Model for Analysing Collaborative Knowledge Construction in a Quasi-Synchronous Chat Environment

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Abstract: This paper describes a methodology for analyzing the construction of knowledge in an online collaborative environment. A model is constructed 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 illustrate (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 textual representations.

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 et al, 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, 2006b). One such example will be use of text chat (Looi, 2005) to facilitate conversation between participants where the conversation transcript is seen rather than heard. The visibility of the conversation transcript reinforces what is said rather than what is heard. Previous studies have suggested various methods to analyse chat conversations. One method uses the methodology of conversational analysis (Goodwin & Heritage, 1990; Stahl, 2005) to study interactions taking place in online chat environments, leading to the use of turn-taking and adjacency pair as unit of analysis to interpret mathematical chat transcripts. Henri (1992) proposed using an idea within a message as the unit of analysis reinforcing the idea that the unit of analysis could possibly encompass an entire message constructed by an individual at a certain time during the discourse (Gunawardena et al., 1997; Rourke et al., 2001). The selection of the unit of analysis is based on the situation in which it is used (De Wever et al., 2006) and the granularity of the content to be analysed (Chi, 1997). Suthers (2005a) suggested examining patterns of information uptake. Uptake is defined as the process where participants take up and develop prior contributions. He argued that 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. Through the examination of patterns in chats transcripts, intersubjective cognitive activity which is distributed across the participants and manipulation of representations could be analysed (Suthers, 2005b). This paper builds upon the 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, 2006a). 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, 2006b) 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 et al., 2005).

Defining the Mathematical Problem

The participants are given problems related to the arithmetic and the geometric series to solve collaboratively. 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 $\frac{20}{81}(10^n - 1) - \frac{2n}{9}$.

They are expected to carefully analyse the series 2 + 22 + 222 + 2222 + ……. and use their prior experience in problem solving or concept or formulas to derive the nth term of the series. Subsequently, they are to deduce the expression $\frac{20}{81}(10^n - 1) - \frac{2n}{9}$ using the expression developed in the earlier part.

VMT Chat Transcript

Table 1 shows the chat transcript of the three participants solving the above mentioned maths problem. The first column shows the time that the representation was entered into the chat room. The second column shows the name of the participants. The third column shows the chat transcripts logged by the VMT.

Table 1: VMT Chat between LZW, CZW and TCW

Time/Line	Student Name	Chat Transcript	Contribution
4:21:00 Line 1	LZX	Ok	
4:21:07 Line 2	LZX	Lets do it	**C1**
4:27:59 Line 3	CZW	$(2),(2+20),(2+20+200)$	**C2**
4:28:08 Line 4	LZX	No!	**C3**
4:28:53 Line 5	LZX	$2(1),2(1+10),2(1+10+100)$ $+2(1+10+100+...)$	**C4**
4:29:03 Line 6	LZX	Something along this line	
4:29:20 Line 7	CZW	$2(1+11+111.....)$	**C5**
4:30:53 Line 8	LZX	try to calculate	**C6**
4:32:41 Line 9	CZW	1st term ->2, 2nd term-> 2(1+10), 3rd term ->2(1+10+100)	**C7**
4:32:49 Line 10	LZX	Any ideas?	**C8**
4:33:26 Line 11	CZW	Nth term = $2(1+10+...10^{n-1})$	**C9**
4:34:13 Line 12	CZW	then inside the brackets is the sum of Geometric Progression	
4:35:13 Line 13	CZW	$2(\frac{10^n-1}{10-1})$	
4:35:24 Line 14	LZX	Common ratio 10	**C10**
4:35:34 Line 15	CZW	$=\frac{1}{3}(10^n-1)$	**C11**
4:35:42 Line 16	CZW	That's the answer?	
4:35:52 Line 17	LZX	Wait ar I try	**C12**
4:36:56 Line 18	CZW	Sum of $(n-1)=3-3^{(1-n-1)}$	
4:37:25 Line 19	CZW	then sum of n / sum of n-1	
4:38:01 Line 20	CZW	$3-3^{(1-n)}/3-3^n$	**C13**
4:40:54 Line 21	CZW	mistake!	
4:41:42 Line 22	CZW	the sum of $(n-1)$ is $3-3^{-n}$	**C14**
Line 23 4:41:55 TCW joins the room			
4:43:31 Line 24	CZW	oh gosh….another mistake!!	**C15**
4:43:59 Line 25	LZX	wait	**C16**
4:44:01 Line 26	CZW	sum of $(n-1)$ is $3-3^{(2-n)}$	**C17**
4:44:11 Line 27	LZX	wads the answer for part (a)	**C18**
4:45:53 Line 28	CZW	$\frac{1}{3}(10^n-1)$	**C19**
4:46:51 Line 29	CZW	hey gosh..now I realised that I have used the wrong	

		equation	
4:47:17 Line 30	CZW	its term of n / term of (n-1)	**C20**
4:47:28 Line 31	CZW	I am referring to (b)	
4:49:29 Line 32	LZX	$\frac{1}{2}(10^n - 1)$	**C21**
4:49:34 Line 33	CZW	for (a)…I mean $\frac{1}{2}(10^n - 1)$ …not $\frac{1}{3}(10^n - 1)$	
4:49:40 Line 34	CZW	Yes!	**C22**
4:50:05 Line 35	CZW	Eh like wrong leh	**C23**
4:50:16 Line 36	LZX	But you try to calculate the 2nd term	**C24**
4:50:18 Line 37	TCW	I do not know how to do	**C25**
4:50:26 Line 38	CZW	That equation like cannot leh	**C26**
4:50:35 Line 39	LZX	Never mind try	**C27**
4:53:30 Line 40	CZW	I know	**C28**
4:53:35 Line 41	TCW	Are you all at question (a)	**C29**
4:53:55 Line 42	LZX	ok	**C30**
4:54:00 Line 43	CZW	Let's continue from…. $2(1+10+100+...10^{(n-1)})$	**C31**
4:54:04 Line 44	LZX	I got the correct equation	
4:54:12 Line 45	LZX	Answer for (a)	**C32**
4:54:51 Line 46	CZW	$2(\frac{10^n - 1}{10 - 1})$	**C33**
4:54:59 Line 47	TCW	1st term is 3	**C34**
4:55:10 Line 48	CZW	Yes so it is $\frac{2}{9}(10^n - 1)$	**C35**
4:55:22 Line 49	LZX	$2(\frac{10^n - 1}{10 - 1})$	**C36**
4:55:30 Line 50	LZX	Yes	
4:55:32 Line 51	CZW	TCW this is the answer for (a)	**C37**
4:55:40 Line 52	LZX	okay now question (b)	**C38**
4:55:43 Line 53	TCW	no	**C39**
4:55:49 Line 54	CZW	okay so now we do (b)?	**C40**
4:55:59 Line 56	TCW	ok	**C41**
4:56:07 Line 57	LZX	Ya	**C42**
4:56:20 Line 58	CZW	Yes its right….answer for (a) is $\frac{2}{9}(10^n - 1)$	**C43**
4:57:09 Line 59	LZX	Yes	**C44**
4:57:27 Line 60	LZX	Part (b)	
4:57:59 Line 61	LZX	Is it find 1st term ist?	**C45**
4:58:09 Line 62	CZW	Yes its 2	
4:58:45 Line 63	CZW	2nd term is $\frac{2}{3}$	**C46**

5:00:35 Line 64	LZX	Why is it $\frac{2}{3}$?	**C47**
5:00:37 Line 65	TCW	Is that $S_{n+1} - S_n$	**C48**
5:01:17 Line 66	TCW	to find term	
5:07:18 Line 67	CZW	Okay so 1st….We find the S_{n-1}	**C49**
5:07:52 Line 68	CZW	its $3 - 3^{(2-n)}$	
5:08:13 Line 69	LZX	huh	**C50**
5:08:16 Line 70	CZW	then $S_n - S_{n-1}$ = term n	**C51**
5:08:18 Line 71	LZX	Wait you doing which one?	**C52**
5:08:32 Line 72	TCW	$3 - 3^{(1-(n-1))}$	**C53**
5:09:52 Line 73	LZX	So using equation $S_n - S_{n-1} + T_n$	**C54**
5:10:23 Line 74	LZX	I mean $S_n - S_{n-1} = T_n$	
5:10:46 Line 75	TCW	How to solve $-3^{(1-n)} + 3^{(2-n)}$	**C55**
End of Chat			

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 the analysis on the relationship between adjacent contributions does not give a holistic view on the relevant relationships between contributions (Stahl, 2005; Suthers, 2006a). Our proposed model called the Collaboration Interaction Model (CIM) is designed to analyze the relationship between 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, 2006b) 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)

CIM is designed to trace the development of knowledge construction in an online collaborative environment by tracking 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. Each uptake arrow is assigned an uptake number. Taking for example, 1 is assigned to the uptake between contribution 1 and contribution 2. The CIM Uptake Descriptor Table shows the uptake numbers in the CIM where the uptake numbers correspond to the description of the meaning behind the uptakes.

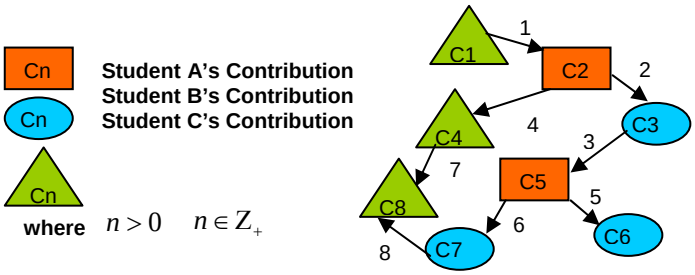

Figure 1: 3-Person Team Collaboration Interaction Model

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. 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. The numbers on each uptake represent the value assigned to the uptake.

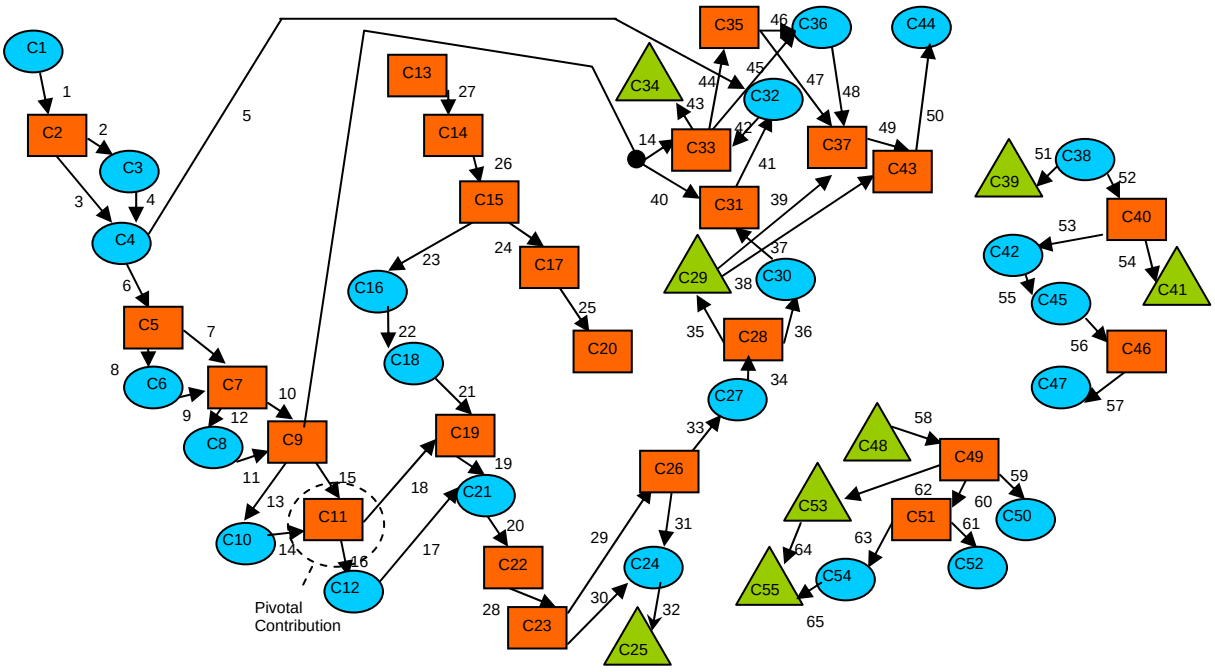

Figure 2: Collaboration Interaction Model

Table 2: Representation of the contributor and the contribution number in chat transcript

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

Table 2 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's assurance that "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)

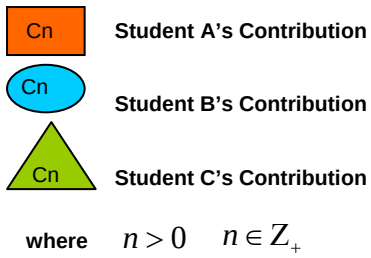

Figure 3: Contributions by participants

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.

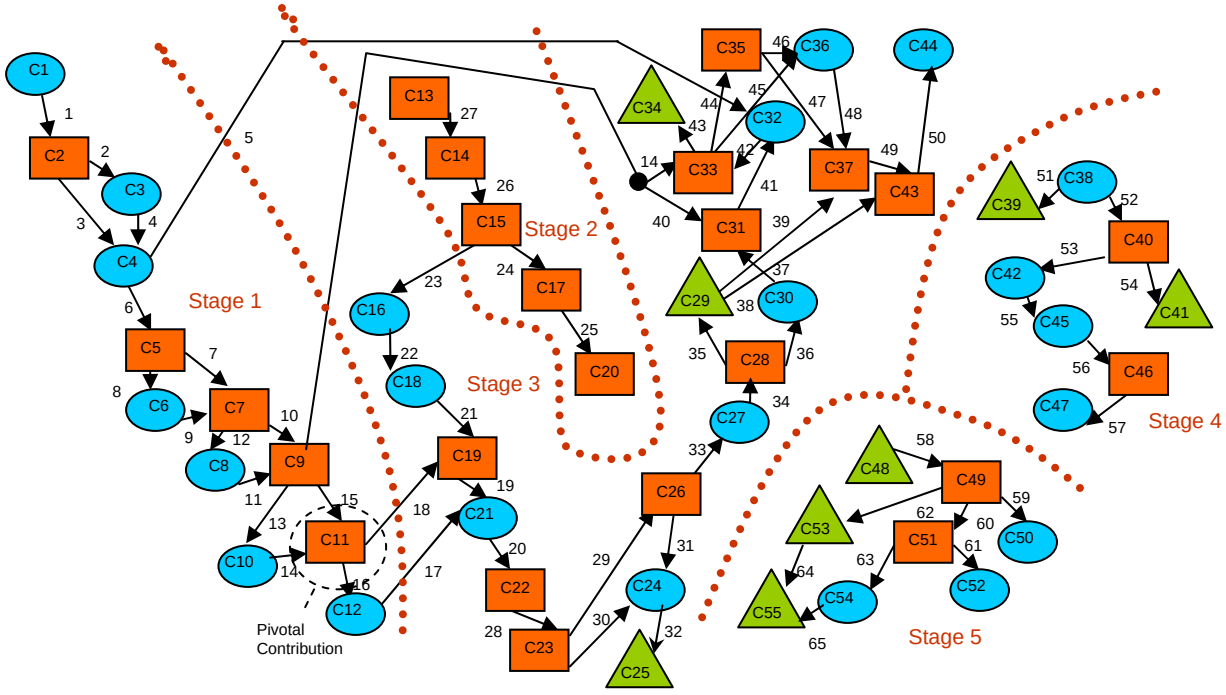

Figure 4: Stages in the Collaboration Interaction Model

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 3: Stage Transition: Stage 1 to Stage 2

Time/Line	Participant	Contribution	Contribution Number
4:35:24 Line 14	LZX	Common ratio 10	**C10**

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

Table 3 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

The concept of uptakes is defined as situations where participants are manipulating previous contributions (Suthers, 2006a) which are either theirs or belonging to other participants. 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. Uptake is a function of the following variables. (1) Participants must interpret contributions that are related somehow to their prior understanding, making a connection between a prior understanding and the current interpretation in order to construct a new contribution. (2) Prior understanding is achieved from previous contributions or knowledge constructed prior to the discourse. Intersubjective and Intrasubjective uptakes resulting in knowledge constructed from previous contributions form the basis of interpretation but knowledge constructed prior to the discourse such as previous encounters with similar types of problem also contribute actively to the interpretation. (3) Language and cultural representations are mutually dependent and they form the vehicle of communication in the discourse. Language and cultural representations are embedded in the contribution, forming part of the interaction and affording a meaning-making

process similar to that of another group of a different cultural and language background. Uptakes encompass not only information related to the tasks but also language and culture of the participant.

Table 4: CIM Uptakes Descriptor

Uptake Number	Relationship of Contributions	Uptake Description
1	C1-C2	CZW develops LZW's proposal to begin solving the problem
2	C2-C3	LZW disagrees with CZW's proposed statement
3	C2-C4	LZW amends CZW's proposed statement
4	C3-C4	LZW disagrees with CZW's proposed statement and amends it.
5	C4-C32	LZW agreeing with his previous proposed statement
6	C4-C5	CZW developing LZW's contribution $2(1), 2(1+10), 2(1+10+100) +2(1+10+100+...)$
7	C5-C7	CZW developing his own proposal $2(1+11+111.....)$
8	C5-C6	LZW proposing to CZW to calculate $2(1+11+111.....)$

The CIM identifies and describes different types of the uptakes taking place in the chat transcript. Table 4 shows examples of uptake numbers, relationship of contributions and uptake description. The uptake numbers are assigned to each uptake arrow in the CIM. The relationship of contributions and uptake description illustrates the meaning behind each uptake, providing a qualitative description of meaning-making process undertaken by each participant as they manipulate the contributions.

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.

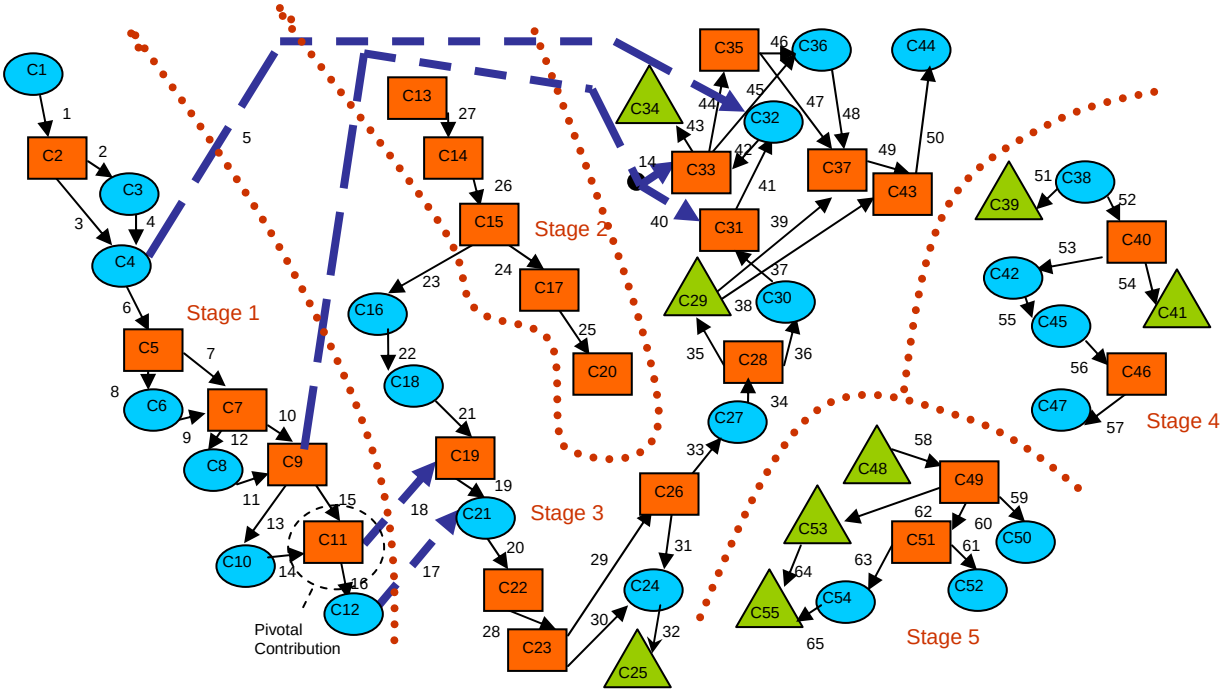

Figure 5: Intrasubjective/Intersubjective Uptakes across Stages

Figure 5 shows the 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, 2006b).

It is possible to view the construction of meaning through the sufficient capture of collaborative interactions. (Stahl, 2006a) 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, 2005a) of contributions form the elemental cell of interactional meaning making (Stahl, 2006a) 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.*

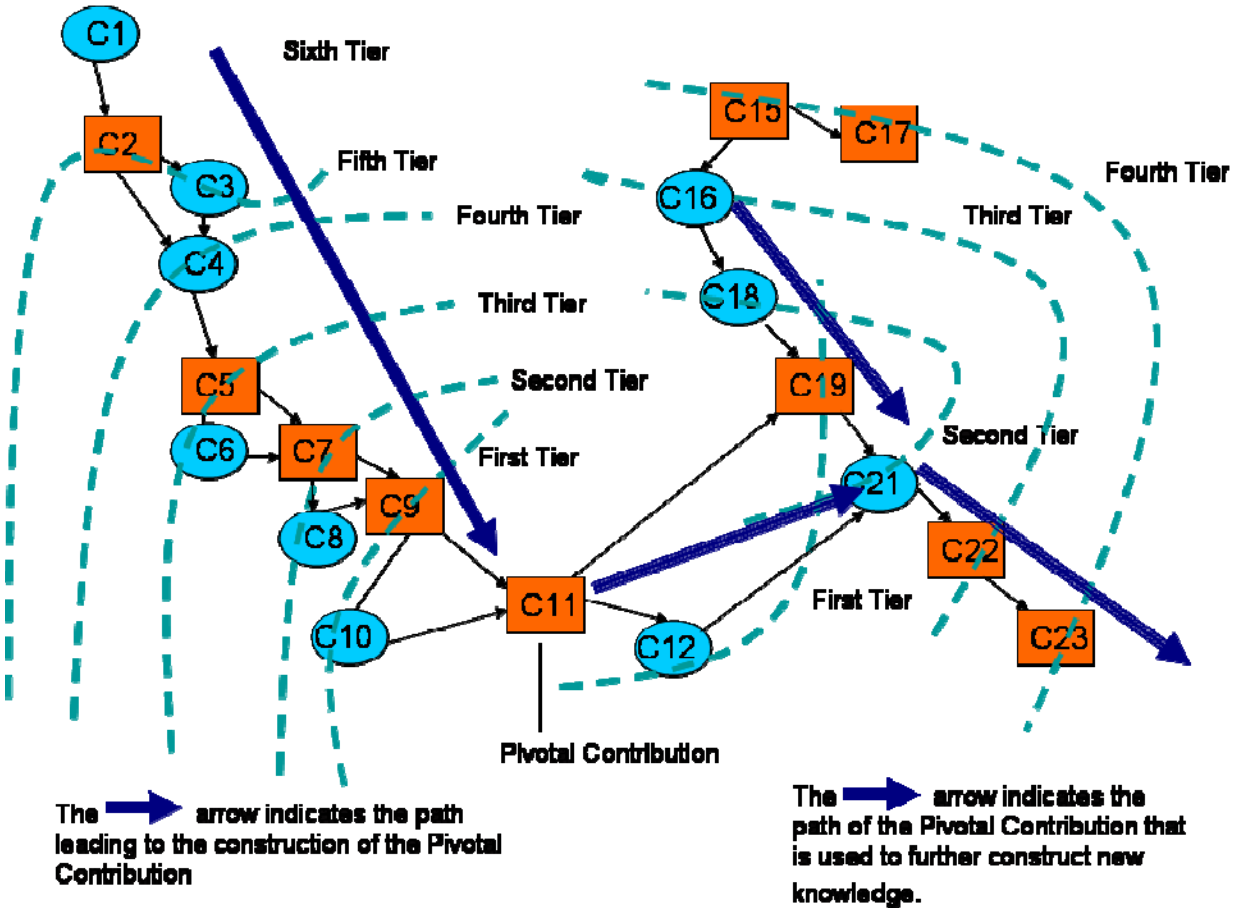

Figure 6: Collaboration Interaction Model Tier Analysis

Discussion

Collaborative learning analysis is the fundamental motivation for the development of the CIM. The Model provides an alternative approach to analyse contributions in quasi-synchronous chat environments. The following describes the characteristics of the CIM.

1. ***Generality of the CIM:*** The CIM is designed to analyse quasi-synchronous chat transcripts across various disciplines. We are doing ongoing research studies that implement English Project Work in the VMT and applying the model to more chat transcripts, further exploring the generality of the CIM.

2. ***Data session:*** The construction of the CIM was based on several data sessions conducted to analyse the chat transcripts. The data were analysed from the researcher's perspective and triangulated with interviews with the participants. Subsequent research will explore the development of a coding framework of the CIM for objectivity in the construction process.

3. ***Unit of Analysis:*** The CIM proposes uptakes as the unit of analysis. Table 4 shows the CIM Uptake Descriptor Table where each uptake is assigned a number and described qualitatively. The meaning-making process is embedded in the uptakes. Further analysis on clusters of uptakes will shed light on the negotiation of the meaning-making process, enabling researchers to understand the moment to moment interaction taking place between participants.

4. ***CIMTA:*** 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.

5. ***Stages in CIM*****:** The CIM 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.

6. ***Problem Design:*** The type of problem design will affect the pattern of discourse. This study was implemented using traditional problem design which has its limitation. One such limitation is the difficulty of the problem leading to interruption of the flow of knowledge construction in the discourse. Subsequent VMT sessions will explore the use of the *Guided Collaborative Critique (GCC)* (Wee, 2007) to promote a different flow of knowledge construction during the discourse.

7. ***Level of Analysis:*** The model provides the framework of analysis of textual contributions both at the micro level and the macro level for appropriate understanding of the ways group meaning making is achieved. The CIM captures the moment to moment interaction between participants through the analysis of uptakes at the micro level. The tracing of the flow of knowledge

construction using the CIMTA and pivotal contributions is intended to inform the understanding of group cognition and functionality at the macro level.

Conclusion

This paper proposes an approach that builds on the concepts of intersubjective and intrasubjective uptakes to understand group cognition in small group problem solving. The model provides a structural view to the uptakes. The arrows in the model linking the contributions represent the uptakes. The linking of contributions affords the opportunity for deeper analysis of the way an individual's contribution is influenced by the uptake or interpretation of another participant's contribution. From the model, we distill the notion of a pivotal contribution as one which is pivotal in the group's knowledge building or problem-solving process. 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-making is the interaction itself which is a group effort. Subsequent research will further develop key ideas addressed in this paper.

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References

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

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.

Chi, M. T. H. (1997). Quantifying qualitative analysis of verbal data: A practical guide. *The Journal of learning Sciences, 6*, 271-315.

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

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.

De Wever, B., Schellens, T., Valcke, M. and Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: a review. *Computers & Education, 46*, 6-28.

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

Gunawardena, C. N., Lowe, C. A., & Anderson, T. (1997). Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing. *Journal of Educational Computing Research, 17(4)*, 397- 431.

Henri, F. (1992). Computer conferencing and content analysis. In A. R. Kaye (Ed), *Collaborative learning through computer conferencing: The Najaden Papers,* (pp.117-136). Berlin: Springer-Verlag.

Jonassen, D. H., Peck, K. L. & Wilson, B.G. (1999). *Learning with Technology: A Constructivist Perspectives*. Upper Saddle River, NJ: Merrill/Prentice Hall.

Looi, C. K. (2005). Exploring the affordances of online chat for learning. *Int. J. Learning Technology, 1(3),* 322–338.

Rourke, L., Anderson, T., Garrison, D.R. & Archer, W. (2001). Assessing social presence in asynchronous text-based computer conferencing. *Journal of Distance Education, 14(21),* 50-71.

Schank, R.C. (2002). *Designing World-Class E-learning*. New York: MacGraw-Hill Publishing.

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.

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.

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.

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.

Stahl, G. (2006a). Sustaining group cognition in a Math chat environment. *Research and Practice in Technology Enhanced Learning (RPTEL), 1* (2).

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

Suthers, D.D. (2005a) 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).

Suthers, D.D. (2005b) *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.

Suthers, D.D. (2006a). *A qualitative analysis of collaborative knowledge construction through shared representations.* Research and Practice in Technology Enhanced Learning (RPTEL), 1(2), 1-28.

Suthers, D.D. (2006b) *Technology affordances for intersubjective meaning making: A research agenda for CSCL*. International Journal of Computer-Supported Collaborative Learning (ijCSCL), 1(3), 315-337.

Wright, E.L., Sunal, D.W., & Day, J.B. (2004), *Reform in Undergraduate Science Teaching for the 21st Century*. IAP.

Wee, J.D. (2007). Construction of Mathematical Knowledge through the use of Guided Collaborative Critiques in Problem Solving. *Paper submitted to the Redesigning Pedagogy: Culture, Knowledge and Understanding Conference (May 2007),* Singapore, Singapore.