

Critical Moments of Knowledge Co-construction: Reconsidering Meaning-making of Postings in Online Group Discussion

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Abstract: This study attempts to investigate the critical moments in online knowledge co-construction. We analyzed the episodes of the dynamic group discussion by reconsidering the meaning-making of each posting in order to gain a full contextual understanding of how collective knowledge developed. The results identified three critical moments: “confusion and hesitation”, “from stick around to move forward” and “making justification and breaking through”. Unlike using the single posting or adjacent pairs of postings as the unit of analysis, this study claims that linking backwards to earlier turns is as important as linking forwards to later turns for discovering a complete picture of how online group members co-construct knowledge. The nuance of dealing with the time dimension across different approaches in CSSL is also discussed.

Introduction

Learning through knowledge co-construction is increasingly regarded as having a significant effect (e.g., Stahl, 2009). Ideally, through observing and responding to each other, group members establish a focus for their discussion and maintain a heterogeneous environment of revision and complement within which knowledge is deepened and augmented. Practically, however, it is not easy to achieve a positive effect. In the process of group collaboration, members encounter a lot of problems, such as: having different levels of domain knowledge, becoming distracted from on-topic discussion, struggling in coordination with other members, logging on sporadically etc. The quality of the knowledge co-construction in group discussion is therefore decreased.

To investigate this online knowledge building phenomenon, many researchers used the “single posting” as the unit of analysis (Suthers, Dwyer, Medina & Vatrappu, 2007) to more easily scrutinize visible messages in order to identify the quality of knowledge co-construction in group discussion. Others treated the “each thread” as the unit of analysis in order to capture the response relationship in the group discussion, the formation of the sub-thread, the lifespan of a thread, the frequency and type of certain behavior of the group members, and so on (e.g., Hewitt, 2005). This study extends this line of research by exploring exactly how the “whole thread” is analyzed and what aspects of knowledge co-construction can be discovered.

In this study, we analyze the discussions in the Learning Atmospheric Sciences via InterNet, LAIN, an independent and voluntary discussion forum. Unlike the related literature, we purposely use both the “single posting” and “the whole thread” as units of analysis in order to compare and contrast the distinct differences found in capturing the relationships between the members, and the roles of the group members, respectively. With these, we then attempt to address the following issues: First, to identify the critical moments of knowledge co-construction in heterogeneous online group discussion, and second, to determine how the heterogeneous group members collaboratively accomplish knowledge co-construction.

Analytical Approaches to Knowledge Co-construction

“Knowledge co-construction” is a promising issue addressed by different parties with similar terms in the CSSL field. For example, knowledge building (Scardamalia, 2002), knowledge convergence and collaborative learning (Jeong & Chi, 2007) and group cognition (Stahl, 2010). Knowledge building communities have to tackle the difficult problem of handling complexity and reaching a common understanding. By the same token, approaches to knowledge building groups or communities are also diverse and multi-voiced. Two issues have been the focus: 1) proposing elements in capturing the phenomenon of knowledge co-construction, and 2) proposing analytical approaches in analyzing interaction among knowledge co-constructors.

First, rather than strive to understand the process by which knowledge co-construction developed, most previous studies on knowledge co-construction attempted to investigate the elements of knowledge co-construction. In particular, these studies explored those that contributed to the success or failure of group collaboration and identified certain elements: question and response construction, engagement in the group process (Zhou, 2009), knowledge sharing and the willingness to revise (Chiu, 2008), the focus of discussion, the connection between old and new ideas, the association of the discussion with the topic (e.g., Aalst, 2009), knowledge convergence and knowledge divergence (Jeong & Chi, 2007), the heterogeneous group member (e.g., Scardamalia & Beretier, 2006), the peer as each member’s reader or writer (e.g., Dennen & Wieland, 2007), the

application of information, and references or authoritative materials (Scardamalia & Brierley, 2006; Hmelo-Silver, 2006; Stahl, 2008). Such lists are helpful in grasping partially the knowledge co-construction in group discussion. However, we argue that an authentic process of knowledge co-construction in heterogeneous group discussion could be represented not just as isolated incidents in interaction episodes, but also as a mixture of coherent and incoherent processes. It is unlikely to be possible to separate knowledge co-construction from the process of dynamic interaction when all elements in this context are so thoroughly intertwined. In the present study, we therefore attempt to broaden our view in order to capture the critical moments and the contextually situated processes of group knowledge co-construction.

Second, many researchers have devoted a great deal of effort to analyzing the quality of knowledge co-construction. We therefore trace the development of the analytic method during the last decade: In the early period, previous research adopted the following analytic methods to measure learning in discussion forums: (a) restricting subject behaviors; (b) setting certain variables; (c) coding and counting the content of “single posting”, “adjacency pairs” and “taking turns”; and (d) the quantitative-statistics. Lately, however, some researchers claim that the above methods hinder appreciation of sequential structure and ignore the nature of collective group growth (e.g., Suthers, Dwyer, Medina & Vatrappu, 2007). Besides which, the order, sequentiality and timing typically play a significant role in how the postings are understood (Stahl, 2010). Therefore, from the perspective of sequential and situated interaction, researchers have developed particular concepts and methods, such as statement analysis, interaction analysis, episode analysis (e.g., Jeong & Chi, 2007; Zhou, 2009; Reimann, 2009), uptake analysis (Suthers, 2006), CORDTRA Diagrams (Hmelo-Silver, Chernobilsky, & Mastov, 2006), inter-subjectivity and group cognition (e.g., Stahl, 2010) and prior posting (Diggelen, Janssen, & Overdijk, 2008). Some have used the multi-threads or cross threads as the unit of analysis in order to understand the formation, structure, growth, and lifespan of the thread, and the synergetic interaction and the interaction pattern between the threads (e.g., Schrire, 2006; Hewitt, 2005). Along with this line of research approach, our analytic method focuses on the sequence of contextual events, and on the meaning-making of individual postings in the process of knowledge co-construction in heterogeneous online group discussion.

Specifically, in an attempt to highlight the distinct difference in the effect of capturing the nature of knowledge co-construction between the “contextual-situated process” and the “single posting”, we purposely apply two different units of analysis to the same dataset. First, using the “single posting” as the unit of analysis, we identify the level of group members’ role-behaviors; then by using the “whole thread” as the unit of analysis, we recognize the relationship between the current posting, the postings of earlier turns (Chen & Chiu, 2008), and the postings of later turns; and finally, by comparing and contrasting the results of the above two kinds of units of analysis, we interpret our findings in a dialectic way.

Research Method

The Context

487 voluntary participants attended a 6-week inquiry learning in LAIN, in which they were divided into different groups as determined by the topics in which they are interested. Group members in this inquiry activity collectively justify a hypothesis and complete the task.

The members of group C2 were selected to be our research subjects. The C2 group consisted of 6 members whose postings totaled 389 and whose online presence frequency totaled 526 (Table 1). The main topic of the C2 group discussion was “Fog”.

Table 1: The frequency of postings and online presence totals of C2 group members.

ID	Posting	Online
010124	150	182
Milkbottle	123	119
Cathyjudy	53	94
Icebox	34	60
Snowlove	28	70
Beer	1	1
	389	526

Since we were interested in how knowledge co-construction developed, we focused on the longer threads, and chose the 15th as the sample discussion thread. The 15th thread consisted of 69 postings which were posted by the 4 members during the second week. Icebox and Beer had not participated in this 15th thread. The long thread provides us a better opportunity to discover the progress and the dynamic interaction in the C2 group discussion.

Data Collection and Analysis

The data log of the discussion forums served as the main resource of data analyses. Data were analyzed to determine each member's participation level and learner-role behavior. In addition to the frequency of total postings and weekly postings, and the timing of the postings; the content of the postings, the interrelationships between them, and the weekly diary of inquiry process were also collected. Two kinds of unit of analysis were used: "single posting" and "the whole thread".

First, the "single posting" was used as the unit of analysis to recognize and identify the level of group members' role-behaviors. We adopted Waters and Gasson's (2006) approach — "the classification of the primary learner-role behaviors" — to examine the contribution of the participant's behavior in the online forum. The eight learner-role behaviors are: Passive-learner, Knowledge-elicitor, Contributor, Vicarious-acknowledger, Closer, Facilitator, Initiator, and Complicator (Table 2). The classification further provided a framework for three levels of involvement: participation, involvement, and social engagement. This classification was accomplished by 1) identifying the contribution of each posting through comparing the relationship of prior postings to the current one in order to recognize the level and the contribution of the posting, and 2) counting the classification of each posting of each group member, and 3) selecting the highest frequency as the most fitting classification to define the participation level of each group member.

Table 2: The classification of primary learner-role behaviors.

level	Form of Behavior	Milkbottle	Cathyjudy	010124	Snowlove
I. Participation	Passive-learner				
	Knowledge-elicitor	1	3		
	Contributor			13 *	
II. Involvement	Vicarious-acknowledger	1	1	1	
	Closer	7		1	
III. Social engagement	Facilitator	19 *	8 *	1	1
	Initiator	2			
	Complicator				3 *
Total		30	12	16	4

PS. The result of the classification of each member is indicated with *.

From the results showed in Table 2, most of the members fell into the *III. social engagement* level. Milkbottle and Cathyjudy were classified as the *Facilitators* and Snowlove as the *Complicator*. 010124 was the only person to be classified as the *Contributor* and fell into the *I participation* level. It seemed that Snowlove, Milkbottle and Cathyjudy made a higher level of contribution to the group discussion, while 010124 was deemed to have contributed to this group at a relatively superficial level. Interestingly, although 010124 was the most active person in this group in terms of the number of postings, the nature of her postings in thread #15 was more that of a contributor. Table 3 summarized a profile of each member from our online observation notes.

Table 3: Observation of the characteristics of the learners in the C2 group.

ID	Form of behavior	The characteristics
Milkbottle	III <i>Facilitator</i>	Actively participates in group discussion, and often integrates other members' opinions into one posting.
Cathyjudy	III <i>Facilitator</i>	Actively asks questions, shares her thoughts, and triggers other's participation in the discussion.
010124	I <i>Contributor</i>	Actively responds to others with authoritative content via "copy and paste".
Snowlove	III <i>Complicator</i>	Contributes fewer postings to the group but is quite aware of the context of the discussion and points out the problems.

In addition to using Waters and Gasson's approach, we purposely reexamined the contribution of each participant by using "the whole thread" as the unit of analysis (Figure 1). In this way, we were able to trace the evolution of the whole 15th thread by referring to both the backward and forward postings and by selecting isolated postings with similar focus within the thread. The time dimension emerged as a pivotal issue to deal with in knowledge co-construction. In order to represent the meaning of every "single posting" in the accomplishment of knowledge co-construction in online discussion, domain experts and learning scientists collaboratively analyzed the 69 postings with these characteristics in mind: 1) the depth of domain knowledge of

the posting, 2) the evolution of the concept's physical property, 3) the flow of the group discussion, 4) the interrelationship between the postings, 5) the participation features of the group member, 6) the timing of the posting and the atmosphere of the group discussion, and 7) the nature of the response of group members. The results of the second approach provide a distinctively different picture of group knowledge co-construction from those of the first approach—but these two viewpoints are dialectically interrelated.

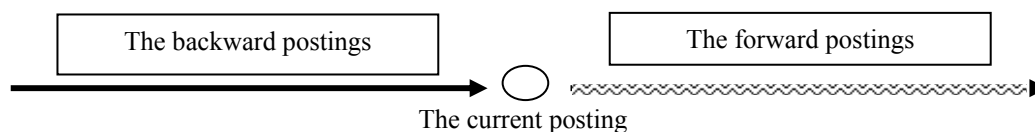


Figure 1. The Analytic Structure for “The Whole Thread” as the Unit of Analysis.

Using the emergence of these particular convergent postings as an index, #21 and #49 were determined to be the watersheds at which to divide the 69 postings into 3 separate pieces for detailed analysis of knowledge co-construction. The 3 separate pieces represented the different meaningful-activities and showed the different phrase existed in the 15th thread. And we found that each posting came from the prior postings and had the effect on the forwards postings. For example, the posting #48 is not just the result of the prior postings #1~#47, but also has the effect on the forward postings #49~#69.

Research Findings

These three episodes contain different stories about how the “whole thread” as the unit of analysis revealed deeper understanding of knowledge co-construction than the “single posting” could. To be specific, the present study demonstrated that the second approach not only interpreted the learning situation of the group discussion differently, but also contrasted sharply with the first approach on the contribution of group members.

Confusion and Hesitation

The first episode shows that the progress of the group discussion had gotten into a confusing condition by using the “single posting” as the unit of analysis. However, using “the whole thread” as the unit of analysis, we discovered that the group members were simply waiting for next opportunity to clarify the problem.

The phenomenon of knowledge co-construction could be a slow process and could have a pre-condition. An authentic situation for knowledge co-construction to develop is in response to encountering a confusing situation. The following excerpt is an example. Milkbottle came up with a hypothesis(#11), Cathyjudy tried to clarify the question(#12), Milkbottle and 010124 not only responded to Cathyjudy but also became mired in confusion thinking about an uncertainty (#13~15).

No	ID	Content
11	Milkbottle	(.....)I have an idea about the hypothesis: Fog occurs in the interface of warm and cold air masses. When atmospheric convection is not efficient, the cold and warm air masses come in contact with each other.
12	Cathyjudy	What does it mean that atmospheric convection is not efficient? Does it mean there is no wind??
13	Milkbottle	It might not be possible that there is no wind when cold and warm air contact each other in an air mass within the specific area. I don't know. Can anyone respond to this?
14	010124	No matter whether it is breezy or windy, lower atmosphere is always flowing. The solar energy is the source of all activities in the atmosphere. The air is heated, expanding and drifting upward and the low air occurs at the surface. It is impossible to have no wind because warm air goes up; cool and height-density air replaces the warm air and thereby generates the wind. Therefore it is not possible to happen in a situation with no wind.
16	010124	I don't know if my response was correct. Keep thinking about it.
31	Cathyjudy	The example that the car and the glasses should not be related to the concept of convection.

The appearance of confusion might be invalid in knowledge co-construction. Group members mixed up the concepts of “convection” and “wind”. They all felt frustrated and shifted discussion to another topic after #16. Using the “single posting” or “adjacent pair” as unit of analysis, one might consider this episode as ineffective and exclude it from knowledge co-construction. However, using “the whole thread” as the unit of analysis, we discovered that the messy conception had become less unclear. Cathyjudy started to clarify the idea of “convection” in #31, which is far from the earlier turns. That is, linking backwards to earlier turns is as

important as forward to later turns in investigating the process of knowledge co-construction.

Furthermore, the discontinuity between smoothness and stagnation would be regarded as an opportunity for evoking growth or new turns. In the first episode, group members appeared to change to another topic because they could not discuss the present topic any further. Later on, we noticed that the group members still cared about the question and kept it in mind. They engaged more and associated relevant ideas to the previous answer. Were we to assume that there was no progress in this episode of group discussion, we might misinterpret their pondering time as valueless in knowledge co-construction. But by putting together pieces of puzzle, that is, related postings of earlier turns as well as of later turns, we discovered that the group members cross from discontinuity and stagnation to renewal of progress as a result of an apparently imperative time period of confusion and hesitation.

From Stick Around to Move Forward

The second episode would appear that the group was engaged in a warm and well-focused atmosphere when using the “single posting” as the unit of analysis. However, using “the whole thread” as the unit of analysis, we found that although the two *Facilitators* actively developed their ideas and presented a sustained discussion, the discussion was not really making further progress and had lapsed into stagnation. Moreover, it was the *Contributor* who eventually advanced the group discussion “from stick around to move forward”.

Knowledge co-construction deals with the development of collective and public knowledge. It therefore involves negotiation and a bid for currency of each other’s ideas. The ones who contribute more in the discussion forum seem to have a higher level of social engagement, and this results in greater contributions to knowledge co-construction. The interaction between the two facilitators, Cathyjudy and Milkbottle, in the second episode was identified as consisting of effective postings using the “single posting” as the unit of analysis. Interestingly, in some cases “effective discussion” might actually cease growing. In contrast it was the contributor, 010124, who made group progress in knowledge co-construction. Earlier by using the “single posting” as the unit of the analysis in identifying the roles of group members, Cathyjudy and Milkbottle were identified as *Facilitators* who engaged in and contributed more to the discussion, while 010124 was regarded as a *Contributor* who engaged in and contributed less to the discussion because her postings (#37, #38, and #40) mainly consisted of copying and pasting references and never conveyed her own independent opinions.

However, the above interpretation of the roles of group members was overthrown by using “the whole thread” as the unit of analysis in recognizing the roles the members played. Since 010124 came close to Cathyjudy and Milkbottle in the creation and assimilation of knowledge over a long period of time, she paid a great deal of attention to Cathyjudy and Milkbottle’s postings, and at the same time, she proceeded to diagnose and justify Cathyjudy and Milkbottle’s postings. In the process of following Cathyjudy and Milkbottle’s discussion, 010124 seemed to play the role of a semi-outsider, but 010124 participated in and observed the group discussion in a salient fashion. When Cathyjudy and Milkbottle developed a series of 16 postings about the topic of “the relationship between Fog and Wind”, 010124 found them to be unfocused. Apparently the 16 postings seemed to go deeper than earlier; 010124 noticed a knowledge gap which stopped the discussion from growing. She therefore tried to speak up and present her opinion. As Lave (1991) claimed from a situated learning perspective: “This is the time that they (members) feel that they belong enough to carry the message”

No.	ID	Content
37	010124	Fog occurs more easily in a low-lying area!!!
38		Fog occurs over the land more easily than over the sea.
39	Milkbottle	Low-level cold air should be left behind by the cold front, so it has not enough energy to raise warm air up.
40	010124	Fog takes place at night easier than during the day
41	Milkbottle	010124! Give the reasons of your hypothesis or you will not be able to convince anyone.
42	Milkbottle	Rain in Spring is too light to be felt. Is it a kind of drizzle?
43	010124	Wind at high altitude is stronger than at lower altitude, so I proposed the first hypothesis. Wind over the sea is stronger than over the land, so I proposed the second one. The reason of the third one is that wind is always stronger during the day than at night.
48	Cathyjudy	According to #15-42 According to 010124, can we summarize them all into a hypothesis? The occurrence of fog is related to wind, because only one key point that 010124 mentioned is wind.....

Engagement including inviting and accepting the ideas of others is important in the process of knowledge co-construction. 010124 avoided joining in the discussion about “the relationship between Fog and Wind” in which Cathyjudy and Milkbottle were actively involved. Instead, 010124 subtly joined them by

initiating a title about “hypotheses involving the factor of fog” (#37, #38 and #40). Although 010124’s 3 postings were mainly authoritative information forwarded from websites, these 3 postings did evoke negotiation within the group.

The subtlety of the value of a posting is not dependent upon its having the appearance of being a “copy and paste” contribution, but on its timing and the need it filled during knowledge co-construction. Using the “single posting” approach, postings such as “copy and paste” are defined as superficial contributions. However, using “the whole thread” approach, the contribution of such postings changed. In our case, Milkbottle noticed these 3 information-based postings, and negotiated a bid for them (Wenger, 1998) (#41). Then, Milkbottle invited 010124 to elaborate more upon her opinion. As a result of Milkbottle’s invitation, 010124’s posting was able to increase in value and become used as a bargaining chip, adopted by other group members (Zhou & Stahl, 2008). At this moment, 010124’s long engagement did clearly produce the positive effect of acquiring more knowledge. 010124 used the knowledge that was learned from tracking the history of the evolution of the group discussion to validate and support her opinion (#43). Then, Cathyjudy and Milkbottle adopted 010124’s opinion (#48) and it became legitimate knowledge in the group discussion. In the above mentioned case, we can see that Cathyjudy and Milkbottle’s willing adoption created an opportunity for 010124, who played a crucial role in bringing about opportunities for group success. 010124 took advantage of an opportunity to justify and produce a dramatic shift which improved group discussion, as a result of which, Cathyjudy and Milkbottle made an adjustment which led the group discussion toward greater progress and away from its stymied state – thus expanding the lifespan and longevity of threads. In this second episode, we can see and understand how groups maintain their continuity of interaction across discontinuities.

Doing Justification and Breaking Through

The third episode showed that the *Complicator*’s opinion was more powerful and the *Contributor*’s posting weaker in the group discussion when using the “single posting” as the unit of analysis. However, when using “the whole thread” as the unit of analysis, we found that nobody but the *Contributor* cared about the *Complicator*’s opinion. Again, the *Contributor* justified and supported the correctness of the *Complicator*’s opinion by copying and pasting. In this process of justification, the *Contributor* clarified misconceptions in the group discussion, and affected the direction of the group discussion.

The *Contributor* who was regarded as demonstrating a lower level of contribution, may play a critical role with the *Complicator* in knowledge co-construction. In the third episode, group members seemed to exhibit a great deal of commonality and consensus; but the condition was actually somewhat ambiguous at this stage.

The concept of “wind” as the main hypothesis(#43) was started back in #18, and went through 25 postings (#18~43), eventually to be accepted and integrated in the group hypothesis for the group member who had engaged more over a long period of time. But, the *Complicator*, Snowlove, who always remained silent in the group, at this stage broke her silence and submitted 3 postings (#45~47) to address the question of the concept of “wind” as the main hypothesis and one that was in her opinion justified, specifically “advection fog is not restricted by wind speed, but the advection of warm and wet air.....”. When we identified Snowlove’s 3 postings using “single posting” as the unit of analysis, we had considered them as deeper and more contributive to the group discussion. However, we found that the 3 postings had different meaning-making for other members in the process of discussion when using “the whole thread” as unit of our analysis. The 3 postings’ meaning for other members is as follows.

No.	ID	Content
45 46 47	Snowlove	This is used data..... I thought radiation fog took place on land mostly and the weather must be less wind. advection fog is not restricted by wind speed, but the advection of warm and wet air..... Maybe other teams study radiation fog and advection fog, so can we start from another point of view, like looking for some materials of other kinds of fog, then discussing?
48	Cathyjudy	<i>According to #15-42.</i> According to 010124, can we summarize all into a hypothesis? The occurrence of fog is related to wind, because of only one key point that 010124 mentioned is wind.....
49~50	Milkbottle	The conditions of formation of fog: 1. low temperature, 2 high humidity, 3. less wind, and condensation nuclei.
51, 52, 55, 57~60	010124	<i>frontal fog, fog, fog, Upslope fog, Spring fog in early morning is a sign of clear sky. Summer fog in early morning, Heavy rain in the afternoon</i> (All the contents forwarded from the website were omitted due to the limited space)
53	Milkbottle	<i>Frontal fog, fog.</i>
62	Cathyjudy	<i>The main hypothesis.</i> When the cold and warm air contact each other, fogs take place at where the large temperature difference, more humid warm air, and more condensation nuclei. I specially point out the humidity of warm air...

65	Milkbottle	<i>The main hypothesis.</i> In nature, cold air is below warm air when cold and warm air contact each other. A big temperature difference means the difference between the temperature of cold air and warm air. More temperature difference, suitable wind speed, higher humidity and more nuclei in the air, then fog forms easily. <i>The main hypothesis.</i> Humidity of warm air
67		
68	Cathyjudy	<i>The explanation for the main variable.</i> The main variable is not just humidity, but the humidity of warm air. If the humidity of warm air is not high enough and the saturated water vapor pressure becomes lower, it does not reach saturation.

Although the *Complicator*, Snowlove's opinion was strong (#45~47), the group members had given it an unfriendly reception, in contrast to that which they gave to the *Contributor*, 010124. We could see a decrease in postings and a silent and conflicted atmosphere when Snowlove attempted to raise a point counter to the direction of the current group discussion. The *Faciliator*, Cathyjudy, tried to counter Snowlove's opinion by using 010124's previous opinion (#48). The *Faciliator* Milkbottle kept summarizing group members' opinions but excluded Snowlove's proposal from the "the summarization of hypotheses postings" and did not respond to Snowlove. At this point, Snowlove's posting was ignored by the group members.

We recognize a bid to negotiate interactively between the *facilitator* and the *Contributor*: the *Contributor* 010124 justified the *Complicator*, Snowlove's, posting to help build a bridge between their conflicting opinions. It appeared that nobody cared for Snowlove's argument (#45~47), but 010124 did pay sufficient attention to it. Instead of using personal internal resources to judge the opinions of other group members, 010124 sought an external resource to evaluate Snowlove's claim. 010124 took Snowlove's opinion and looked for authoritative references to check it, then copied and pasted seven authoritative references (#51, 52, 55, 57~60) to justify Snowlove's opinion as right. In this way, 01024's posting eventually evoked negotiation within group. The group members renewed negotiation of the value of Snowlove's claim. Milkbottle also sought out the external resource to justify Snowlove's posting (#53) and then, convinced of its validity, supported Snowlove's argument. Snowlove's argument became legitimate knowledge for the group members. The *Facilitators*, Cathyjudy and Milkbottle, adopted the *Complicator*, Snowlove's, opinion to make an adjustment to the direction of group discussion (#62~68). We could see that the vindication of this view revived the progress of group discussion which then went forward again toward knowledge co-construction.

Discussion and Conclusion

Our study introduces new ideas for knowledge co-construction. First, previous research explored the frequent "give and take" of the success dialogue of episodes. The present study shows that the occurrence of knowledge co-construction may start right in the process of confusion when "give and take" goes less smoothly among the group members. If we don't recognize the "confusion and hesitation" stage of group discussion, we may not capture and recognize that starting moment and arrive at a complete picture of knowledge co-construction.

Second, most related research has focused on the predominant group members, such as the leaders or the active ones, and has tried to capture the learning process from their dialogue interaction. In the present study, we uncover the complex dynamics of group practice in ways that might further illuminate the phenomenon that weaker and less active members do bring about a turning point in knowledge co-construction. If we had not focused equally on the role of ordinary people in the group discussion, we would have achieved merely a partial understanding of the knowledge co-construction.

Insights into knowledge co-construction are developed by re-considering the analytic method for group discussion. We compare and contrast the results of analysis by using the "single posting" and "the whole thread" as the unit of analysis. We first adopted the "single posting" as the unit of analysis for recognizing the content of each posting, classified each posting, and identified the classification of the primary learner-role behaviors. Then, we adopted "the whole thread" as the unit of analysis for interpreting the meaning of the current posting by carefully investigating both the earlier and the later ones. Using this compare-and-contrast method, we demonstrated that most of the meaning differed from that determined before, and that the classification of primary learner-role behaviors was modified.

As with any other research, certain limitations of our findings must be noted. First, the sampling of the group. Lain was a naturalistic virtual setting in which participants in this study were able to withdraw, intermit, wander, or engage at will and at their own pace. C2 was selected from the 64 groups because the members had more focused and on-topic discussion, and members participated more equally in the discussion. We considered knowledge co-construction to be more recognizable in this group. The findings therefore need to be viewed with caution as they would not be representative of other types of online group collaboration. Second, the sampling of the thread. In analyzing co-construction among group members, we purposely selected the thread with the longest lifespan, the 15th thread. Future studies with short threads would be useful to verify our findings.

The results of this study have implications for analytic methods to examine knowledge co-construction. In conventional analytic methods, previous research ignored the significance of the time dimension in group

discussion when quantifying data in classifying the role of each group member and in recognizing the relationships between group members. In contrast to the conventional view, we argue that we must necessarily focus on contextually-situated processes and the time dimension of the process of knowledge co-construction, and must avoid making unwarranted assumptions about the role of group members. We suggest using “the whole thread” as the unit of analysis in tracking critical moments and identifying the contribution of members in knowledge co-construction. From “the whole thread as the unit of analysis” perspective, we further suggest that both linking backwards to earlier turns and linking forward to later turns were equally important in determining the meaning of a posting, and result in a more complete picture of knowledge co-construction.

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