Polyphonic Support for Collaborative Learning

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Abstract. This paper argues that one reason for the success of collaborative problem solving where individual attempts failed is the polyphonic character of work in small groups. Polyphony, a concept taken from music, may occur in chats for problem solving, transforming dialog into a "thinking device": Different voices jointly construct a melody (story, or solution) and other voices adopt differential positions, identifying dissonances (unsound, rickety stories or solutions). This polyphonic interplay may eventually make clear the correct ("sound") construction. The paper illustrates the polyphonic character of collaborative problem solving using chats. It also proposes prototyped software tools for facilitating polyphony in chats.

1 Introduction

This paper is considering the role of polyphonic inter-animation of multiple voices in collaborative learning. Inspired by the work of Mikhail Bakhtin, this idea shed new light on the dialogic nature of discourse in human language. It would also have consequences for the design of collaborative learning environments.

In polyphony, several voices jointly construct a melody (or a story, or a potential solution in the textual-chat case) while other voices situate themselves on a differential position, identifying dissonances (unsound, rickety stories or solutions). This polyphonic game may eventually make clear the correct, sound solution.

The ideas are exemplified with chat excerpts for collaborative learning of mathematics problem solving, investigated in the Virtual Math Teams (VMT) project at Math Forum @ Drexel University. Inter-animation patterns in two dimensions were discovered: longitudinal (chronologically sequential) and vertical, towards two opposite trends: unity vs. difference. We consider that even individual thinking is also an implicit collaborative (dialogic) process that involves multiple voices. However, actual collaborations, in small groups of different personalities empower the dialogic process.

An environment for collaborative learning (that may be seen also as a groupware) based on the polyphonic inter-animation principles is introduced. Several modules are already implemented while others are in a final stage.

The paper continues by introducing discourse, the dialogic theory of Mikhail Bakhtin and polyphony. The next section of the paper introduces Computer-Supported Collaborative Learning (CSCL) and analyses the polyphonic welding of longitudinal-vertical unity-difference dimensions. Software tools that support the polyphonic inter-animation are presented in the fourth section. The paper ends with conclusions and references.

2   Discourse, Dialogic and Polyphony

Learning may be seen as directly related to discourse building, as Sfard remarked: "rather than speaking about 'acquisition of knowledge,' many people prefer to view learning as *becoming a participant in a certain discourse*" [11]. Koschmann [5] emphasized the social dimension of learning and discourse, quoting Deborah Hicks [4]: "Learning occurs as the co-construction (or reconstruction) of social meanings from within the parameters of emergent, socially negotiated, and discursive activity" (p. 136).

The above ideas follow the socio-cultural learning paradigm initiated by Vygotsky. He has a permanently increasing influence on learning theories, stating that learning is a social process, mediated by specific tools, in which symbols and especially human language plays a central role [15]. However, he did not investigated in more detail how the language and discourse are actually used in collaborative activities. It is the merit of Mikhail Bakhtin to propose a sound theory of how meaning is socially constructed.

Mikhail Mikhailovici Bakhtin extended Vygotsky's ideas in the direction of considering the role of language and discourse, with emphasis on speech and dialog. Bakhtin raises the idea of dialogism to a fundamental philosophical category, *dialogistics*. For example, Voloshinov (a member of Bakhtin's circle who, according to many opinions, signed a book written by his more famous friend because the former has an interdiction to publish during Stalin regime) said: "… *Any true understanding is dialogic in nature*. Understanding is to utterance as one line of dialogue is to the next" [14]. This is in consonance with Lotman's conception of text as a „thinking device" [17], determining that: "The semantic structure of an internally persuasive discourse is not *finite*, it is *open*; in each of the new contexts that dialogize it, this discourse is able to reveal ever new *ways to mean*" [1].

Any discourse may be seen as an intertwining of at least two threads belonging to dialoguing voices. Even if we consider an essay, a novel or even a scientific paper, discourse should be considered implying not only the voice of the author. The potential listener has an, at least, as important role. The author makes a thread of ideas, a narrative. Meanwhile, in parallel to it, he must take into account the potential flaws of his discourse; he must see it as an utterance that can be argued by the listener. In this idea, discourse is similar to dialog and to music polyphony (in fact, it should not be a surprise that different art genres like music, literature and conversation have similar features), where different voices interanimate.

Discursive voices weave sometimes in a polyphonic texture, feature which Mikhail Bakhtin admired so much in Dostoyevsky's novels. They are characterized by Bakhtin as "a plurality of independent and unmerged voices and consciousnesses" [2]. However, polyphony is not only a randomly overlay of voices. It has also musicality; it is in fact one of the most complex types of musical compositions, exemplified by the complex contrapuntal fugues of Johann Sebastian Bach. "When there is *more than one independent melodic line happening at the same time* in a piece of music, we say that the music is contrapuntal. The independent melodic lines are called counterpoint. The music that is made up of counterpoint can also be called polyphony, or one can say that the music is polyphonic or speak of the polyphonic texture of the music." [7].

In polyphonic music, the melodic, linear dimension is not disturbing the differential, vertical harmony. Moreover, for example, in Bach's fugues, the voices inter-animate each other. The main theme is introduced by a voice, reformulated by the others, even contradicted sometimes (e.g. inverted) but all the voices keep a vertical harmony in their diversity.

Starting from Bakhtin's ideas, we extend these ideas to collaborative learning. Therefore, we will further describe how polyphony may arise in collaborative learning and we will propose ways of supporting it in learning environments.

3   The Polyphony of Problem Solving Chats

3.1   Collaborative Learning in Virtual Math Teams

Computer and communication technologies offer now new possibilities for collaboration, by virtualizing classroom group interaction. New types of artifacts like hypertext, the World Wide Web, chats or forums of discussions, are changing the classical learning scenarios. In addition to classical sheets of paper or blackboards for drawing diagrams and writing formulas and sequences of problem solving steps, computer animations, simulations or even virtual participants in the dialog (artificial agents) may be used now for collaboration. It is extremely important to analyze the particularities of discourse in this new context. A good example is the fact that in chats we can much more easily use a multiple threaded discourse, similar to contrapuntus in classical music than in face-to-face conversations.

The (VMT) research program investigates the innovative use of online collaborative environments to support effective K-12 mathematics learning as part of the research and development activities of the Math Forum (mathforum.org) at Drexel University. VMT extends the Math Forum's "Problem of the Week (PoW)" service by bringing together groups of 3 to 5 students in grades 6th to 11th to collaborate online in discussing and solving non-routine mathematical problems. Currently, participants interact using a computer-supported collaborative learning environment, which combines quasi-synchronous text-based communication (e.g. chat) and a shared whiteboard among other interaction tools.

At the core of VMT research is the premise that primarily, group knowledge arises in discourse and is preserved in linguistic artefacts whose meaning is co-constructed within group processes [10]. Key issues addressed by the VMT include the design challenge of structuring the online collaborative experience in a meaningful and

engaging way, and the methodological challenge of finding appropriate methodological approaches to study the forms of collaboration and reasoning that take place.

3.2 Polyphonic Inter-animation in Chats

Let us consider the following problem:

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Three years ago, men made up two out of every three
internet users in America. Today the ratio of male to
female users is about 1 to 1. In that time the number
of American females using the internet has grown by
30,000,000, while the number of males who use the
internet has grown by 100%. By how much has the total
internet-user population increased in America in the
past three years? (A) 50,000,000 (B) 60,000,000 (C)
80,000,000 (D) 100,000,000 (E) 200,000,000
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This problem was one of an eleven problems set that were used for an experiment in which a group of students had to solve first individually and after that collaboratively, using chat. It was one of the two that were not solved individually by any students but it was solved collaboratively.

Let us now consider a chat excerpt that includes the main utterances that contributed to the finding of the solution (see figure 1).

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350 Mic how do we do this..              376 Cosi ok, so what's 11 – just guess on 10
351 Mic Without knowing the total number      ....
352 Mic of internet users?                386 Mic lets get back to 5
    ....                                  387 Cosi i think it's more than 60,00000
357 Dan it all comes from the 30000000    388 Mic way to complicate things
358 Mic did u get something for 10?       389 Cosi haha sorry
359 Dan we already know                   390 Mic life was good until you said that
360 Mic 30000000 is the number of increase in   391 Mic :(
    american females                      392 Cosi they cant get higher equally and
361 Mic and since the ratio of male to female    even out to a 1 to 1 ratio
362 Mic is 1 to 1                         393 Cosi oh, no wait, less than that
363 Mic thats all i got to give. Someone finish it   394 Cosi 50000000
364 Mic Haha                              395 Cosi yeah, it's that
365 Cosi haha you jackass                 396 Cosi im pretty sure
366 Mic Haha                              397 Mic Haha
367 Dan Hahaha                            398 Mic how?
368 Mic u all thought i was gonna figure it out   399 Cosi because the women pop had to grow
    didn't                                    more than the men in order to even out
369 Mic U                                 400 Cosi so the men cant be equal (30)
370 Mic huh?                              401 Mic oh wow...
371 Hal it would be 60,000,000            402 Mic i totally skipped the first sentencw e
372 Mic Hal                               403 Cosi therefore, the 50,000,000 is the only
373 Mic its all u                             workable answer
374 Mic See                               404 Dan very smart
375 Mic i helped                          405 Cosi Damn im good
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Fig. 1. An excerpt illustrating the collaborative solution construction

Discourse begins with Dan's idea of starting from the 30000000 number specified in the problem statement (line 357). It continues with Mic's problem solving buffoonery (lines 360-364, 366 and 368-370), remarked by Cosi (line 365) and Dan (line 367): Mic seems to start writing a reasoning but he only fakes, writing fragments

of the problem statement linked by a typical phrase "… and since … ". However, this fake discourse fragment seems to belong to a mathematics speech genre and, even being a pastiche, is continued by Hal which extrapolates the 1:1 ratio from the present (as stated in problem) to the whole 3 years and advances 60000000 as a solution (line 371).

Mic continues the buffoonery (lines 372-375). After about one minute, Cosi's (incorrect) utterance "i think it's more than 60,00000" appears as a critique or as an intuition of something wrong, of some kind of an "unsuccessful story". Nevertheless, after less than another minute, she realizes that her own supposition is wrong because the ratio cannot be 1:1 or bigger.

The collaborative discourse enabled Cosi to solve the problem. She didn't solve it in the first phase, when they had to solve it individually. However, when she listened to the discourse proposing a solution (correct in the case of Dan's beginning proposal, fake at Mic and wrong at Hal), she felt the need to put herself on a different position. Therefore, the discourse acted as a tool, as an artifact that enabled Cosi to find the correct answer.

Discourse in chat collaborative problem solving has an obvious sequential, longitudinal, time-driven structure in which the listeners are permanently situated and in which they emit their utterances in a threaded manner. In parallel with this linear threading dimension, the participants situate themselves meanwhile also on a critical, transversal (or differential) position. For example, in the excerpt considered in this section, Dan's theme was continued by Mic's buffoonery, continued itself by Hal and then contradicted by a first theme of Cosi that was eventually totally changed, in its opposite. We could say that the critique of Cosi appeared as a need to bring the harmony of a correct solution.

In this longitudinal-transversal space, voices behave in an unity-difference manner. This phenomenon is not specific solely to chats. It appears also to polyphonic music: "The deconstructivist attack (…) – according to which only the difference between difference and unity *as an emphatic difference* (and not as a return to unity) can act as the basis of a differential theory (which dialectic merely claims to be) – is the methodical point of departure for the distinction between polyphony and non-polyphony." [6].

The unity and difference trends take different shapes in chat problem solving. We can include in the unity category cumulative talk [8] or collaborative utterances [9], repetitions [12], socialization or jokes. For example, many times participants in chats feel the need to joke, probably in the need to establish a closer relation with other participants, in order to establish a group flow state [3]. In fact, in all the chats we examined there is a preliminary socialization phase, inter-animation appearing not immediately after the beginning of chats.

4   Groupware for Polyphonic Inter-animation

Difference making has a crucial role in chats for collaborative learning, role which may be best understood from a polyphonic, musical perspective. The possibility of contemplating (listening), from a critical position, the ideas (melodies) of other peoples and entering into an argumentation (polyphony of voices), enhance problem

solving and enables learning through a trial-error process. Such processes appear also in individual problem solving (we can say that thinking is also including multiple inner voices) but the presence of multiple participants enhance both the possibility of developing multiple threads and, meanwhile, of differences identification. The inter-animation of the multiple perspectives of the participants, the opposition as result of contemplation and the presence of a third opinion in case of conflict, and sometimes the synthesis it brings are a better asset to success than a multi-voiced discourse performed by an individual (as inner thinking), that is inherently much less critique.

Evidence that participants permanently keep a differential position is also provided by the statistics of personal pronouns usage in chat sessions. For example, in a corpus of chats recorded in May 2005, "I" was used 727 times, much more than the usage of "we", with 472 occurrences. First person "me" was used 84 times comparing to "us", used only 34 times. However, the second person addressing is very well represented by 947 uses of "you".
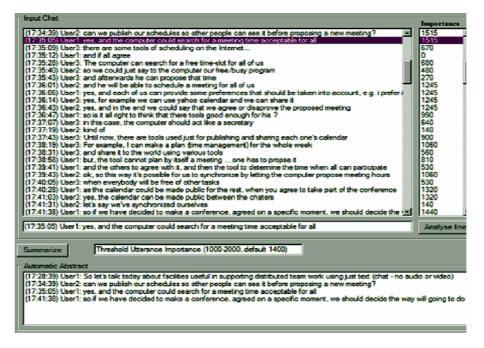

Fig. 2. A summarization module that offers an abstraction of the flow of main ideas

A natural consequence of the theoretical considerations discussed above is the need for a software support for small groups that facilitates polyphonic development. Such a groupware, named "POLYPHONY", is now under development. The system is built around a chat system, which has some additional modules, not present in usual instant messaging. These modules offer abstractions of the ongoing chat, in the idea of making clear the flow of ideas and the other "voices" (the melody) and, the most important, to induce polyphonic, differential ideas .

In figure 2, a snapshot of one of the first implemented modules, the summarizer, is illustrated. This module builds a summary using natural language processing and heuristics, It automatically assigns an importance score to each utterance, and selects the most important utterances. Summarization is important in chats because knowing what came before, starting from clear summaries would help people to respond, to carry on the "melody" and to contribute to the polyphony with a personal, differential voice.

In addition to the summarization module, other facilities for chats, based on natural language processing are developed in POLYPHONY. They abstract and display facts about each participant, for example, the emotional state, the degree of relevance of the utterances of each participant. A module for speech acts identification has been already implemented [13]. The goals aimed by these modules are to induce self-reflection and images about the others, to facilitate inter-animation, and finally to encourage multiple voices to enter into a polyphonic framework.

5   Conclusions

Discourse in chats implies an inter-animation of multiple voices along two dimensions, the sequential, utterance threading and the transversal, differential one. These two dimensions correspond to a unity-difference (or centrifugal-centripetal, [1]) basic feature of polyphony. The unity directed dimension is achieved at diverse discourse levels by repetitions, collaborative utterances, socializing and negotiation discourse segments.

The second, differential dimension could be better understood if we consider discourse as an artifact that, taking into account that every participant in collaborative activities has a distinct personality, is a source of a critical, differential attitude. Even if individual, inner discourse may be multi-voiced, difference and critique are empowered in collaborative contexts, in a community of different personalities.

A consequence of the sequential-differential perspective for the design of CSCL environments is that they must facilitate inter-animation not only on the longitudinal dimension, through threading but also the transversal, differential, critical dimension. Tools that may enter in this category should be able to provide abstractions or summarizations of previous discourse, in order to facilitate differential position taking. They should also allow the participants to emphasize the different proposed themes and to relate them in threads, polyphonically.

Wegerif also advocates the use of a dialogic framework for teaching thinking skills by inter-animation: "meaning-making requires the inter-animation of more than one perspective" [16]. He proposes also that questions like "'what do you think?' and 'why do you think that ?' in the right place can have a profound effect on learning" [16]. However, he did not remark the polyphonic feature of inter-animation.

Acknowledgements

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