A Learning Interaction Memory using Contextual Information

S. A. Siebra[1, 2], A. C. Salgado[1], P. A. Tedesco[1] and P. Brézillon[3]

[1] Centro de Informática – UFPE, Caixa Postal 7851, Cidade Universitária,
CEP 50732-970 Recife – PE - Brasil
{sas, acs, pcart}@cin.ufpe.br

[2]Faculdade Integrada do Recife (FIR) - Av. Abdias de Carvalho, 1678 – Madalena
CEP: 50720-635 Recife – PE – Brasil

[3] LIP6, University Paris 6, 8 rue du Capitaine Scott, 75015 Paris, France
Patrick.Brezillon@lip6.fr

Abstract: Some of the main weaknesses of the current Computer Supported Collaborative Learning Environments (CSCLE) include using inadequate persistence mechanisms to keep track of the discussions. Moreover, CSCLE also neglect the importance of contextual information to provide the correct cues to interpret sentences. In this light, this paper proposes the creation of a Learning Interaction Memory (LIM) to store the learning interactions occurred in CSCLE. It will be modelled in a multidimensional structure so that interactions can be viewed from different perspectives and could be presented selectively, according to users' needs. The information contained in the LIM can be dynamically adapted to the current situation. This is done to provide better just-in-time feedback for students and teachers.

Keywords: CSCLE, Context, Learning Interaction Memory, Multidimensional Modelling.

1. Introduction

Collaborative Learning is a strategy in which small teams, each with students of different levels of ability, use a variety of learning activities to improve their understanding of a subject. Each member of a team is responsible not only for learning what is taught but also for helping teammates learn, thus creating an atmosphere of achievement and collaboration (Dillenbourg 1999).

As Vygotsky (1978) pointed out, *"in a collaborative scenario, students interchange their ideas for coordinating when they work for reaching common goals. When dilemmas arise, the discussion process involves them in learning"*. When learners work in groups they reflect upon their ideas (and those of their colleagues), explain their opinions, consider and discuss those of others, and as a result, they learn. In this way, each learner acquires individual knowledge from the collaborative interaction. In fact, interacting with our peers gives us a forum to discuss our ideas, to take a stand on our views, to reflect about and to elaborate on them. Consequently, the capture of the context related to each interaction (to better characterize the discussion), the storage and subsequent analysis of collaborative interactions is fundamental for the evaluation of the learning and teaching processes, and for the provision of support to teachers and students.

In this state of affairs, a basic requirement to support this analysis of collaborative interactions is to provide an adequate persistence mechanism to store the interactions. Without persistence, interaction is ephemeral and cannot be shared afterwards with people who were not involved at the time it occurred (Borges and Pino 2000). With an adequate persistence mean, the interactions will constitute what we call Learning Interaction Memory (LIM), which make past information about the interactions readily and selectively available when required.

The LIM should be modelled in such way that stored interactions can be viewed from different perspectives (e.g. information can be easily crossed or filtered) and could be presented selectively, according to users' needs (i.e. depending on their context, users could access different information). Indeed, the LIM model has to facilitate the interaction analysis as means to provide access to the information and construction and generation of customized reports to teachers and students. Designing data models to support this analysis requires a different approach called multidimensional modelling (Kimball et al. 1998) which organises and summarises large amounts of data so it can be evaluated quickly using on-line analysis and graphical tools.

Other point to consider when constructing a complete model to store the learning interactions is to discover and register the context where each interaction occurred. Context is a collection of relevant conditions and surrounding influences that make a situation unique and comprehensive (Brézillon 1999). Thus, to fully understand many actions or events, it is necessary to access relevant contextual information (Brézillon 1999). For example, understanding why a student is finding it difficult to complete a task or to answer a question depends on what his/her knowledge level is, whether his/her workgroup is good or bad, what is the difficulty level of the task or question. In the interaction analysis the more details the system can provide about user's interactions, the better support it can give to teachers and students in the reflection process and to complete their activities based on historical informations.

Through the analysis of the contextualized information stored in the LIM, it will be possible to characterize interactions for a better understanding of the collaborative learning process and to give support to teachers and students in the reflection process and to complete their activities based in historical information.

In this light, this paper proposes the creation of this LIM to store the learning interactions occurred in CSCLE. This LIM will be modelled in a multidimensional structure (implemented using a data warehouse (Inmon 1996)) and analysed via On-Line Analytical Processing (OLAP) (Kimball et al. 1998). As result, the interactions can be explored in different dimensions and levels of detail, and specific feedback can be provided to both teachers and students (an advantage over common log files). The LIM includes contextual information in its model to enrich the stored knowledge. This paper also shows some uses of the contextual information in the LIM.

The remainder of this document is structured as follows: Section 2 presents the reasons to create the LIM and the way to model it. Section 3 discusses identifying of context in CSCLE, context levels and the dynamic dimension of the context. Section 4 presents our proposal for the LIM. Section 5 describes the reasons for contextualizing the information in the LIM. Finally, section 6 presents our conclusions and suggestions for further work.

2. The Learning Interaction Memory (LIM)

In Computer Supported Collaborative Learning Environments (CSCLE), learning is promoted by peer interaction (either between students or students and more experienced collaborator). Thus, learning takes place through interactions and what is learned can be used when the learner tries to solve a similar problem independently.

Nowadays, there are several proposals of CSCLE (e.g. (Eleuterio, Barthès and Bortolozzi 2002; Fuks, Gerosa and Lucena 2003)) that provide a wide variety of interaction mechanisms such as forums, blackboards, chats, email and videoconferences. However, one of the main problems with the use of interaction mechanisms in CSCLE is the frequently inappropriate match between the interaction mechanism available and the persistency required (Borges and Pino 2000). Group members may find it difficult to recall and justify their decisions when using interaction mechanisms with low or no persistence. Important information may be lost or need to be reproduced several times in order to achieve the desirable level of common knowledge (Borges and Pino 2000).

Although many CSCLE (Constantino-González and Suthers 2001; Eleuterio, Barthès and Bortolozzi 2002; Fuks, Gerosa and Lucena 2003; Soller, Wiebe and Lesgold 2002) provide a way to store previously sent or received messages (e.g. by using sequential log files, normally organized in temporal order), what it is really needed is a common space to store the information in order to comfortably refer to it and add new contributions. This common space will be the LIM. Thus, the LIM is the record of the complete group interaction process. It is a common organized memory that corresponds to the discussion database. It is the result of a process of accumulating data generated by group members during discussions in synchronous and asynchronous tools.

This dialogue history is viewed as an important resource in collaborative dialogue since it provides a common reference to previous activity (unlike most spoken dialogues) that may encourage reflection and more effective collaboration (Collins and Brown 1988). This kind of information would help teachers to track students' evolution process. Besides, the analysis of the group memory would enable users to reuse historical information to solve future problems, reminding participants of previous ideas (encouraging elaboration on them) and possibly serving as an agenda for further work.

2.1 LIM´s Modelling

For the purpose of facilitating the execution of analytical analysis, the LIM will be modelled in a multidimensional structure (Kimball et al. 1998), implemented using a data warehouse (Inmon 1996). Indeed, using multidimensional modelling the LIM's information can be viewed from different perspectives (e.g. information can be easily crossed or filtered) and could be presented selectively, according to users' needs.

Besides, if the LIM is modelled in a multidimensional way, analytical queries can be applied in it using OLAP technology (Kimball et al. 1998). OLAP queries can be used as much by the users as by the CSCLE to support students and teachers. In this way, it will be possible to answer questions such as: which kind of knowledge has been shared within the environment? Which members are participating more actively? Which are the most frequent problems that have been found during the learning processes via the environment? Which topics are being more difficult to students? Which students are not motivated? Which students have already faced the problem Y, considering the context X?

The LIM considers contextual elements (such as access time, access local, user level and role that users are playing during the interaction) in its modeling to adapt dynamically its information to the concrete situation based in past facts. This is important because making explicit and using context in collaborative learning is a way to improve the conditions in which each student participates in the group take into account his/her specificity.

Thus, to build the LIM's multidimensional structure, we had to proceed with an analysis of which contextual elements will be considered relevant in a CSCLE, as a means to characterize each interaction in particular. This is because the knowledge about the contextual elements related to the interactions is very relevant to a better understanding of the collaboration.

3. Identifying Context Information in CSCLE

Learning always takes place in dynamic environments, characterised by a collection of relevant conditions and surrounding influences that make a situation unique and comprehensive called context (Brézillon 1999). Each attribute of the context (e.g. location, user level, user name, task name) is called contextual information. Situations with apparently the same context can differ from each other in some aspect. This diversity and unpredictability of the aspects are factors that influence the identification and representation of contextual information related to group interactions (Borges, Meire and Pino 2003).

The issue of context has been an important area of research in recent years, although, there is no consensus yet about what context really means, what its implications are and how it can be generalised (Borges et al. 2004). Several domains (Brézillon 1999; Brézillon 2002; Dey, Salber and Abowd 2001) have already elaborated their own working definition of context and Bazirre, Brézillon and Tijus (2003) show that all the definitions found on the web can be assembled around six questions:

- Who? - Information about people
- When? - Information about Time and Historical Information
- Where? - Information about environment
- How? - Information about user's action plans
- What? - Information about users activities in progress
- Why? - Information about the reasons related to the user actions

Until now, most researchers (Bouquet et al. 2003; Byun and Cheverst 2001; Dourish and Bellotti 1992; Pasquier, Brézillon and Pomerol 1999; Young 2003) are concerned with one context, very few by different contexts at different granularity as in a collaborative community (Borges et al. 2004; Brézillon et al. 2004). In CSCLE, one must deal with several contexts at different granularity, such as the context of the group (why this group is constituted), the individual contexts of the members (e.g. their technical background) and the context of the project (e.g. the artefact to be built) (Brézillon et al. 2004).

3.1 Context Granularity

To model the LIM, we need to identify different types of contexts at different levels, trying to reach all the elements related to CSCLE and trying to answer the questions mentioned in the last section that summarise the definition of context (Bazirre, Brézillon and Tijus 2003). These contexts have not the same granularity (Brézillon 2003b) and make difficult a simple representation of the contextual cues in the LIM's model. Thus, based in the generic conceptual framework for analysing the use of context in groupware proposed by Rosa, Borges and Santoro (2003), we have organised context in five different categories, resumed in Table 1 and described in the following. This organization will be useful to map out the information that it must be captured to qualify each interaction in the LIM's model.

Table 1. Conceptual Framework for Learning Context

Information Type	**Associated Contexts**	**Some Examples of Contextual Elements**
Scheduled Tasks	Task	• Name • Description • Activities • Constraints
Group Members	Group	• Name • Members • Abilities • Roles
	Individual	• Name • Abilities • Knowledge Level • Previous Experience
Relationship between People and Tasks	Interaction	• Related Task • Messages Exchanged (including: author, addressee, date, time, discussion subject, message subject, abstraction used, related message)
	Planning	• Course Planning • Pedagogical Strategies
Setting	Environment	• Connection quality • Organizational Structure
Completed Tasks	Historical	• Contextual Elements used to carry out the task

1. *Information about scheduled tasks (Task Context)* - in CSCLE several tasks are possible (for example, to study a lesson, do exercises, do tests, discuss about a subject, share files, or draw something). It is necessary to keep information about these tasks in the LIM in order to identify what an individual or group is doing;
2. *Information about people and groups (Individual and Group Context)* - The knowledge about the characteristics of individuals and the group as a whole is a resource that can be used by teachers to encourage interaction and collaboration (Pinheiro, Lima and Borges 2003). This category includes:
   - *Group Context* – it is important have in the LIM some knowledge about the group to understand the evolution of the individuals in CSCLE;
   - *Individual Context* - The elements in this category help to characterise the user, as well as let other users better understand her/his doubts, difficulties and actions in the CSCLE. Some of the contextual information in this category can be obtained from the user's model (generally present in the CSCLE).
3. *Information about the relationship between people and tasks (Interaction and Planning Context)* - in CSCLE it is important to know who is doing what, i.e. what the task's execution plan and what is being discussed into the environment. Indeed the interaction analysis is important for discovering more about the student (e.g. her/his difficulties or doubts). This type of information is represented in two kinds of context:
   - *Interaction Context* that have information about the interactions occurred into the environment and about users' behavior when interacting;
   - *Planning Context* – It consists of information about the course execution plan (generally present in the pedagogical model of CSCLE). The Planning Context could be implemented using the idea of proceduralised context and contextual graphs presented in (Brézillon 2003a). The interest of contextual

graphs is to do not limit the representation of a problem solving to the solution identified by the teacher, but to account for all the variants of the learners that lead also to the same solution. This is the difference between the official plan (made by the teacher) and the practices developed by students when they "contextualize" the plan in order to tailor the problem solving to the context at hand. In learning, an interesting side-effect of this approach is to identify clearly when a learner goes towards a dead-end way before the learner be in it;

4. *Information about the environment where the interaction takes place (Environment Context*) - it consists of information that characterises the environment where the interaction takes place and influences task completion;
5. *Information about tasks and activities already concluded (History Context)* - the information in this category tries to characterise the interactions that have already occurred. Its goal is to provide background information about the experiences learned either from the same group or from similar tasks performed by other groups. In this category, all contextual information generated is stored for future retrieval. This is exactly the goal of the Learning Interaction Memory (LIM). It is the repository of the "group memory" (including contextual elements). In this way a situation can be reconstructed with the context in which it occurred. Since the LIM provides historical context, students and/or teachers can access past incidents. This can also be used to share the latest news, seek advice and compare notes. Thus, it might be a source of reflection for both the teacher and the student.

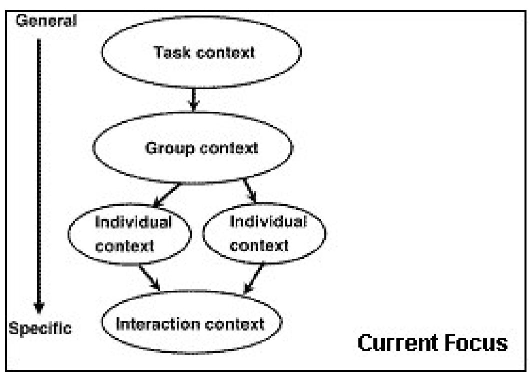

Fig. 1. Context Levels in a current focus

All these categories of context are at different levels of generality. For example, the task's context is more general than the group's context because it is the context that everybody knows about what needs to be accomplished within the CSCLE. The context of group contains more general contextual information than the context of each individual (see Fig. 1). This does not imply that a context at one level is a subpart of a more general context (Brézillon 2003b). Indeed, the context of any situation in a CSCLE can be understood at different levels depending on the current focus (see Fig. 1). For instance, while executing a task (e.g. develop a software program), the context of a student (individual context) can be explained in terms of the perspective of the group. The context determines that the student A is, for example, building the module X that will have to be integrated to the code being constructed by the students B and C.

3.2 The Dynamic Dimension of the Context

Everybody uses a large amount of knowledge (which may vary from one person to another) to picture a situation. Pomerol and Brézillon (1999) proposed a classification for differentiating the contextual elements related to task performing. The set of contextual elements that are relevant to the task execution and can be mobilized to understand a given situated problem is called contextual knowledge. The knowledge that is shared by all people involved but is not used to perform a task is called external knowledge. During the execution of a task, a portion of the contextual knowledge is actually employed. This portion is called proceduralised context. The proceduralised context is a part of the contextual knowledge which is invoked, structured and situated according to a given focus.

Context has a dynamic dimension intertwined with its static dimension. This dynamics comes from the fact that along the learning process, a part of the *contextual knowledge* is assembled, organized, structured in a *proceduralised context* (Pomerol and Brézillon 1999) that is built and used at one step of the process, and then stored in the LIM as contextual knowledge (sometimes in a different context level). For example, a teacher establishes a problem (task context) and a group of students contextualize these tasks to develop efficient practices. Put differently, each group of students develops their own practice, tailoring the problem in order to take into account the current group context (e.g. background, ability, other group components), which is particular and specific. Two groups having the same problem to solve will build two different proceduralised contexts. It happens because they have different interpretations of the problem according to their body of contextual knowledge (group context and individual context of the group members).

In fact, an important issue is the passage from contextual knowledge to proceduralised context (Pomerol and Brézillon 1999). The contextual knowledge needs some further specification to perfectly fit the problem at hand because the contextual knowledge is subjective and can be shared by many individuals (Brézillon and Pomerol 2001). The result of this proceduralization process depends on the focus (e.g. a problem to solve) (Brézillon and Pomerol 2001). Thus, the LIM is a repository of shared contextual knowledge (divided in levels as group and individual context) that was discussed or used by students to solve a given problem or discuss about some subject. Two students that want to solve a similar problem to one discussed and solved before, can access different information in the LIM (according to their focus) and they can use this information to reach their goal. This is an example of the proceduralization process.

A way to represent this proceduralization process is using contextual graphs (Brézillon 2003b). They will be presented in the next section

3.3 Proceduralised Context Building in a Contextual Graph

A contextual graph (CG) is a context-based representation of a task execution (e.g. solve a problem or discuss about something). CG is oriented without circuits, with exactly one input and one output and a general spindle structure (Brézillon 2003b). A path (from the input to the output in a graph) represents a practice, i.e. a way of executing a task with the application of selected methods and using selected contextual knowledge.

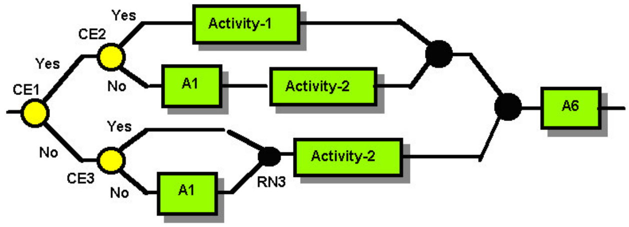

Fig. 2. Contextual Graph for solving a generic problem (e.g. an exercise)

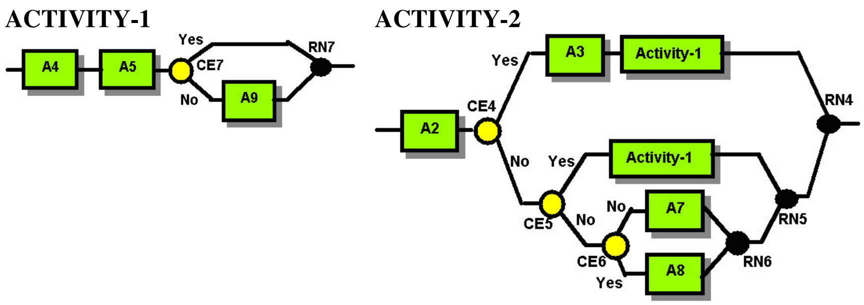

Fig. 3. Activity-1 and Activity-2 in Fig. 2

Table 2. Symbols in the contextual graph example (Fig. 2 and Fig. 3)

Symbols	Description	Contextual Knowledge Used
CE1	Is this problem already known?	Historical context
CE2	Can I remember how solve this problem?	Individual Context
CE3	Have my group understood the problem?	Group Context + Individual Context of the group members
CE4	Have I already seen a similar problem?	Individual Context
CE5	Have I enough knowledge to solve the problem?	Individual Context
CE6	Is there someone in the environment that can help me?	Interaction Context
CE7	Is the problem correct?	Planning Context
A1	Understand the problem	
A2	Plan the problem solution	
A3	Re-use similar concepts acquired	
A4	Solve the problem	
A5	Test the results	
A6	Finalize the exercise	
A7	Review the content (lessons) related to the problem	
A8	Ask someone for help (teacher or other student)	
A9	Try to solve the problem again	

Fig. 2 gives an example of CG based on the steps to solve a generic problem (e.g. an exercise) suggested by Polya (1995). A path is followed from the left to the right and corresponds to the crossing of a series of elements. Square boxes represent action and circles represent contextual elements (large circles for contextual nodes and back circles for recombination nodes). An Activity is a particular sub-graph that is identified by actors because appearing in several CGs. The activities in the Fig. 2 are presented in the Fig. 3. The definition of symbols are given in the Table 2 and they are divided in contextual elements (CE) and Actions (A). The proceduralised context is knowledge that is explicitly used at the current focus (e.g. the action A3 in Fig. 2 is executed because the contextual element CE4 is instantiated with the value "Yes" that is thus explicitly considered in the focus). Each contextual element could be found in one or more level of context (see Table 2).

One way to obtain an operational representation of a CG is to use production rules (Brézillon 2003b). An example that represents the beginning of the contextual graph in Fig. 2 is:

RULE-1	RULE-2
IF CE1 = (yes)	IF CE2 = (yes)
THEN Check RULE-2	THEN Execute action A4
ELSE Check RULE-3	ELSE Execute action A1

4. Importance of the Contextual Information in the LIM's Modelling

The issue of context is central to interaction analysis. It provide the social, cultural and organisational factors in which interaction emerges and on which the user will draw in making decisions about actions to take and in interpreting the system's and/or user's response. Consequently, identifying the contextual information relevant to characterise the interaction is very important to enrich and qualify the information store in the LIM.

Additionally, in conversation, context plays a fundamental role in disambiguating utterances: in many cases only the context can provide the correct cues to give the right interpretation to a sentence. In situations where geographically separated individuals have to collaborate (especially if they are interacting asynchronously), technological support for understanding and storing the contextual information involved (for example, location and users' goals) is very important. For example, the choice of an example must be relevant in the socio-cultural environment of the student. This identification of contextual information can help to clarify users' utterances, as well as to repair misinterpretations. Moreover, by knowing the context, teachers and systems can decide better on which is the adequate feedback to the learner. In fact, context provides the semantic enrichment of the LIM´s information and allows the CSCLE to better support user reflection.

The contextualized historical information included in the LIM allow teachers and students to reflect upon past interactions, and to learn from their (or other's) past performances or errors.

5. Conclusions and Future Work

In the learning process the more details the system can provide about user's interactions, the more it can support their reflection and knowledge construction. However, although context is a relevant aspect in the learning process, to the best of our knowledge, there are no CSCLE explicitly using the concept of context in their development.

In this paper, we have proposed a Learning Interaction Memory to store the interactions (in a multidimensional structure) occurred in CSCLE. The LIM considers contextual elements in its modelling to adapt dynamically its information to the concrete situation based in past facts. By including contextual elements in our modelling, we are able to semantically enrich the support provided to participants. And by using multidimensional modelling and OLAP, the interactions can be explored in different dimensions and levels of detail (an advantage over store informations in common log files) and specific feedback can be provided to both teachers and students.

The LIM is a component in a more generic and large project that it intends to analyse collaborative interactions so that we can support the students' reflection process and the teacher in his/her activities (e.g. student evaluation and guiding) (Siebra, Salgado e Tedesco 2004).

Our future research will concentrate on identify and representing all relevant contextual information related to CSCLE and we will also study how the contextual knowledge pieces can be combined to produce proceduralised context. After this step, we will model the LIM in a multidimensional structure (Inmon 1996; Kimball et al. 1998).

References

1. Bazire, M.; Brézillon, P. and Tijus, Ch. (2003) Eléments intervenants dans le contexte d'une activité finalisée. J.M.C. Bastien (ed.). Actes des Deuxièmes Journées d'Etude en Psychologie Ergonomique – EPIQUE'2003, INRIA, 281-286.
2. Borges, M. R. S.; Pino, J.A. (2000) Requirements for Shared Memory in CSCW applications. Proceedings of 10th Annual Workshop On Information Technologies and Systems (WITS'2000), Brisbane, Australia, 211-216.
3. Borges, M.R.S.; Brézillon, P.; Pino, J.A.; Pomerol, J.C. (2004) Bringing Context to CSCW. Proceedings of the 8th International Conference on Computer Supported Cooperative Work in Design. CSCWD´2004, Xiamen, China.
4. Borges, M.R.S.; Meire, A.P. and Pino, J.A. (2003) An interface for supporting versioning in a cooperative editor. Proceedings of the 10th International Conference on Human - Computer Interaction, v. 2, Lawrence Erlbaum Associates Publishers, Crete, Greece, 849-853.
5. Bouquet, P.; Ghidini, C.; Giunchiglia, F. and Blanzieri, E. (2003) Theories and uses of context in knowledge representation and reasoning. V. Akman, C. Bazzanella (eds.) Journal of Pragmatics. 35(3) Elsevier Science 455-484.
6. Brézillon P. (1999) Context in problem solving: A survey. The Knowledge Engineering Review, v. 14, n.1, 1-34.
7. Brézillon P. (2002) Making context explicit in communicating objects. C. Kintzig, G. Poulain, G. Privat and P-N. Favennec (Eds.), Communicating Objects, Hermes Science Editions, Lavoisier.
8. Brézillon P.; Pomerol J. Ch. (2001) Is context a kind of collective tacit knowledge? M. Jacovi and A. Ribak (Eds.). European CSCW 2001 - Workshop on Managing Tacit Knowledge. Bonn, Germany, 23-29.
9. Brézillon, P. (2003a) Context dynamic and explanation in contextual graphs. Modeling and Using Context (CONTEXT-03), P. Blackburn, C. Ghidini, R.M. Turner and F. Giunchiglia (Eds.). LNAI 2680, Springer Verlag, 94-106.
10. Brézillon, P. (2003b) Representation of procedures and practices in contextual graphs. The Knowledge Engineering Review, 18(2) 147-174.
11. Brézillon, P.; Borges, M.R.S.; Pino, J.A.; Pomerol, J.C. (2004) Context-based Awareness in Group Work. Proceedings of the 17th International Flairs Conference, Miami Beach, Fl, USA.
12. Byun, H.E.; Cheverst, K. (2001) Exploiting User Models and Context-Awareness to Support Personal Daily Activities. Proceedings of Workshop on User Modelling in Context- Aware Applications. 8th International Conference on User Modelling UM2001. Sonthofen, Germany.
13. Collins, A; Brown, J. S. (1988) The computer as a tool for learning through reflection. H. Mandl and A. Lesgold (Eds). Learning Issues for Intelligent Tutoring Systems, Springer-Verlag, New York, 1-18.
14. Constantino-González, M.; Suthers, D. (2001) Coaching Collaboration by Comparing Solutions and Tracking Participation. P. Dillenbourg, A. Eurelings and K. Hakkarainen (eds). Proceedings EuroCSCL 2001, Maastricht, The Netherlands, 173-180.
15. Dey, A. K., Salber, D. Abowd, G. D. (2001) A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. Context-Aware Computing, Human-Computer Interaction (HCI) Journal, v. 16, 97-166.
16. Dillenbourg P. (1999) What do you mean by collaborative leraning? P. Dillenbourg (ed.). Collaborative-learning: Cognitive and Computational Approaches, Oxford: Elsevier, 1-19.
17. Dourish, P.; Bellotti, V. (1992) Awareness and Co-ordination in Shared Workspaces. Eds. J. Turner and R. Kraut. Proceedings of the conference of the Computer Supported Cooperative Work (CSCW'92). ACM Press, Toronto, Ontario, 107-114.
18. Eleuterio M., Barthès JP, Bortolozzi F. (2002) Mediating collective discussions using an intelligent argumentation-based framework. Proceedings of Computer Supported Cooperative Learning *(CSCL 2002)*, Boulder, Colorado, USA.
19. Fuks H.; Gerosa, M. A.; Lucena, C. J. P. (2003) Using the AulaNet Learning Environment to Implement Collaborative Learning via Internet. Innovations 2003 - World Innovations in Engineering Education and Research, iNEER, USA.
20. Inmon, W.H. (1996) Building the data warehouse (2nd ed.). New York: John Wiley & Sons.
21. Kimball, R.; Reeves, L.; Ross, M.; Thomthwaite, W. (1998) The data warehouse lifecycle toolkit: tools and techniques for designing, developing and deploying data warehouses. New York: John Wiley & Sons.

22. Pasquier, L.; Brézillon, P.; Pomerol J.-Ch. (1999) Context and decision graphs in incident management on a subway line. CONTEXT 1999. Lecture Notes in Artificial Intelligence, n. 1688, Springer Verlag, 499-502.
23. Pinheiro, M. K.; Lima, J. V.; Borges, M. R. S. (2003) A framework for awareness support in groupware systems. Computers in Industry, Netherlands, v. 52, n. 1, 47-57.
24. Polya, J. (1995) A Arte de Resolver Problemas: um novo aspecto do método matemático. Rio de Janeiro, Interciência.
25. Pomerol J.-Ch.; Brézillon P. (1999) Dynamics between contextual knowledge and proceduralized context. Proceedings of the 2nd International and Interdisciplinary Conference on Modeling and Using Context. Lecture Notes in Artificial Intelligence, n. 1688, Springer Verlag, 284-295.
26. Rittenbruch, M. (2002) ATMOSPHERE: A Framework for Contextual Awareness. International Journal of Human-Computer Interaction, v. 14, n. 2, 159-180.
27. Rosa, M. G. P.; Borges, M. R. S.; Santoro, F. M. (2003) A Conceptual Framework for Analyzing the Use of Context in Groupware. Proceedings of the International Workshop on Groupware, Autrans, France, Lecture Notes in Computer Science, Berlin, Germany, v. 2806, 300-313.
28. Siebra, S. A; Salgado, A.C.; Tedesco, P. A. (2004) Analysing Participants' Interactions in Collaborative Learning Environments. Proceedings of the CLEI'2004, Arequipa, Peru.
29. Soller, A.; Wiebe, J.; Lesgold, A. (2002) A Machine Learning Approach to Assessing Knowledge Sharing During Collaborative Learning Activities. Proceedings of Computer Support for Collaborative Learning, Boulder, CO, 128-137.
30. Vygostki, L. (1978) Mind and society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.
31. Young, R. A. (2003) Demonstratives, Reference, and Perception. CONTEXT 2003. Series Lecture Notes in Computer Science, Springer Verlag, 383-396.