Model for Analysing Collaborative Knowledge Construction in a Synchronous Chat Environment

Juan Dee WEE, Chee-Kit LOOI
National Institute of Education, Nanyang Technological University, 1 Nanyang Walk
Singapore 637616
WEEJ0002@ntu.edu.sg, cklooi@nie.edu.sg

Abstract: This paper describes a methodology for analyzing the construction of knowledge in an online collaborative environment. A model is built to represent the flow of the discourse by linking contributions based on intersubjective and intrasubjective uptakes. A framework of analysis of the model is designed to explain (1) how participants manipulate textual representations such as mathematical symbol, concepts, formulas and language (2) the shift of focus in the discourse, (3) the emergence of meaning making paths and (4) the uptake of contributions leading to knowledge construction. The key motivation behind this paper is to develop a structure for analysing collaborative learning. More importantly, this methodology uses a holistic approach to understand the process of meaning-making embedded in interactions between chat contributions.

Keywords: Meaning making, intersubjective, intrasubjective, collaborative environment, knowledge construction

Introduction

Participants learn in conversation because they have to perform their roles to keep their end of the dialogue. This process enables learners to construct meaning and relate experiences into knowledge construction (Baker, Jensen & Kolb, 2002). Participants have to think of a response to what they have heard. The reasoning process leading to the response requires analysis of what they have heard for an extraction of something meaningful and then relating this extraction to something they have in their memories (Schank, 2002). Collaboration often requires conversation where participants work in groups to socially negotiate a shared understanding of the approaches they use to accomplish any given tasks (Jonassen, 1999). The computer offers many opportunities to bring the whole concept of conversation into an online environment to support the building of collaborative knowledge (Stahl, 2006). It develops conversation into a new dimension where participants are able to view the conversation transcript rather than hearing them. This reinforces what is said rather than what is heard. There have been several recommendations suggested to analyse such chat conversations. One such recommendation uses conversational analysis (Goodwin & Heritage, 1990; Stahl, 2005) to interpret interactions taking place in online chat environments. This lead to the development of the concept of adjacency pair used to analyse mathematical chat transcripts. Another recommendation was to examine patterns of information uptake. Uptake is the process where participants take up and develop prior contributions. Any analysis of intersubjective meaning making must start with the identification of uptakes acts in which one participant takes up another participant's contribution and act on it (Suthers, 2005). Through the examination of patterns of the chats, intersubjective cognitive activity distributed across the participants and the manipulation of representations could be analysed (Suthers, 2006). We build upon these ideas of group cognition and uptakes to propose a new model to analyse small groups of collaboration in the VMT-Chat. Most of the paper will explain the development of the proposed model, using chat segments to examine how participants construct knowledge and mediate shared understanding in a collaborative environment.

Participants and Chat transcripts

Our target group are students from a junior college in Singapore. They have a basic foundation in mathematics and are among the top 20% of the cohort in terms of academic ability. The participants have gone through two major standardized examinations, the Primary School Leaving Examination and Singapore-Cambridge General Certificate of Education (Ordinary Level) Examination. The two major examinations have provided the participants with a rigorous foundation in mathematics problem solving. The students have received sufficient mathematical training to the extent that the level of mathematical background knowledge assumed in any contribution is compatible with the expertise of the participants (Stahl, 2006). The chat transcripts are extracted from samples of interactions of three college students using the VMT. This discourse offers an insight into how learners might accomplish collaborative knowledge construction through such media (Suthers, 2006) and how they attempt

to negotiate meaning making in mathematics. Some descriptions within the textual posting have been improved for readability by an international audience.

Collaborative Online Environment

The participants' task were to collaborate together to solve a mathematical problem with three parts. Details of the mathematical problem can be found in the next section. The VMT environment affords the opportunity for participants to collaborate to solve maths problem in a synchronous setting. VMT is a collaboration research project between The Math Forum (www.mathforum.org) and the College of Information Science and Technology at Drexel University (Stahl, Shumar &Weimar, 2004; Cakir, Xhafa, Zhou & Stahl, 2005).

Defining the Mathematical Problem

The participants are to collaboratively solve problems related to the arithmetic and the geometric series. Here is one such problem:

Find an expression for the nth term of the series 2 + 22 + 222 + 2222 + ……. and deduce that the sum of the first n terms of the series is $\frac{20}{81}(10^n - 1) - \frac{2n}{9}$. The learners are to observe the series 2 + 22 + 222 + 2222 + ……. and using prior experience in problem solving or concept or formulas to derive an expression for the series. After which they are to deduce the expression $\frac{20}{81}(10^n - 1) - \frac{2n}{9}$ using the expression developed in the earlier part.

Design of an Analysis Model

As contributions are sent as complete units, there is a probability that the contributions arrive in different order to the participants. Focusing analysis on the relationship between adjacent contributions does not give a holistic view on the relevant relationships between contributions (Stahl, 2005; Suthers, 2006). A proposed model called the Collaboration Interaction Model (CIM) is designed to analyze the relationship between any contributions. The complexity of analysis cannot be reduced by shrinking the time window to search for relevance relations to adjacent contributions. There is a chance that any contribution could be taken up again (Suthers, 2006) The Collaboration Interaction Model combines a series of intersubjective and intrasubjective contributions which are not constraining within a time window for analysis. Prior knowledge of the participants plays an important role in determining how much they can learn in the discourse (Wright, Sunal, Day, 2004) The Collaboration Interaction Model is designed to interpret how participants come to a shared understanding with the manipulation of prior knowledge, intrasubjective uptakes and intersubjective uptakes.

Collaborative Interaction Model (CIM)

The model designed to trace the development of knowledge construction in an online collaborative environment. The objective is to track contributions throughout the discourse. Learners exchange textual postings to facilitate interaction, communication, shared understanding and knowledge construction (Stahl, 2005). The model is applicable for a team or a group of 3 to 5 persons. Figure 1 shows a segment of a 3-Person Team Collaboration Interaction Model. Each object (rectangle or oval or triangle) represents a participant and the contribution constructed in the discourse. The object with a contribution number is known as a node in the CIM.

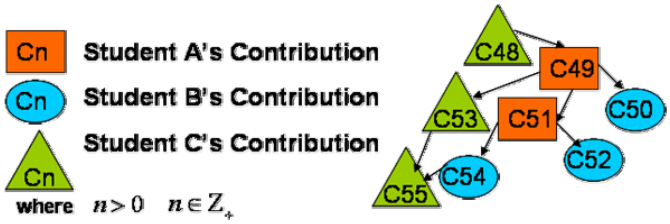


Figure 1: 3-Person Team Collaboration Interaction Model

CIM Assumptions

The model does not directly address any design issues. It does not analyze the design of the software or compare it to other designs. It is designed to understand how learners make use of cognitive resources, and the conversion of such resources into representations for collaboratively learning. More importantly, it is used to trace emerging paths of knowledge construction. The CIM is a methodology that is descriptive and attempts to look into how online collaboration takes places (Suthers, 2006). This descriptive method could help instructional designers review different ways of improving existing collaborative interface designs.

How the CIM works?

Figure 2 shows the entire chat transcript consisting of uptakes of contributions in the CIM. Each node represents the contributor and the contribution number. The contributor is represented by nodes with different shapes. Table 1 shows the representation of the contributor and the contribution number in chat transcript. The contribution number is a sequential running number assigned to the chat transcript. The arrows indicate the uptakes of contributions by the participants.

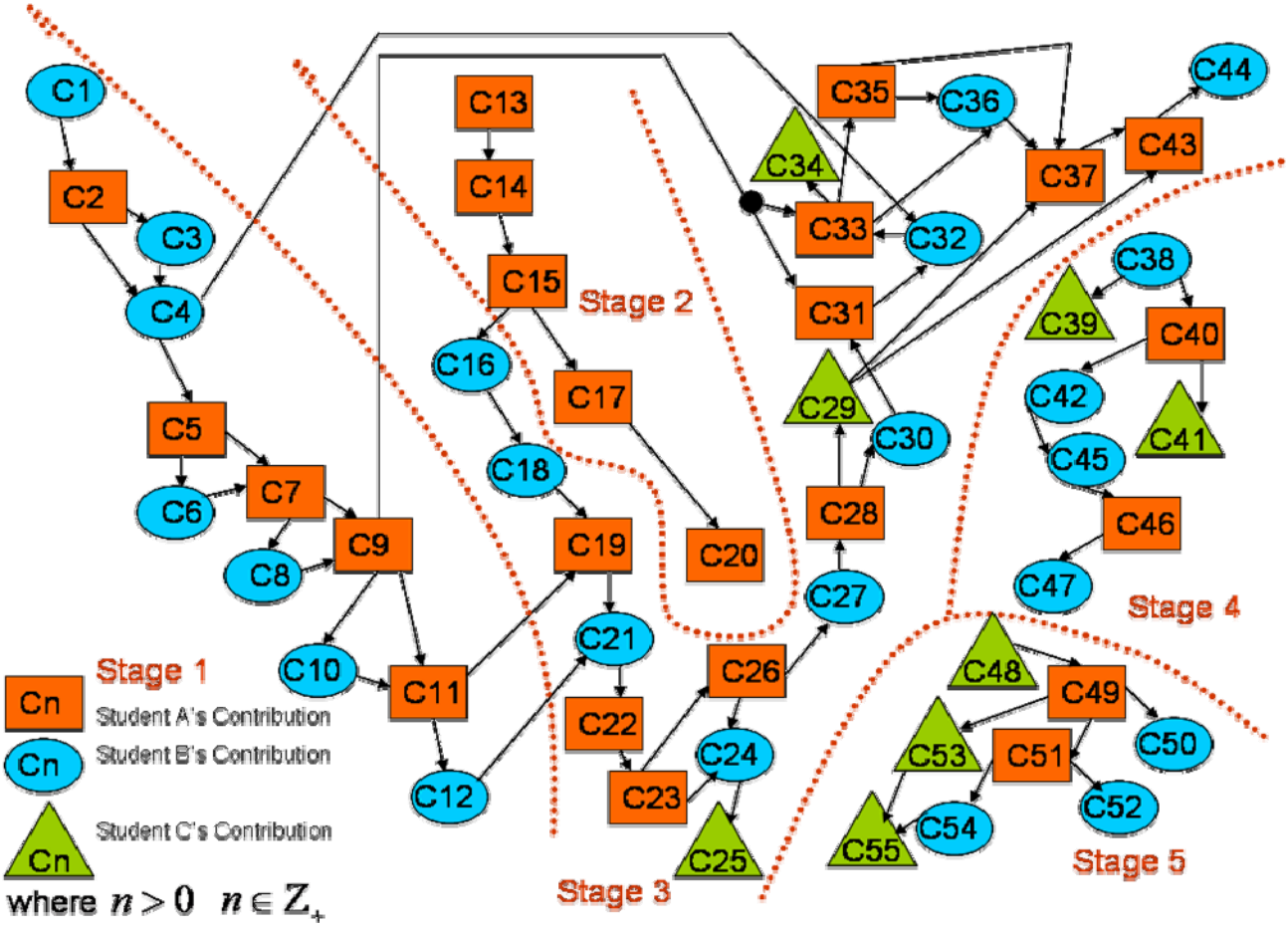


Figure 2: Collaboration Interaction Model

Table 1: Representation of the contributor and the contribution number in chat transcript

Line	Time	Participant	Contribution	Contribution Number
Line 1	4:21:00	LZX	Ok	**C1**
Line 2	4:21:07	LZX	Lets do it	
Line 3	4:27:59	CZW	$(2),(2+20),(2+20+200)$	**C2**
Line 4	4:28:08	LZX	No!	**C3**
Line 5	4:28:53	LZX	$2(1),2(1+10),2(1+10+100)$ $+2(1+10+100+...)$	**C4**
Line 6	4:29:03	LZX	Something along this line	
Line 7	4:29:20	CZW	$2(1+11+111.....)$	**C5**
Line 8	4:30:53	LZX	try to calculate	**C6**

Table 1 shows the starting of the chat. LZX expressed "Ok" and "Lets do it" [C1] to commence the problem solving. CZW intersubjectively uptakes [C1] to construct $(2),(2+20),(2+20+200)$ [C2] which was intersubjectively uptaken by LZW and [C2] was modified to form [C4]. CZW intersubjectively uptakes $2(1),2(1+10),2(1+10+100)$ $+2(1+10+100+...)$ and LZX assurance that what he typed was "Something along this line" [C4] to create $2(1+11+111.....)$ [C5], with the intention of trying to obtain a pattern in the series. LZX intersubjectively uptakes $2(1+11+111.....)$ [C5] by prompting CZW to calculate [C6] to review what CZW has deduced. The contributions [C1],[C2] ,[C3],[C4],[C5] and [C6] are represented in the Collaboration Interaction Model. (see figure 2) and the arrows represent the respective uptakes by the participants.

Definition of a Contribution

A contribution represents a *concept/definition/symbol/expression* articulated with one or more textual representation in the chat transcript. Each contribution is assigned a contribution number in the chat transcript. In the CIM, participants are represented by different objects. Taking for example a rectangle represents student A's contribution, an oval represents student B's contribution and a triangle represents student C's contribution. Each object (see figure 3) has a contribution number which represents the textual representation of the student in the chat transcript. (see table 1)

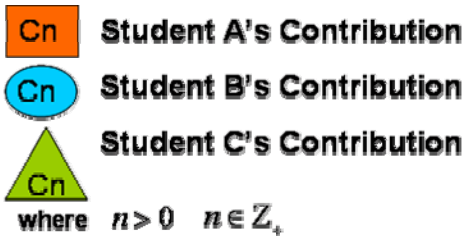


Figure 3: Contributions by participants

Stages in CIM

The CIM illustrates how students negotiate meaning to solve mathematical problems. Participants will come together with a task in mind. They will commence at stage 1. Each stage represents a different focus of negotiation in the discourse. A stage transition occurs when there is a shift of focus in the discourse. Contributions within stages show more significance than just representing several conversional turns leading to a common ground between participants. (Clark & Schaefer, 1989; Clark & Brennan, 1991)The contributions bring out the interactional strategies (Stahl, 2005) undertaken by participants to meet the objective of the focus within the stage. The analysis on the shift of focus will shed some light on the efficiency and viability of the meaning making approaches by the participants. The next section will explain more on the implications of such a shift of focus in the discourse. Figure 4 shows the stage 1, stage 2 and stage 3 in the CIM.

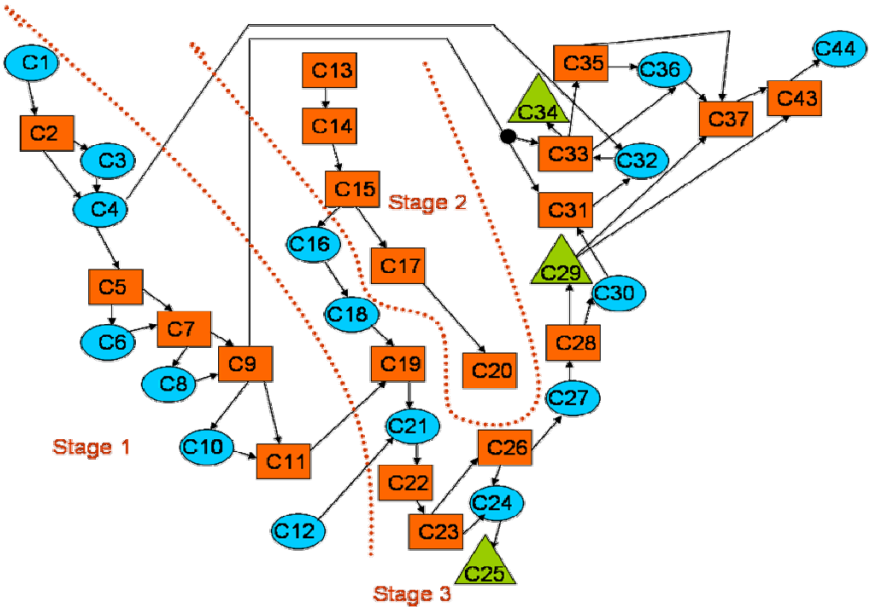


Figure 4: Stages in the Collaboration Interaction Model

Occurrence of Stage Transition

One possibility of a Stage Transition occurring is when shared understanding is reached between two or more participants. This depends on the participants reaching a common understanding to meet the focus of the discourse. This will then shift the focus of negotiation into another direction, with the intention completing other tasks to solve the problem. Stage Transition may also occur when any participant has achieved some form of understanding of the subject individually, hence shifting the focus of the discourse into another direction without the common consensus of other participants. Figure 4 shows the Stage Transition from stage 1 to stage 2 which has a different discourse from that of stage 1.

Table 2: Stage Transition: Stage 1 to Stage 2

Line	Time	Participant	Contribution	Contribution Number
Line 14	4:35:24	LZX	Common ratio 10	**C10**
Line 15	4:35:34	CZW	$=\frac{1}{3}(10^n-1)$	**C11**
Line 16	4:35:42	CZW	That's the answer?	
Line 17	4:35:52	LZX	Wait ar I try	**C12**
Line 18	4:36:56	CZW	Sum of $(n-1)=3-3^{(1-n-1)}$	**C13**
Line 19	4:37:25	CZW	then sum of n / sum of n-1	
Line 20	4:38:01	CZW	$3-3^{(1-n)}/3-3^n$	
Line 21	4:40:54	CZW	mistake!	**C14**
Line 22	4:41:42	CZW	the sum of $(n-1)$ is $3-3^{-n}$	

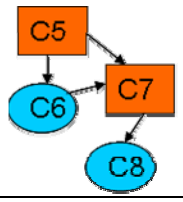
Table 2 shows the Stage Transition occurring from stage 1 to stage 2. Contributions [C10], [C11] and [C12] focused on understanding whether the expression equaled $\frac{1}{3}(10^n-1)$ while [C13] and [C14] focused on working on the sum of (n-1), a different focus to that of [C10], [C11] and [C12]. After contribution [C12], there is a stage transition from stage 1 to stage 2. [C10], [C11] and [C12] belong to stage 1 and [C13], [C14] belong to stage 2.

A Stage Reversal occurs when the participants revert back to an earlier focus in the discourse. In conversation analysis, participants attempt to repair failed understanding in the next turn (Schegloff, 1992). In similar sense, the probability of an occurrence of a Stage Reversal is dependent on the level of shared understanding achieved by the participants in the previous stages. The accuracy of the knowledge constructed in the earlier stages may also result a Stage Reversal applied in later chat segments. A Stage Reversal could also occur when participants require knowledge constructed in previous stages to solve tasks in the current stage. The analysis of a Stage Reversal should not consist of just interpreting the causes of the reversal but also the significance of the reversal itself with respect to the discourse. In Figure 4, stage 3 shares a similar focus to that of stage 1. Stage 1 and stage 3 consists of similar intrasubjective and intersubjective contributions.

Intrasubjective and Intersubjective Contribution Uptake

Meaning is created at the group unit of analysis rather by particular individuals (Stahl, 2004). Analysis of knowledge construction consists of several intrasubjective and intersubjective uptakes of contributions by different individuals. The contributions maybe manipulated by both the participants as well as other participants Any form of manipulation on representations can be an addition, modification to existing information or relation to new information (Suthers, 2006). Newly created contributions may be further manipulated intersubjectively or intrasubjectively to form new contributions. In the CIM, intersubjective uptake is defined as manipulation of representations by different participants within the time frame of the chat. It can also be defined as simple as a response to a proposal by one participant to commence the discourse. Intrasubjective uptake is defined as manipulation of representations by the same participant within the time frame of the chat. Representations are in the form of mathematical symbols, concepts, definitions, or language. Table 3 illustrates how intersubjective uptakes and intrasubjective uptakes are interpreted in the Collaboration Interaction Model. The contributions [C5], [C6], [C7] and [C8] are extracted from a VMT chat transcript.

Table 3: Contribution C5, C6, C7 and C8

Line	Time	Participant	Contribution	Contribution Number	Collaboration Interaction Model
Line 7	4:29:20	CZW	2(1+11+111.....)	**C5**	
Line 8	4:30:53	LZX	try to calculate	**C6**	
Line 9	4:32:41	CZW	1st term ->2, 2nd term-> 2(1+10), 3rd term ->2(1+10+100)	**C7**	
Line 10	4:32:49	LZX	Any ideas?	**C8**	

CZW's contribution 2(1+11+111.....) [C5] was intrasubjectively uptaken to construct 1st term ->2, 2nd term-> 2(1+10), 3rd term ->2(1+10+100) [C7]. An arrow connecting the two contributions [C5] and [C7] illustrates this relationship in the Collaboration Interaction Model. This connection indicates that [C5] was intrasubjectively uptaken to create [C7]. LZX suggested "try to calculate" [C6]. LZX's contribution [C6] was intersubjectively uptaken by CZW construct the contribution 1st term ->2, 2nd term-> 2(1+10), 3rd term ->2(1+10+100) [C7]. An arrow connecting the contributions [C6] and [C7] illustrates this relationship in the Collaboration Interaction Model.

Intrasubjective and Intersubjective Uptakes across Stages

The intersubjective and intrasubjective uptakes of contributions can occur within and across stages. A stage transition occurs when there is a shift of focus in the discourse. An intrasubjective and intersubjective uptake across stages indicates that a contribution in an earlier stage is manipulated and used for knowledge construction in a later stage. During a stage reversal, intersubjective and intrasubjective of contribution shifts the focus in the discourse, resulting uptakes across stages. Another possibility of uptakes across stages occurring is when contributions are required for knowledge construction in other stages. Participants will uptake contributions from earlier chat segments to construct knowledge. Figure 5 shows the five different intrasubjective/intersubjective uptakes of contributions across stages.

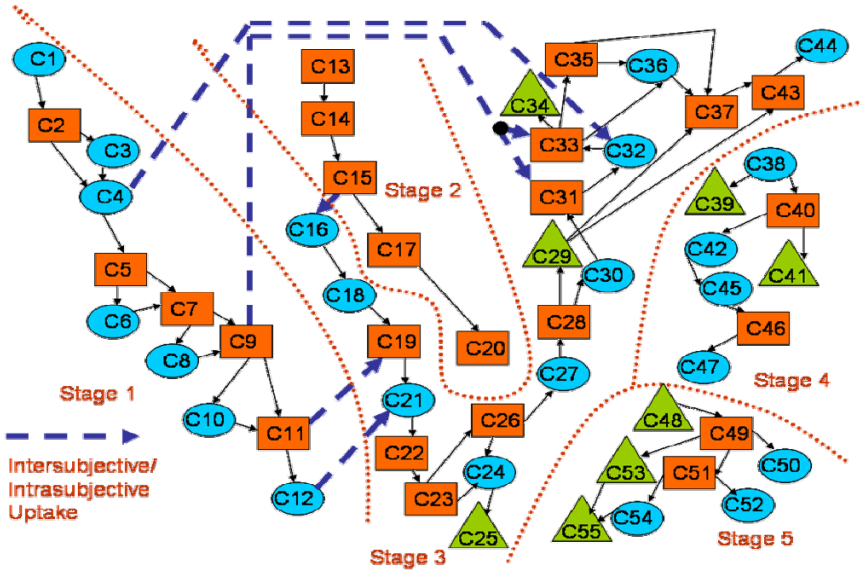


Figure 5: Intrasubjective/Intersubjective Uptakes across Stages

Table 4: Contribution C4, C31 and C32

Line	Time	Participant	Contribution	Contribution Number	Collaboration Interaction Model
Line 5	4:28:53	LZX	$2(1), 2(1+10), 2(1+10+100)$ $+2(1+10+100+...)$	**C4**	
Line 6	4:29:03	LZX	Something along this line		
……					
……					
Line 43	4:54:00	CZW	Let's continue from…. $2(1+10+100$ $+...10^{(n-1)})$	**C31**	
Line 44	4:54:04	LZX	I got the correct equation	**C32**	
Line 45	4:54:12	LZX	Answer for (a)		

Table 4 illustrates how uptakes across stages are interpreted in the Collaboration Interaction Model. The contributions [C4], [C31], [C32] are extracted from a VMT chat transcript. LZX [C32] intersubjectively uptaken the contribution by CZW who mentioned "Let's continue from…. $2(1+10+100+...10^{(n-1)})$" [C31]. LZX mentioned that he had gotten the correct equation [C32] which meant $2(1), 2(1+10), 2(1+10+100) +2(1+10+100+...)$ [C4]. [C32] was constructed in stage 3 while [C4] was constructed in stage 1. There is a shift of focus in the discourse back to stage 1 when [C4] was uptaken to construct [C32]. This can be interpreted as a stage reversal, where stage 3 is the stage reversal back to stage 1.

Tracing of newly-constructed knowledge using CIM Tier Analysis (CIMTA)

Some newly-constructed contributions play a significant role in the discourse. We call them the *Pivotal Contribution* in the CIM. *Pivotal Contributions are* platforms where knowledge construction can be created. In online chat, participants represent mathematical concepts, symbols or formulas in textual representations. They may have constructed new mathematical concepts, symbols, or formulas. This newly constructed mathematical concepts, symbols or formulas are represented as a contribution. This contribution could influence the construction of new knowledge. *The paths leading to the construction of the Pivotal Contribution* and *the paths diverging from the Pivotal Contribution that are involved in further construction of new knowledge* can be analyzed. Tracing of such

paths leads to the emergence of meaning-making paths where the analysis of how participants negotiate shared understanding of the subject through intersubjective and intrasubjective uptakes of contributions can be observed at the group level (Stahl, 2006).

It is possible to view the construction of meaning through the sufficient capture of collaborative interactions. (Stahl, 2006) Tracing of the paths captures such interactions extensively, where the definition of sufficient is subjected to the number of Tiers available for analysis. The tracing is based on a procedure called the Collaboration Interaction Model Tier Analysis. Figure 6 shows the contributions being segmented into different tiers. The → arrow indicates meaning making paths represented by paths leading to the construction of the *Pivotal Contribution* and the ⇒ arrows indicate meaning making paths diverging from the *Pivotal Contribution* used to further construct new knowledge. By analyzing how contributions in different tiers influence one another, the meaning making paths can be observed at a group level. The emergence of mean making paths consisting over intersubjective and intrasubjective uptakes (Suthers, 2005) of contributions form the elemental cell of interactional meaning making (Stahl, 2006) The *Pivotal Contribution* affords the opportunity for the emergence of mean making paths hence creating an appropriate condition for the selection criteria of the *Pivotal Contribution*.

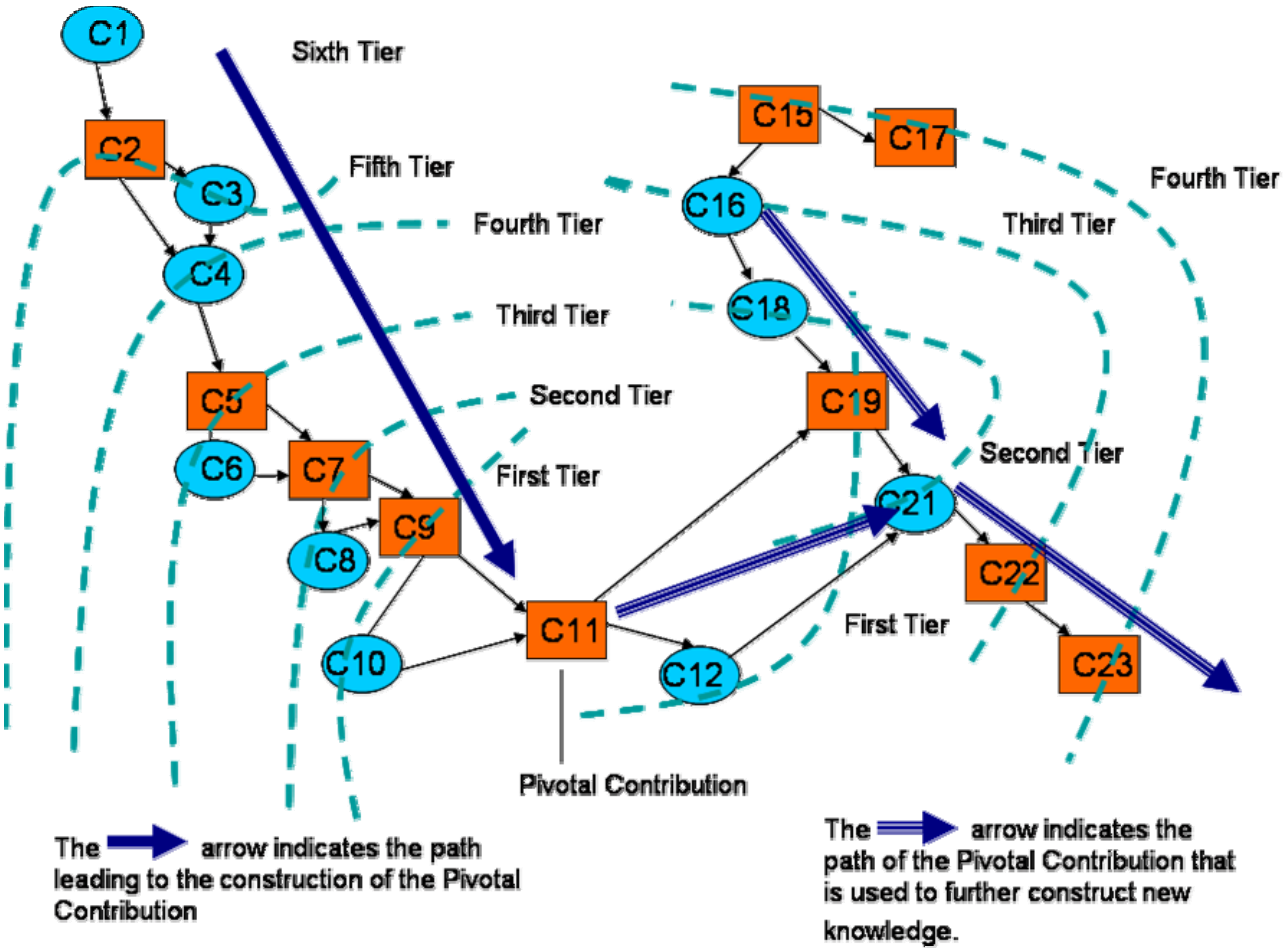


Figure 6: Collaboration Interaction Model Tier Analysis

Conclusion

Collaborative learning analysis is the fundamental motivation for the development of the Collaboration Interaction Model. The Model provides an alternative approach to analyse contributions in synchronous chat environments. The approach builds on the concepts of intersubjective, intrasubjective uptakes and group cognition. The arrows linking the contributions represent uptakes. The linking of contributions affords the opportunity for deeper analysis of the way individual's contribution is influenced by the interpretation of other participant's contribution. A sequence of posting forms the elemental cell of interactional meaning making. Shared meaning is constructed across several postings of more than one participant, and the unit of meaning is the interaction itself which is a group effort of meaning making rather than just an individual effort of meaning making. The Collaboration Interaction Model Tier Analysis (CIMTA) analyses the significance of the *Pivotal Contribution*. The emergence of meaning making paths leading to the construction of the *Pivotal Contribution* and paths of knowledge construction diverging from the *Pivotal Contribution* are traced by CIMTA. The emergence of such paths forms the basis for analyzing how meaning making is achieved at a group level rather than at an individual level. The Collaboration Interaction Model divides groups of contributions into stages. The concept of stages simplifies the analysis of the discourse to its respective focus. Each stage represents a different focus in the discourse and a change of stage indicates a shift of focus. The construction of meaning is embedded in the interactions. By clustering contributions into different stages, not only the construction of meaning can be found within the interaction of contributions but also a sense of focus is given to the interaction itself. The Collaboration Interaction Model provides the framework of analysis of textual contributions at the micro level for appropriate understanding of the ways group meaning making is achieved. Our subsequent research will explore the generality of the model on applying it to more chat transcripts.

Acknowledgements

We wish to thank Gerry Stahl and Dan Suthers for comments for earlier drafts of this work.

References

[1] Baker, A., Jensen, P.J., & Kolb, D.A. (2002). *Conversational Learning: An experiential approach to knowledge creation*. Westport Connecticut: Quorum Books.

[2] Cakir, M., Xhafa, F., Zhou, N., & Stahl, G. (2005) *Thread-based analysis of patterns of collaborative interaction in chat*, In: Proceedings of international conference on AI in Education (AI-Ed 2005), Amsterdam, Netherlands.

[3] Clark, H., & Schaefer, E. (1989). Collaborating on Contributions to Conversations. In R.Dietrich and C.F. Graumann (eds.), *Language Processing in Social Context*, Elsevier Science Publishers, North-Holland.

[4] Clark, H., & Brennan, S. (1991). Grounding in communication. In L.Resnick, J. Levine & S. Teasley (Eds.), *Perspectives on socially-shared cognition* (pp. 127-149). Washington, DC: American Psychological Association.

[5] Goodwin, C., & Heritage, J. (1990). Conversation Analysis. Annual Review of Anthropology, 19, 283-307

[6] Jonassen, D.H., Peck, K.L & Wilson, B.G (1999), *Learning with Technology: A Constructivist Perspectives*. Merrill.

[7] Schank, R.C. (2002). *Designing World-Class E-learning*. McGraw-Hill.

[8] Schegloff, E. A. (1992). Repair after next turn: the last structurally provided defense of intersubjectivity in conversation. American Journal of Sociology 97(5):1295-1345.

[9] Stahl, G., Shumar, W.,& Weimar, S. (2004) *Diversity in Virtual Math Teams*. Presentation to Sixth International Conference of the Learning Sciences, June 22-26 2004, Santa Monica, CA.

[10] Stahl, G. (2004) *"Building Collaborative Knowing: Elements of a Social Theory of Learning"* In J.-W. Strijbos, P. Kirschner, R. Martens (Editors) (2003) What We Know about CSCL in Higher Education. Kluwer, Amsterdam, NL.

[11] Stahl, G. (2005) Group Cognition in chat: Methods of Interaction/Methodologies of analysis *Presentation to the CSCL SIG workshop: Nordic Analysis of Interaction and Learning (NAIL 2005*). Gothenburg, Sweden

[12] Stahl, G. (2005). Sustaining online collaborative problem solving with math proposals. *Paper presented at the International Conference on Computers and Education (ICCE 2005)*, Singapore, Singapore.

[13] Stahl, G. (2006). *Group cognition: Computer support for building collaborative knowledge*. Cambridge, MA: MIT Press.

[14] Suthers, D.D. (2005) Collaborative knowledge construction through shared representations *Proceedings of the 38th Hawai`i International Conference on the System Sciences (HICSS-38)*, January 3-6, 2005, Waikoloa, Hawai`i (CD-ROM), Institute of Electrical and Electronics Engineers, Inc. (IEEE).
[15] Suthers, D.D. (2005) *Technology affordances for intersubjective learning: A thematic agenda for CSCL*. In T. Koschmann, D. Suthers & T. W. Chan (Eds.),Computer Supported Collaborative Learning 2005: The Next 10 Years! Mahwah, NJ: Lawrence Erlbaum Associates. pp. 662-671
[16] Suthers, D.D. (2006). *A qualitative analysis of collaborative knowledge construction through shared representations.* Research and Practice in Technology Enhanced Learning (RPTEL), 1(2), 1-28.
[17] Suthers, D.D. (2006) *Technology affordances for intersubjective meaning making: A research agenda for CSCL*. International Journal of Computer-Supported Collaborative Learning (ijCSCL), 1(3), 315-337
[18] Wright, E.L., Sunal, D.W., & Day, J.B. (2004), *Reform in Undergraduate Science Teaching for the 21st Century*. IAP
.