

## POLYPHONIC DESIGN, CONDUCT, EXPERIENCE, AND EVALUATION IN CSCL CHATS

Ștefan TRAUȘAN-MATU<sup>1</sup>

**Abstract.** *The paper presents an approach directed towards enforcing a polyphonic structure to a CSCL chat, with the aim of increasing inter-animation and collaboration. Another leading idea of the paper is that we should start from the analysis of the polyphonic experience of the learners, which occurs when they are situated in the presence of multiple collaborating voices in small groups. A carefully designed assignment, in which learners are assigned roles (or 'instruments' in the musical perspective) can induce a polyphonic structure along both longitudinal and transversal directions, as in musical counterpoint. Another major consequence is that such a design facilitates the analysis of the collaboration and personal contributions of students.*

**Keywords:** Computer-Supported Collaborative Learning (CSCL), Polyphonic analysis, Discourse analysis, Natural Language Processing, Conversation Analysis

### 1. Introduction

Instant messenger (chat) has been used in recent years for Computer-Supported Collaborative Learning (CSCL) for various types of small group assignments [1,2,3,4]. Meanwhile, among the main theoretical foundations of CSCL were proposed the social-cultural theory and the view of language as a tool idea of Vygotsky [5] and Bakhtin's dialogism [5,6,7,8,1,4].

Some developed CSCL systems offer interaction analysis tools of wikis and especially conversations, either spoken or through chat or forums: TATIANA [9], CORDTRA [10], VMT-Basilica [11], KSV [12], COALA [13], DIGALO [14], ColAT [15], the Scaffold-Argument visualization [16], and Dong's system [17]. Some of these systems use several kinds of argumentation graphs, some of them in the idea of Toulmin [18], or more elaborated structures like the contingency graphs [19].

The approach presented in this paper is based on a totally different theoretical basis. It aims at identifying in chats a polyphonic structure and inter-animation patterns [4]. This theoretical framework was used as a starting point for the implementation of a series of systems for chat analysis: *Polyphony* [20], *PolyCAFe* [21], *ReaderBench* [22] and several others. The *PolyCAFe* system (Polyphonic Conversation Analysis and Feedback generation) was designed for

---

<sup>1</sup> Member of AOSR. Prof., PhD, Faculty of Automatic Control and Computers, "Politehnica" University of Bucharest and Senior Researcher, Research Institute for Artificial Intelligence of the Romanian Academy, Romania. stefan.trausan@cs.pub.ro

supporting both learners and tutors with abstraction and feedback-giving services for evaluating the assignments based on chat or forum conversations [21]. *PolyCAFe* is implemented using natural language processing tools for discourse and content analysis. Three classes of information are investigated: if the content of the utterances is semantically close to the topics supposed to be discussed, if there is a real collaboration (for example, the acceptance of others' opinions and inter-animation patterns) and if discourse and debate threads may be identified.

The paper presents an approach directed towards enforcing a polyphonic structure to a CSCL chat, with the aim of increasing inter-animation and collaboration. Another leading idea of the paper is that, in CSCL chat analysis we should start from identifying polyphonic experiences of learners, similar to players in polyphonic music. A careful designed assignment, in which students are assigned roles (or 'instruments' in the musical perspective) can induce a polyphonic structure along both longitudinal and transversal directions, as in musical counterpoint [4]. Another consequence is that such a design facilitates the analysis of the collaboration and personal contributions of students.

The polyphonic assignment presented in the paper was used in the last five years at the "Politehnica" University of Bucharest in a course on Human-Computer Interaction (HCI) for the Computer Science and Engineering students in their last year of undergraduate studies. The assignment was well accepted by the students, which participated with interest. It was also used for the validation of the PolyCAFe system in the LTfLL project (<http://ltfll-project.org/>). The paper continues with an introduction to the polyphonic model, with a discussion about the experiencing of CSCL chats and the conducting of CSCL in a polyphonic manner. The following section presents the ideas of designing polyphonic chats. The facilities for evaluation of the polyphonic structure are presented in the end.

## 2. The Polyphonic Model of CSCL

Musical polyphony is a remarkable case of collaboration in which, starting from a *theme*, several "voices" concomitantly play it or its variations achieving a coherent joint piece. Each "voice" may be either a distinct instrument or group of instruments (a *participant*) or a sequence of notes played, together with other voices on a same instrument. For example, there are polyphonic musical pieces for 3-4 voices played by a single interpret at piano. The same piece may be also played by an orchestra where each voice is played by a group of instruments. Therefore, there is not a one-to-one association between a voice and a participant. Musical polyphony may be achieved by composition in classical music on paper (e.g. the fugues of Johann Sebastian Bach) or by improvisation, with a lower degree of complexity in other types of music, as jazz and latin music.

The idea of considering a polyphonic model in natural language was introduced by Mikhail Bakhtin [7], which developed also the theory of dialogism, which sees everything as a dialog. Dialogism was proposed as a paradigm in CSCL [8] and together with the associated concept of inter-animation was used for analyzing CSCL chats [4,23].

The polyphonic model of CSCL group interaction considers, similarly with the musical case, that the students are experiencing the presence of a number of concurrent voices, each of them having independence but contributing to a joint discourse. The *theme* is the discussion subject or the problem to be solved assigned by the teacher or tutor. Each of the participants emits a coherent sequence of utterances and, interacting in a group, inherently has to solve the dissonances appearing between them. Therefore, participants face centrifugal and centripetal; convergent and divergent forces, along two directions: longitudinal and transversal, following the musical counterpoint rules [4].

However, these forces have an important effect, they allow the participants to perceive dissonances which put under question their utterances, they generate an *inter-animation* phenomenon. The polyphonic analysis tries to identify inter-animation patterns along the two dimensions and corresponding to the two types of forces. The longitudinal dimension may be found in references (links), which may be explicit or implicit and in repetitions of words which form threads which may be seen as parallel voices to which implicit voices (e.g. of the teacher, of the authors of the readings) are added. The transversal dimension may be generated by dissonances or differential positions among voices.

## 2.1 Experiencing and Conducting the CSCL Polyphony

The Polyphonic music is a complex process of developing a theme in a community of voices, which is validated by the reception of the listeners. It may be seen also as a model of creative thinking. For example, those who enjoy the fugues of Johann Sebastian Bach understand that sometimes his music is like an explosion of ideas.

If we consider the polyphonic model of CSCL, attention should be paid to avoid that a cacophony result appears, where voices interfere in an disarmonic way. In fact, in classroom based education, or in group learning, professors usually conduct the discussions along a theme, on a longitudinal dimension. Meanwhile, many times they stimulate learners to consider transversal dimensions, for discovering differences that drives to the concepts that should be learned.

The dialog in the classroom or in learning groups is many times directed towards constructing a coherent discourse driving to the concepts to be learned or to experience the needed skills (for example the reasoning in mathematics problem

solving). The role of dialog was emphasized by Sfard, which defined learning not as a transfer of knowledge, but rather as “becoming a participant in a certain discourse” [24]. Therefore, it is extremely important to placing the learners in the position of experiencing and contributing to dialogue.

Starting from the idea of Mikhail Bakhtin that everything is a dialog, individual, internal thinking of learners is also a dialog and should also be considered for the analysis of the conversation. Moreover, means of inducing it are beneficial. In fact, when teachers encourage students to put themselves questions and find answers, this is, in fact, an implicit urge to internal dialog.

One important feature of listening or contributing to polyphonic music or, in our CSCL perspective, to contribute to group knowledge construction, is the perception, the following and the participation to the threads (voices) of discussion in dialogs.

In a face-to-face conversation, due to the impossibility that two persons speak in the same time, there is very difficult to handle more than a single thread of discussions. This is not the case when using chat environments like the one of the Virtual Math Teams (VMT) project [2], which offers explicit referencing facilities. By this facility, learners in groups may indicate to which previous utterance(s) they refer to, allowing the existence of several discussion threads (or voices), in parallel.

The co-occurrence of several threads generates *inter-animation*, a general feature of CSCL in chats [4]. Participants to CSCL chats face the need to handle many threads in parallel. The threads are formed by the explicit referencing facilities (when the VMT chat environment is used), by the temporal sequence of utterances, the implicit links of co-references, the adjacency pairs, or, at another abstraction level, transacts [25]. In addition, one important source of thread generation is the repetition of words, which has a very important role in inducing the sense of participation [26].

In Figure 1 several threads of the kinds discussed above are emphasized (curly arrows represent explicit references). To these threads/voices we should add other implicit ones, generated by the subject of discussion, teacher’s voice (even in absence) and by the implicit assumptions of each participant.

For example, Tim, at utterance 26 should take into account the threads generated by the repetition of the words “topic”, “reply”, “double-clicking”, “presentation”, those of explicit referencing, and the implicit thread of the subject of the CSCL assignment (to discuss ways of developing collaborative environments), which may be considered as the voice of the teacher. As a consequence, at utterances 34-36 he contributes to several threads of the dialog.

Nr	Ref	Time	User	Text
17		10.26.25	tim	You discussed about a <b>topic</b> separation
18	15	10.26.37	adrian	First of all, <b>the reply</b> method is cumbersome
19	17	10.26.50	john	yes, because we did not like the way the <b>topics</b> were presented in concert chat
20	18	10.26.56	john	yes!!
21	20	10.27.04	john	i hate <b>double-clicking</b> !
22	20	10.27.18	tim	and how can we find <b>topics</b> ?
23	18	10.27.26	adrian	What bothers me is the <b>linear presentation</b> of the discussion
24	23	10.27.43	john	Yep
25	18	10.27.46	adrian	and <b>double-clicking</b> too
26		10.27.54	tim	You mean u want something like a chat forum? :D
27	24	10.27.58	john	and the <b>reply-to</b> facility is supposed to help you
28	18	10.28.15	adrian	i'd like a <b>tree presentation</b> more
29	18	10.28.38	adrian	or maybe multiple chat columns, for each chat sub-thread
30	27	10.28.58	john	but it is really difficult to use in real-time because there are so many <b>topics</b> discussed which intertwine each other
31	28	10.29.18	john	i subscribe to a <b>tree-like presentation</b> form
32	P30	10.29.20	adrian	yes, that's why a clear separation of <b>topics</b> is needed
33	31	10.29.47	adrian	this is easy to implement, no problem here :)
34	30	10.29.49	tim	You need also a clever visual <b>representation</b>
35	30	10.30.05	tim	you'll need also a clever visual interface
36		10.30.22	tim	Who decides the <b>topics</b> ?
37	33	10.30.33	john	i suppose you are referring to the <b>visual representation</b> , right?
38	37	10.30.45	john	What i would like is a clever way to separate the <b>topics</b> :)
39	38	10.30.59	john	not just doing it myself, manually
40	37	10.31.00	adrian	Yeah
41	39	10.31.44	adrian	When you start a new thread (a new message, non-related to other message), the app can assume a new <b>topic</b>
42	39	10.31.46	john	i would like the application to be able to detect w <b>topic</b> change all by itself

Fig. 1. An image of a subset of the threads in a conversation.

### 3. Designing and Detecting Polyphonic Dialogism in Chatting Virtual Groups

#### 3.1 A Case Study

CSCL chats has been used for the last ten years at the “Politehnica” University of Bucharest in a course on Human-Computer Interaction (HCI) for the Computer Science and Engineering students in their last year of undergraduate studies. More than 90 students enroll each year for this course, the maximum of 324 students being reached in the 2008-2009 year (when was a special situation because two generations completed the studies).

During the course, students had lectures where they were taught the theory of interface design and evaluation. They had also laboratory hours and homework aiming to apply their theoretical knowledge by individually developing several applications.

An important emphasis is given in the course to collaborative applications. In order to enhance the quality of their learning, we designed an assignment using CSCL chats where they discussed about collaborative technologies (forums, chat, blog and wiki).

### 3.2 Polyphonic Design of CSCL chats

For the increase of the interest and participation of the students, we started in the design of the scenario of the CSCL chat assignment from a polyphonic perspective, in which inter-animation is induced. Students were divided in groups of four and each of them was assigned a role: They were told to consider that they were the directors of a company selling one of the collaborative technologies presented at the course (chat, forum, blog and wiki). Before the chat they were supposed to individually study collaborative technologies and after that to have a 1-2 hours chat. In the first part of the chat conversation, each student had to champion the technology he represented by presenting its features and advantages and criticize the others by invoking their flaws and drawbacks. In the second part of the chat, they had to discuss on how they could integrate all these technologies in a single online collaboration platform. Therefore, in a single conversation the students first engaged into a debate where a differential position should be taken. The results of the discussion in the first part were then used for collaboratively building a solution to the given problem. The VMT environment [2] was used due to its features of facility of inserting explicit references to previous utterances. The chat logs were analyzed by the tutors for evaluating and grading the activity of the students in the assignment.

### 3.3 The Data

For the purposes of validation of our approach we have selected two chat logs, one that we considered a good collaboration (Team36) and one (Team34) which was an example of a bad collaboration, with a lower degree of inter-animation. The chat logs of the two teams of students were evaluated and graded by four tutors (T1, T2, T3 and T4) and by an automatic grading system [4]. They gave marks from 1 to 10 (10 is the best) for each student (see Tables 1 and 2) and they also wrote some feedback. Tutors were also asked to report what were the problems they faced.

**Table 1.** Team34

	T1	T2	T3	T4	Average	Aut.eval
Marian – F	6	6	7	6	6.25	6.5
Delia – C	8	7	8	7	7.5	7
Madalin – W	5	7	7	6	6.25	8
Cristian – B	7	4	7	6	5.875	10

**Table 2.** Team36

	T1	T3	T4	Average	Aut.eval
Raluca – F	10	8	10	9.33	10
Bogdan – C	9	8	9	8.66	9.5
Florin – W	9	9.5	8	8.83	7.8
Elena – B	9	8	8.5	8.5	8

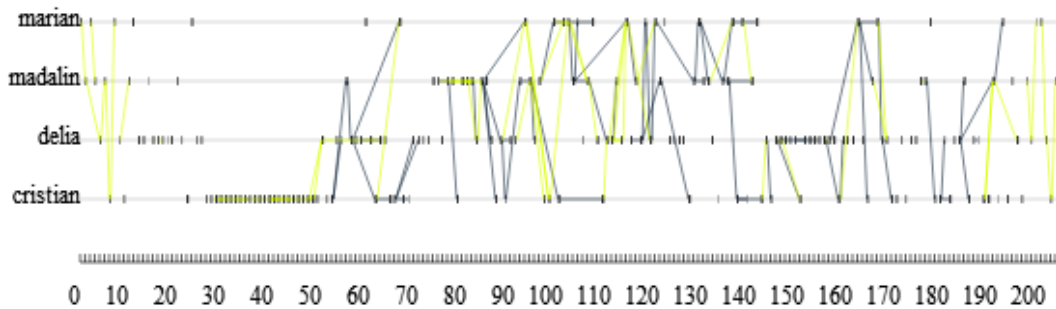
### 3.4 The Polyphonic Analysis

The polyphonic analysis was performed manually with the visualization facilities of *PolyCAFe*. The longitudinal and transversal dimensions were analyzed, with a focus on threading. The polyphonic design has been facilitating the analysis because we knew what ‘instrument’ played each learner.

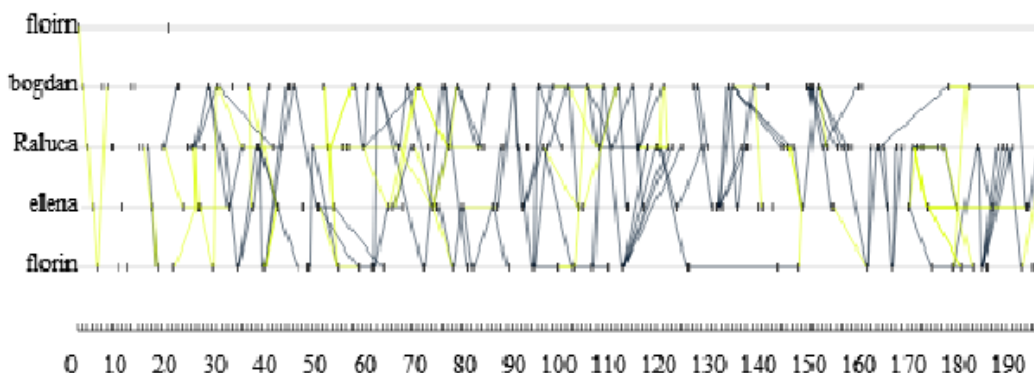
#### *The Longitudinal Dimension - Referencing*

One first image of the degree of inter-animation in a chat is the usage of explicit and implicit references along the longitudinal dimension. The explicit references are those indicated by the learner when using the VMT system [2]. The implicit references are detected by the instruments we have developed in *PolyCAFe*.

One idea of analyzing the degree of participation of a student is to start from the assumption that if she uses many explicit references and the system detects also many implicit ones, she displays a collaborative attitude. For example, it is obvious from seeing the Figures 2 and 3 that the participants in Team34 are linked by much lesser references than those in Team36, fact which is consistent with the evaluations of the tutors.



**Fig. 2** References of Team34 (dots are utterances; blue lines are explicit references and yellow lines are implicit references; numbers are utterances' numbers; time flows from left to right).



**Fig. 3.** References of Team36. Blue lines are explicit references.

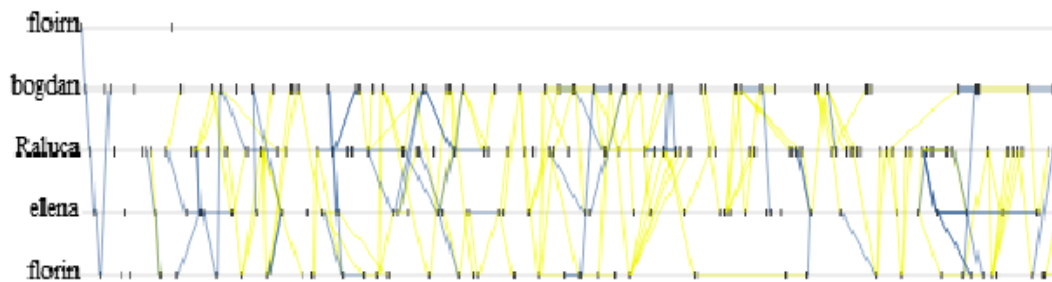


Fig. 4. References of Team36. Blue lines are implicit references.

An analysis of the distribution of implicit and explicit links (the difference between Figure 2 and 3) shows that they are in the majority of cases distinct. For example, in the Team36 example, only one link was common. This shows that the learners are aware of the implicit links and they also feel the need of assuring the threading. Therefore, they use explicit links only when they feel that the threading could not be obvious. However, a problem with this kinds of diagrams and analysis is that, even if they can give an image of the degree of collaboration, more precise analysis should be performed in order to detect zones of good collaboration or to identify real, important, contributions. For example, one may use a lot of explicit references, or may write utterances that generate implicit utterances, but these might be insignificant (e.g. only formal approvals or unjustified denials of the others' utterances). A solution to this problem is the analysis of the other features of a good polyphony: threading and transversal utterances.

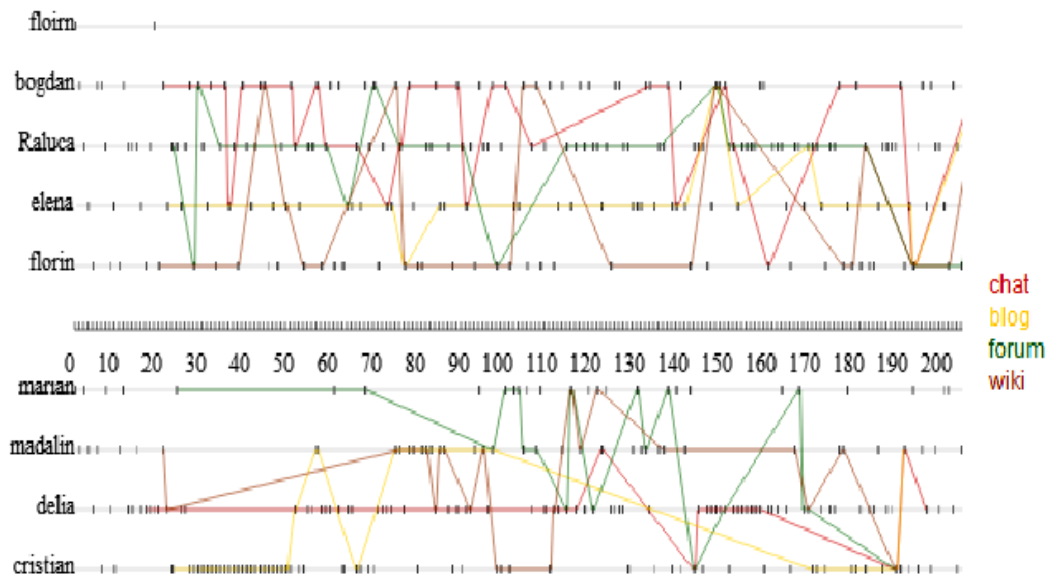


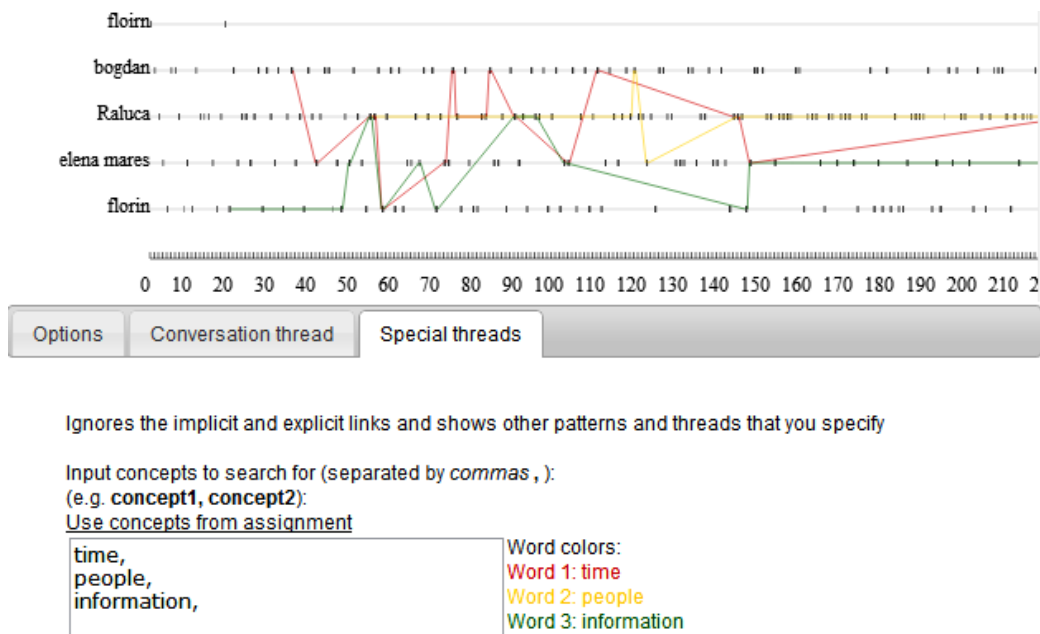
Fig. 5. The threads of the assigned topics in Team36 (up) and Team34 (down).



### Threading

The majority of approaches for chat analysis mentioned in the introduction are based on the analysis of pairs of utterances. One of the main ideas of the polyphonic model is the emphasis on threads and their interactions. For this aim we have developed a facility of visualizing threads of repeated words in *PolyCAFe* [21]. For example, in Figure 5 you can see comparatively the threads of the assigned concepts to be discussed (chat, blog, forum and wiki). The fact that in Team34 there is less variation signifies that the collaboration was not so good as compared to Team36.

The visualization of the threading of additional concepts proved also very useful to see the polyphonic structure and the contributions of the participants. These additional concepts were detected from the analysis of the most used concepts in the chats. For example, in Figure 6 is presented the threading of the most used concepts in Team36 (besides the assigned topics – chat, forum, blog and wiki).



**Fig. 6.** The threading of some additional concepts in Team36.

### *The Transversal Dimension - The Differential Positioning*

Even if explicit and implicit references and the threads of repeated words may give an image of the contribution of each learner, they are not covering all the aspects of the collaboration, of the inter-animation. Therefore, some other analysis methods are needed. Moreover, an analysis of the performance of each learner is needed.

The fact that the chats were designed from a polyphonic perspective, based on assigning roles is not only inducing polyphonic order, it also facilitates the implementation of analysis and feedback giving because we can more easily identify the utterances where a participant takes a differential position discussing about others' roles.

From the polyphonic, counterpoint perspective, we should consider both the longitudinal dimension, when a student discuss about the personal assigned topic and the transversal topic, when she poses herself in a differential position, discussing about others' topics. For example, in Figure 7, utterances 74, 75, 76 are differential, while 75, 76, 84, 85, 86, 88 and 89 are longitudinal. 75 and 76 are utterance combining the two features. Utterance 74 is an example of an utterance which refers to utterances which contain other topic.

Nr	Student	Utterance	iv	cv	rv	Ref
74	bogdan	if you a willing to spend a lot of time, that may be true for a small wiki , but when you a trying to develop an encyclopedia ....you have absolutely no chance	C	W		70
75	Raluca	Messages posted to a forum are publicly available for some time, which is uncommon in chat rooms, with only few exceptions.	F	F	W	74
				C		
76	florin	why are blogs search-engine friendly? I think wikis are more search-engine friendly! :P	W	B	B	73
				W		
77	bogdan	chats work as long as you have an internet connection....	C	C	C	72
78	elena	because you can use keywords	B		B	p 76
79	florin	never say never - what about Wikipedia ?!	W		W	74
80	florin	can you detail on that feature a bit?	W			78
81	Raluca	in terms of 'coding' your application, I bet yours is the hardest	F			77
82	Raluca	and only that could take up a lot of time	F		C	77
83	bogdan	it may be, but you're only going to do it once....and then use it like that for a very long time	C			81
84	elena	the blogs can be grouped by interest and all the articles can be full of keywors that are search engine friendly	B	B		p 80
85	elena	do not forget that a blog is the best way to promote a site	B	B		
86	Raluca	same with forums, and reading the posts looks easier	F	F	B	84
87	florin	ok, thanks for the info	W		B	84
88	bogdan	sorry , but the est way is a message to all your friends..using a CHAT	C	C	B	85
89	Raluca	'but if you want to study, you have a lot of information on the forums, moreover, if you have questions people can take their time to answer you	F	F	C	88

Fig. 7. Evidentiation of the transversal positionings.

In Figure 7, each student has an associated topic (*iv*), in our case one of chat (C), forum (F), wiki (W) or blog (B). She says something that may contain one or more of the associated topics (*cv*) of her or colleagues. She may explicitly refer to another utterance that may also contain some topics (*rv*).

There are several situations that may appear, when there are topics found in the utterance (*cv*) or in the referred utterance (*rv*). The student:

1.  $iv=cv$  - speaks about her personal topic
2.  $iv=rv$  - explicitly refers an utterance containing a topic that is her topic
3.  $cv=rv$  - speaks about the same topic with the one discussed in the utterance she explicitly referred

4.  $iv \neq cv$  - speaks about other topic than her own
5.  $iv \neq rv$  - refers about an utterance containing a topic that is not her own
6.  $cv \neq rv$  - speaks about a different topic than the one discussed in the utterance she explicitly referred

The analysis of the number of occurrences of some of the above situations and of some of their ratios may give an image of the contribution of the participants to collaboration and inter-animation. For example, a good contribution should have a balanced ratio between the utterances oriented towards longitudinal, selfish, on own topic and transversal, directed towards others' topics. In our opinion, a value of  $nr_{iv \neq cv} / nr_{iv = cv}$  close to 1 is characterizing such a situation.

The results of the analysis of Team34 and Team36 using the above terms is displayed in Tables 3 and 4. The relative values of  $nr_{iv \neq cv} / nr_{iv = cv}$  are rather corresponding to the relative appreciations of the tutors in the classification of the learners.

Table 3. Team 34

	$nr_{ut}$	$nr_{iv=cv}$	$nr_{iv \neq cv}$	$nr_{cv \neq rv}$	$nr_{iv=cv} / nr_{iv}$	$nr_{iv \neq cv} / nr_{iv}$	$nr_{iv \neq cv} / nr_{iv=cv}$	Average tutors' mark
Marian – F	27	10	1	3	0,37	0,04	0,10	6.25
Delia – C	74	8	3	4	0,11	0,04	0,38	7.5
Madalin – W	44	11	6	0	0,25	0,14	0,55	6.25
Cristian – B	62	17	2	1	0,27	0,03	0,12	5.875

Table 4. Team 36

	$nr_{ut}$	$nr_{iv=cv}$	$nr_{iv \neq cv}$	$nr_{cv \neq rv}$	$nr_{iv=cv} / nr_{iv}$	$nr_{cv \neq rv} / nr_{iv}$	$nr_{iv \neq cv} / nr_{iv=cv}$	Average tutors' mark
Raluca – F	121	15	15	8	0,12	0,07	1	9.33
Bogdan – C	72	18	5	4	0,25	0,06	0,28	8.66
Florin – W	47	15	5	3	0,32	0,06	0,33	8.83
Elena – B	59	24	7	5	0,41	0,08	0,29	8.5

In tables 3 and 4:

$nr_{ut}$  is the number of utterances emitted by the student

$nr_{iv=cv}$  is a lower bound of the number of utterances in which a student speaks about her personal topic

$nr_{iv \neq cv}$  is a lower bound of the number of utterances in which a student speaks about a topic other than her own

$nr_{iv \neq rv}$  is a lower bound of the number of utterances in which a learner referred a topic which is not her own

#### **4. Conclusions and Further Developments**

The polyphonic structuring of a CSCL chat can be conducted by a careful design, in which each learner is assigned a role that is conflicting with the other participants in the first part of the conversation, but in the end it should reach a consensus. The fact that the ‘interests’ of each learner are assigned by the teacher simplifies also the evaluation of the collaboration and of the participation of the learners. However, these tasks are challenging and the existence of a series of support tools and an evaluation methodology is beneficial.

The first validation showed that the results of the polyphonic analysis are close to those of tutors which used only reading for the evaluation. In the future, the methodology will be supported also by natural language processing tools that could analyze in more detail the differential positioning of the utterances and the dissonances that appear between voices. Another development is the further analysis of the polyphonic experience of the learners, including also the investigation of the internal dialogues induced by the utterances from the external one.

## REFERENCES

- [1] Stahl, G. (2006). *Group Cognition: Computer Support for Building Collaborative Knowledge*, MIT Press.
- [2] Stahl, G. (Ed.). (2009) *Studying Virtual Math Teams*, Springer, Boston.
- [3] Trausan-Matu, S. (2010). Automatic Support for the Analysis of Online Collaborative Learning Chat Conversations, in Philip M. Tsang, Simon K. S. Cheung, Victor S. K. Lee, Ronghuai Huang (Eds.): *Hybrid Learning, Third International Conference*, Beijing, LNCS 6248, Springer, pp. 383-394
- [4] Trausan-Matu, S., Stahl, G., Sarmiento, J. (2007). Supporting Polyphonic Collaborative Learning, *E-service Journal*, vol. 6, nr. 1, Indiana University Press, pp. 58-74.
- [5] Vygotsky, L. S. (1978). *Mind in society*. Cambridge: Harvard University Press.
- [6] Bakhtin, M.M. (1981). *Dialogic Imagination: Four Essays*, University of Texas Press, Austin.
- [7] Bakhtin, M.M. (1993). *Problems of Dostoevsky's Poetics*, University of Minnesota Press, Minneapolis
- [8] Koshmann, T. (1999). Toward a Dialogic Theory of Learning: Bakhtin's Contribution to Understanding Learning in Settings of Collaboration, in C.Hoadley and J. Roschelle (eds.), *Proceedings of the Computer Support for Collaborative Learning 1999 Conference*, Stanford, Laurence Erlbaum Associates
- [9] Dyke, G., Lund, K., & Girardot, J.-J. (2009). Tatiana: an environment to support the CSCL analysis process. *Computer Support for Collaborative Learning*, 58–67.
- [10] Hmelo-Silver, C. E., Chernobilsky, E., & Mastro, O. (2006). Representations for Analyzing Tool-mediated Collaborative Learning. *Proceedings of ICLS 2006*, New Brunswick.
- [11] Kumar, R., Chaudhuri, S., Howley, I., & Rosé, C. P. (2009). VMT-Basilica: an environment for rapid prototyping of collaborative learning environments with dynamic support. *Proceedings of the 9th international conference on Computer Support for Collaborative Learning*, 192–194.
- [12] Teplovs, C. (2008). The Knowledge Space Visualizer: A Tool for Visualizing Online Discourse, In *Workshop on A Common Framework for CSCL Interaction Analysis, ICLS 2008* (pp. 12). Utrecht, Netherland..
- [13] Dowell, J., & Gladisch, T. (2007). Design of argument diagramming for case-based group learning. *ACM International Conference Proceeding Series*; Vol. 250, 99–105.
- [14] Harrer, A., Hever, R., & Ziebarth, S. (2007). Empowering researchers to detect interaction patterns in e-collaboration. *Frontiers in Artificial Intelligence and Applications*; Vol. 158, 503–510.
- [15] Avouris, N., Fiotakis, G., Kahrmanis, G., & Margaritis, M. (2007). Beyond Logging of Fingertip Actions: Analysis of Collaborative Learning Using Multiple Sources of Data. *Journal of Interactive Learning Research*, 18, 231–250.

- [16] Law, N., Lu, J., Leng, J., Yuen, J., & Lai, M. (2008). Understanding Knowledge Building from Multiple Perspectives. *Proceedings of Workshop on Interaction Analysis, ICLS 2008*, Utrecht.
- [17] Dong, A. (2005). The latent semantic approach to studying design team communication, *Design Studies*, 26(5): 445-461.
- [18] Toulmin, S. (1958/2003), *The Uses of Argument*, Cambridge University Press
- [19] Suthers, D., Dwyer, N., Medina, R., & Vatrappu, R. (2007). A framework for eclectic analysis of collaborative interaction. Paper presented at the *Proceedings of Computer Support for Collaborative Learning 2007*.
- [20] Trausan-Matu, S., Rebedea, T., Dragan, A., & Alexandru, C. (2007). Visualisation of Learners' Contributions in Chat Conversations. In J. Fong & F. L. Wang (Eds.), *Blended Learning*: Addison-Wesley.
- [21] Trausan-Matu, S., & Rebedea, T. (2010). A Polyphonic Model and System for Inter-animation Analysis in Chat Conversations with Multiple Participants. In A. Gelbukh (Ed.), *Computational Linguistics and Intelligent Text Processing*, Lecture Notes in Computer Science, Vol. 6008, pp. 354-363, Springer Berlin / Heidelberg.
- [22] Dascalu, M., Dessus, P., Trausan-Matu, S., Bianco, M., & Nardy, A. (2013). ReaderBench, an environment for analyzing text complexity and reading strategies. In H. C. Lane, K. Yacef, J. Mostow, & P. Pavlik (Eds.), *16th Int. Conf. on Artificial Intelligence in Education (AIED 2013)* (pp. 379–388). Memphis: Springer.
- [23] Trausan-Matu, S., & Rebedea, T. (2009). Polyphonic inter-animation of voices in VMT. In Stahl, G. (ed.), *Studying virtual math teams*, pp. 451-473, Springer, New York.
- [24] Sfard, A., (2000). On reform movement and the limits of mathematical discourse. *Mathematical Thinking and Learning*, 2(3), pp. 157-189
- [25] Joshi, M., Rosé, C. P. (2007). Using Transactivity in Conversation Summarization in Educational Dialog, in *Proceedings of the SLATE Workshop on Speech and Language Technology in Education*.
- [26] Tannen, D.. (1989). *Talking Voices: Repetition, Dialogue, and Imagery in Conversational Discourse*, Cambridge University Press.