Analysing collaborative problem solving activities with Synergo

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Abstract

This paper deals with the analysis of Computer-Supported Collaborative Learning activities. A pilot study conducted on adult students of the Hellenic Open University, is presented in the Introduction. Next we deal with the definition of Collaborative Learning, as well as, Computer-Supported Collaborative Learning (CSCL); we examine how CSCL works and what are the special cognitive mechanisms associated with it. We then present a set of the most commonly used criteria for evaluating the quality of CSCL. Next, a method for analysing collaborative activities is demonstrated. As a CSCL tool we use Synergo, a freeware research tool developed by the HCI group of the Univ. of Patras. Synergo is used for supporting the collaboration as well as for recording and analysing synchronous collaborative activities. A typology based on the higher cognitive mechanisms encountered in collaboration sessions is introduced; based on this typology, we can analyse collaboration sessions qualitatively; then using statistics (which are automatically produced by Synergo) we can also analyse collaboration sessions quantitatively.

1. Introduction

Synchronous computer-supported interaction and collaboration among distance education students is usually a very difficult endeavour for a number of technical and organizational reasons. It usually requires high bandwidth for sharing the screen of partners and high speed connections if teleconference services are used, while support for these activities necessitates a complex infrastructure by the distance learning institution in order to support the students in a timely manner (Xenos et al., 2005).

An interesting alternative to synchronous computer-supported collaboration is the use of low-bandwidth, text-based communication facilities and shared windows, implemented over peer-to-peer interaction protocols; it has been demonstrated that it is feasible to implement and use with the current, commonly available computing infrastructure. The development of an effective peer-to-peer facility for Open and Distance Learning (ODL) involves tackling serious technical, educational and social challenges, as discussed by Xenos et al. (2004) and Haake et al. (2003) who conducted similar experiments.

In this paper, we propose and demonstrate the use of a specific framework and a process for assessing both qualitatively and quantitatively the quality of collaboration. We also examine the implications of this work for Open and Distance Learning environments. At least three categories of people are interested in evaluating CSCL activities, each one for a different purpose:

i) The instructor, for assessing the students (either as a group or separately);
ii) The CSCL researcher, for studying the special cognitive mechanisms and rating the quality of the collaboration;

iii) CSCL tool makers and policy makers, for testing or comparing tools.

2. Defining collaborative learning

Collaborative Learning is a coordinated, synchronous and interactive activity of joint problem solving, where partners attempt to construct and maintain a shared conception of a problem in order to arrive at a joint solution; learning is expected to occur as a result and/or a side-effect of problem solving. This learning is measured by the elicitation of new knowledge or/and by the improvement of problem solving skills of the partners. Dillenbourg has defined three prerequisites for characterising an interaction as collaborative (Dillenbourg, 1999): interactivity, synchronicity and ‘negotiability’ (i.e., the ability to negotiate). When these prerequisites are met, the interaction among learners is expected to trigger higher cognitive mechanisms. Hence a general concern is to investigate the factors which affect the appearance of these mechanisms. These factors are (Dillenbourg, 1999):

- The initial conditions.
- The ‘collaboration contract’ (assignment of roles).
- The productive interactions.
- The monitoring and regulation of interactions and the feedback to all parties engaged (students, instructors, facilitators, technicians and course administrators).
- The stimulation and training of the users.

In the context of this study, we consider only peer-to-peer collaboration, because negotiability is most likely to appear in non-hierarchical relations (Dillenbourg, 1999). A peer-to-peer collaboration is decentralised, hence it promotes social interaction, fairness and equality and inspires democratic sensitivities (Matsaguras, 2004).

During the interaction, knowledge and skills of the partners are being recalled, tested, compared, contrasted, combined and completed. In this way, it becomes clear what each partner knows, what he/she does not know, how confident he/she is about his knowledge, how well he/she can use, explain or defend his/her knowledge, as well as, what he/she does not know but has to learn; partners’ knowledge and skills are upgraded, new knowledge is produced and mutual teaching and learning is promoted. Through the comparison, contrast and confronting with other users, each partner becomes aware of other, different viewpoints and perspectives. The new knowledge includes the commonly built solution, but also, inexpressible things such as the improvement of knowledge or skills or changes in attitudes. The most important special cognitive mechanisms appearing in collaborative learning are:

- Grounding, i.e., the creation of a common background necessary for the collaboration (Harrer et al., 2006).
- Internalisation, i.e., the transfer of knowledge from social to personal level (reasoning) (Karagiannidis, 2002).
- Externalisation, i.e., the transfer of knowledge from personal to social level (Karagiannidis, 2002).
• Explanation by peer learners (Dillenbourg, 1999; Xenos et al., 2005). This is a principal cognitive mechanism of collaborative learning.

• Mutual modelling, i.e., the models each partner creates for the peer learners. Questions concerning the sufficiency of these models; which processes act for the construction of these models, most important of all being, how these processes affect learning (Dillenbourg, 1999).

• Conflict creation and resolution.

• Appropriation, i.e., familiarization with new knowledge or skill.

• Aggregation, i.e., the accumulation of contextual pieces of knowledge.

• Categorisation, i.e., the classification of concepts or objects.

• Revision, i.e., rethinking and revising a notion or a concept.

• Induction, i.e., the process of deriving general principles from particular facts or instances.

According to the theory of the Collaborative Movement (Matsaguras, 2004; Karagiannidis, 2002), the team should receive the same grade; in this way, a good student will be eager to make a weak student learn, because their grades are common. This is an important motivation for collaborative learning to become effective.

The theoretical field of collaborative learning examines items such as: i) criteria for defining the situation (symmetry, division of labour, ways for matching partners and modelling groups etc. (Kitagaki et al., 2007), ii) the design of appropriate activities and settings for various courses (Dillenbourg & Traum, 1999, as cited in Avouris et al., 2003), iii) the interactions among the users, the cognitive processes (grounding, mutual modelling, knowledge elicitation, internalisation, externalisation) and other effects such as the evolution of extra cognition mechanisms (as described above), the experience and the development of collaborative and social skills for better future results.

3. Computer-supported collaborative learning

Computer-Supported Collaborative Learning (CSCL) is collaborative learning aided by computer and ICT technology. The purpose of CSCL is to scaffold students in learning together effectively, through the use of ICT. CSCL supports and facilitates group processes and group dynamics in ways that are not achievable by face-to-face communication. CSCL is evidently not designed to replace face-to-face communication, but to be used in circumstances where the former is impossible, or very expensive. CSCL is often used in combination with face-to-face communication (‘blended’ learning), because it has been shown to produce better results (Pemberton et al., 2002). This type of learning is typically tailored to small groups of learners (i.e., 2-4 persons) working across networked PCs (or even at the same workstation, a case we shall not consider here). In general, CSCL systems can support the process in three ways: first, by communicating ideas and information, sharing information and documents and creating a solution in a specific format using embedded tools (e.g. chat tools, shared blackboards and documents and drawing tools); second, by providing feedback to learners on problem-solving activities and by enabling instructors to monitor learners’ progress; and third, by recording the session for post-processing by researchers and teachers.
CSCL is much more ambitious than previous approaches of ICT-support in education, such as CBT, WBT or TBT (Pantano, 2005), because it targets the acquisition of higher-order cognitive abilities, knowledge acquisition and the improvement of the ability to utilise CSCL tools to a larger extent. This demands the analysis of processes (rather than just products) within complex and authentic contexts. It is therefore more difficult to evaluate the effectiveness and efficiency of CSCL activities. Nonetheless, all actors involved in CSCL processes – from policy makers to everyday users – need to have evidence of whether, how and when, the expected cognitive mechanisms take place. Significant effort is required to provide systematic evaluation of: i) new collaborative technology-based learning systems (Dimitracopoulou, 2005); ii) innovative projects which will trigger the extra cognitive mechanisms (Dillenbourg, 1999), iii) the specific experiences deriving from an action/research framework, in order to create improved systems and projects (Wikipedia: CSCL, 2006).

The above criteria can be assessed by humans, by studying the collaborative learning session a posteriori. CSCL systems may offer valuable help in this task, first by recording and second by analysing the recorded data, which consist of the common result and the dialogues between partners. Obviously, the quality of this support determines the quality and usefulness of CSCL systems. The current educational needs push towards automatic evaluation of collaborative learning sessions, and therefore, it is important to define criteria that will facilitate automatic assessment (Andreatos, 2007).

4. Analysis of collaborative problem solving sessions

A number of approaches for the analysis of collaborative activities in different mediums and environments has been reported in the bibliography. Some of these approaches focus on problem solving strategies or on plan recognition; others, on the evaluation of partners’ involvement or on the process of mutual understanding and the learning effects (Avouris et al., 2003). The analysis objective may be to evaluate the situation or the jointly produced solution or the learning process or even the tools used.

Evaluation of these problem-solving situations is usually done through discourse analysis, task analysis, communication and interaction analysis, analysis based on the produced results or even a combination of methods (Avouris et al., 2003).

The results of collaborative learning are often assessed by evaluating individual task performance; however, it has been objected that a more valid assessment would be to measure group performance (Dillenbourg, 1999; Karagiannidis, 2002; Matsaguras, 2004).

How can ‘good’ collaboration be defined? First, good collaboration should produce a good outcome in terms of both quantity and quality. Hence, group performance is related to the quality and quantity of the produced result and the time it required. Second, good collaborative learning should also trigger the specific cognitive mechanisms encountered in collaboration; thus, another set of criteria should be used to assess mutual assistance, support, encouragement, explanation, negotiation, argumentation, etc., as well as, the ability to collaborate (Dillenbourg, 1999). Third, productive collaboration sessions develop the partners’ cognitive skills. If the above conditions are met, they will result in high quality group results. The latter is related to the produced cognition, partners’ improvements (Avouris et al., 2003), development of the ability to collaborate, etc.
A first intuitive criterion is that a collaborative activity should be highly interactive. The degree of interactivity among peers is not defined by the frequency of interactions, but by the extent to which these interactions influence the peers’ cognitive processes. The degree of interweaving between reasoning and interaction is difficult to define operationally. It is difficult for a CSCL system to recognise the extent to which these interactions influence the peers’ cognitive processes.

However, this extent is somehow related to the quality of the collaborative learning session, in the sense that few interactions imply a poor quality collaboration. On the other hand, it is easy for a CSCL system to measure the frequency of interactions. Hence, this is a good criterion to use. A similar index defined in (Avouris et al., 2004) is the intensity of group activity (actions/min) or density of activity.

Since we consider real-time or synchronous CSCL, the response delay is an important QOS factor of the supporting ICT technology; however, this factor also affects the quality of the CSCL session, since if the delays are long, the users lose the interactivity feeling. But there is another important reason, closely related to the partners’ behaviour: user consistency; it has been observed by the author, when studying CSCL sessions in playback mode, that one of the two collaborating parties apparently left his/her place for several minutes. This phenomenon shows lack of consistency and downgrades the session; hence, long delays due to users’ lack of attention comprise a quality index. This is also a rather easy index to measure automatically.

Another feature of good collaborative interactions is that they are negotiable (‘negotiability’, Dillenbourg, 1999). A main difference between peer (student-student) and hierarchical (e.g., teacher-student) collaborative interactions is that one partner will not impose his/her view on the sole basis of his/her authority, but will - to some extent - argue for his/her standpoint, justify, negotiate, attempt to convince. It is exactly these actions which trigger the special cognitive mechanisms appearing in social or collaborative learning. It will be rather difficult for a system to measure this index, unless it can interpret the dialogues using artificial intelligence or pattern recognition techniques.

Another index, defined in (Xenos et al., 2004), is called balance of group activity (B). B takes high values when the members of the group have acted in the same degree (equal number of flowchart building actions and chat messages), while low B values indicates unbalanced group participation. It is used for pairs of collaborators. When the groups have more than two members, it is more convenient to measure the contribution of the partners. In (Avouris et al., 2004), the authors have measured the contribution of each user at the operations level, as well as, at the actions level. For a detailed taxonomy and discussion on the most important criteria used for evaluating the quality of CSCL see (Andreatos, 2007).

5. Application of the proposed analysis framework

In this section an indicative example of application of the proposed framework is presented. A dyad of undergraduate computer science adult students of the Hellenic Open University (HOU) used Synergo for negotiating and building a flowchart of a given algorithm. The HOU is the official higher-education ODL institution of Greece. Synergo is a freeware research tool developed by the HCI group of the Univ. of Patras for the support and analysis of CSCL sessions through low-bandwidth Internet connections. It has been
used by a variety of higher-education institutions, both conventional and ODL, as well as, in other levels of formal education, such as high school (Kirschner et al., 2005; Voyiatzaki & Avouris, 2005). For more information the reader is referred to http://hci.ece.upatras.gr/synergo. Through Synergo, the ODL students of HOU could interact in pairs in a synchronous way. An analysis of the history of their interaction through server logs has revealed interesting patterns in relation to balance of activity between pair members, peer learning and support, while study of the chat dialogues provided us with an insight on the social implications of this approach for the isolated students of the HOU.

The purpose of this study is to show how someone can use the embedded tools of Synergo in order to assess a collaboration session. A CSCL assessment method, based on discursion (chat) analysis, as well as, quantitative analysis (statistics) produced by Synergo, will be demonstrated. In order for somebody to assess a session, he/she first has to make the learners use the Synergo for their collaboration. The data used in this analysis were recorded during the pilot study performed with the ODL students of the HOU. Synergo registers each user’s actions made in the common working space, as well as, their dialogue. Then the researcher has to go through the dialogue and do the discourse analysis using a typology of the actions taking place. A proposed typology including both collaborative learning mechanisms as well as auxiliary ones, able to cover most observed phenomena, is shown in Table 1. There are four types of characterisations:

- CLM = Collaborative Learning Mechanism
- Social = Social dialogue
- Process = Questions or comments about the process or the tool
- Other = All the rest

<table>
<thead>
<tr>
<th>Characterisation</th>
<th>Meaning - Comments</th>
<th>Category</th>
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<tr>
<td>Social</td>
<td>Social dialogue</td>
<td>Social</td>
</tr>
<tr>
<td>Grounding</td>
<td>Creating a common sense / ground</td>
<td>CLM</td>
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<td>Conflict</td>
<td>Conflict, objection</td>
<td>CLM</td>
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<td>What’s your opinion?</td>
<td>CLM</td>
</tr>
<tr>
<td>Process</td>
<td>Questions or comments about the process or the tool</td>
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<tr>
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<td>Question</td>
<td>CLM</td>
</tr>
<tr>
<td>Explanation/answer</td>
<td>Asking for / giving explanation</td>
<td>CLM</td>
</tr>
<tr>
<td>Agreement</td>
<td>Agreement</td>
<td>CLM</td>
</tr>
<tr>
<td>Intention</td>
<td>I did/am doing/shall do this…</td>
<td>Other</td>
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<td>Turn or token pass</td>
<td>Turn or token passing</td>
<td>Other</td>
</tr>
<tr>
<td>Revision/correction</td>
<td>Revision/correction or shelf- correction</td>
<td>CLM</td>
</tr>
</tbody>
</table>

Table 1: The typology of our case study

The above typology is derived from the list of section 3 after merging some mechanisms for simplification and after adding the most important auxiliary mechanisms such as ‘social’.

Let us next examine a representative session. Figure 1 shows the appearance and intensity of the collaborative learning activities of the above typology as a function of time. Notice that the session lasted for five periods (see Figure 3), totaling 452 minutes.
Now let us examine some statistics of the activity of each actor (user), such as actions and messages produced, as well as, starting and ending time of each subsession. In the figure below we can see that the “red” [“blue”] actor has produced the 30% [69%] of the actions and has sent the 42% [57%] of the messages respectively.
The statistics show that the session is asymmetric (in favour of the blue actor). This may produce the appearance of collaborative learning mechanisms, provided that the other prerequisites of section 2 are met, such as the stimulation of the users.

We may also view each activity of the typology per actor; for example, the projection of “Question” activity per actor is shown by the diagram of Figure 4. It is obvious that the red actor asks most of the questions. Hence, it is possible that he/she is the weakest and the one that is being taught by the blue actor.

In order to investigate our assumption further, let us also project the “explanation” mechanism per actor. The result is shown in Figure 5 below. Now it is evident that the blue actor is teaching the red one.
Figure 5: Projection of “Explanation” indicates that the blue actor is teaching the red one

A close look at the statistics of all activities verifies our assumption (Figure 6).

Figure 6: Concentrated statistics per actor

So far we have shown how someone can rate a session just by assessing the actions and the statistics; but there is also another product, the joint solution. Figure 7 shows a snapshot of the solution of the particular group. The most important criteria here are: the complexity, the size and of course the correctness of the produced solution. Another parameter is the time taken (Andreatos, 2007).

Figure 7: Part of the solution produced by the group (a flowchart)
6. Conclusion

In this paper we have presented some criteria for rating CSCL sessions; A typology based on the higher cognitive mechanisms encountered in collaboration sessions, along with additional auxiliary factors, is introduced; we have also demonstrated a method for analysing computer-supported collaborative learning (CSCL) sessions using Synergo, a freeware research tool developed by the HCI group of the Univ. of Patras. Based on this typology and the proposed method, we can analyse collaboration sessions in depth, both qualitatively and quantitatively, using discourse analysis, the statistics produced automatically by Synergo, and in addition, by assessing the jointly produced solution.

Since Synergo works with usual desktop computing equipment and low bandwidth connections, it may be easily used in distance learning environments.

In order for a researcher to compare and assess collaborative sessions, he/she has to take into account the following:
1. The appearance of higher cognitive mechanisms, found in CSCL environments;
2. The intensity of these mechanisms;
3. The duration of the session;
4. The quality (correctness, completeness, size, etc.) of the jointly produced solution.

The implications of this work for open and distance learning environments is important for the following reasons:

Firstly, it shows that even with low-cost computing equipment and low-bandwidth Internet connections, it is possible to effectively use CSCL approaches in ODL environments and generate conditions in which rich collaborative interactions may be observed.

Secondly, it shows that embedding tools supporting the analysis of CSCL sessions greatly facilitates the analysis task and aids the instructor to assess students quickly and effectively and put in evidence interesting patterns of collaborative behavior.

Finally, it implies that one of the next trends in the further evolution of CSCL tools is the support of automatic assessment. This will greatly support the tremendous demand for distance learning (Burns, 2006).

7. References


