior frameworks developed for online discussion forums (e.g., Wise et al., 2012) and extends CSCL ideas to support collaborative reading and annotation. Second, we developed a revised Interaction Analysis Model for collaborative annotation that is more appropriate for analysis of student discussions "anchored" in web documents. Finally, results of data analysis have shown promise of the designed scaffolding framework for facilitating productive collaborative annotation in the study context. In particular, the *facilitators* and *synthesizers* played roles in deepening collaborative annotation.

These findings have practical implications for online and hybrid classes. First, assigning students to different participation roles, such as *facilitators* and *synthesizers*, is worth considering in classes that involve asynchronous communication. Even though *facilitators* may participate in different manners, when they make high-level contributions that ask well-reasoned questions or make important connections between ideas, the quality of student discussion could be enhanced. Second, the study also implied that students need support to assume different participation roles. Indeed, students are not always natural collaborators and need to make intentional efforts to become better collaborators (Borge & White, 2016). The instructor needs to provide careful scaffolding and detailed guidelines for students to take various roles.

This paper only reports preliminary findings from a series of studies that attempt to facilitate collaborative annotation in college classrooms. There are several future directions for this work. First, we plan to deepen the analyses presented in this paper by incorporating advanced network modeling to examine the effects of social and cognitive factors on peer interaction. We are also in the process of analyzing two other classes that implemented the scaffolding framework. We plan to compare results among these classes to identify commonalities and differences. Finally, we are working on designing new tools for students to assume these participation roles more effectively. These efforts are all geared

towards discovering means to promote new genres of collaborative learning that are supported by CSCL theories, digital tools, and instructional models that are tested in real-world settings.

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