Promoting collaboration in a computer-supported medical learning environment

Elisa Boff — Cecília Flores — Ana Respício — Rosa Vicari

Departamento de Informática/Universidade de Caxias do Sul, Brasil, eboff@ucs.br
Departamento Saúde Coletiva/Universidade Federal de Ciências da Saúde de Porto Alegre, Brasil, dflores@ffmpa.edu.br
Departamento de Informática and Centro de Investigação Operacional/Universidade de Lisboa, Portugal, respicio@di.fc.ul.pt
Instituto de Informática/Universidade Federal do Rio Grande do Sul, Brasil, rosa@inf.ufrgs.br

ABSTRACT. This paper addresses collaborative learning in the medical domain. In particular, it focuses on the evaluation of a component specially devised to promote collaborative learning using AMPLIA. AMPLIA is an intelligent multi-agent environment to support diagnostic reasoning and the modeling of diagnostic hypotheses in domains with complex and uncertain knowledge, such as the medical domain. Recently, AMPLIA has been extended with a new component providing support in workgroup formation. Workgroups are proposed based on individual aspects of the students, such as learning style, performance, affective state, personality traits, and also on group aspects, such as acceptance and social skills. The paper also presents and discusses the results of an experiment evaluating the performance of workgroups composed according to suggestions provided by the system.

KEYWORDS: collaborative learning systems, group processes, medical education, problem-based learning.
1. Introduction

The advent of computer usage as well as the constant development of the capacities of new technologies has brought a new vision regarding the possibilities in using computer support for learning and training. Medical education is not an exception and during the last decade several systems for support learning of medicine have been proposed. These approaches are mainly concerned with collaborative learning, problem-based learning and computer based simulations (Le Beux and Fieshi, 2007).

According to Ward et al (2001), within less than one student generation, communication and information technology (C&IT) will be repositioned as an integral component of the medical knowledge domain. Although C&IT has affected learning in all the domains, medical education has some unique aspects, not least that the learning takes place during clinical care, and it offers opportunities to test methods of learning not used in other contexts.

Clinical reasoning is the way an expert resolves a clinical case – from a possible diagnostic hypothesis, the professionals look for evidence that confirm or reject their hypothesis. This type of reasoning is named top-down, because it starts from the diagnosis to find evidence; this way, the evidence justifies the diagnosis. The student, however, does the opposite; he/she looks for a diagnosis that justifies the evidence, because he/she does not have a diagnostic hypothesis. His/her reasoning is bottom-up, starting from evidence to reach a diagnosis.

The AMPLIA system, an intelligent multi-agent environment, was designed to support the medical students’ clinical reasoning. For this purpose, AMPLIA has a Bayesian Network editor which can be considered an intelligent e-collaborative technological tool. Recently, the system editor has been extended to provide the creation of virtual workgroups to solve tasks in a collaborative way.

Advances in Intelligent Tutoring Systems (ITS) have proposed the use of architectures based on agent’s society (Giraffa, 1998; Mathoff, 1994; Norman, 2000). The group dynamic has also been addressed by much research and in different areas. The multi-agent approach is considered suitable to model the group formation and coordination problem. In addition, it has shown a very adequate potential in the development of teaching systems, due to the fact that the nature of teaching-learning problems is more easily solved in a collaborative way.

In a real classroom, students form workgroups considering mainly the affinity between them. Sometimes, workgroups are composed taking into account geographical proximity (especially for Distance Learning), but these groups do not always present a good performance in learning activities. Here, the system analyses the several students and proposes heterogeneous and small groups considering individual and social aspects, such as learning style, personality traits, acceptance and sociability.

This paper presents and discusses probabilistic networks to model the aspects of individuals, and to promote collaboration between individuals. The following section summarizes some concepts related with collaborative learning. An overview of software specially developed to support learning in the medical domain is presented in section 3. Section 4 describes the group model, recently integrated in AMPLIA. Section 5 presents and discusses an experiment assessing the quality of the collaborative component. Finally, the paper ends with conclusions and future perspectives.

2. Collaborative learning

In the learning and teaching arena, cooperation can be seen as a special type of collaboration. **Collaboration** is a philosophy of interaction and personal lifestyle where individuals are responsible for their actions, which include learning and taking into account the abilities and contributions of their
peers, Panitz (1997). Collaborative learning is a method of teaching and learning in which students explore a significant question or create a meaningful project. A group of students discussing a lecture or students from different schools working together over the Internet on a shared assignment are both examples of collaborative learning. However, cooperative learning is a specific kind of collaborative learning. In cooperative learning, students work together in small groups on a structured activity. They are individually accountable for their work, and the work of the group as a whole is also assessed. Cooperative groups work face-to-face and learn to work as a team.

Collaborative learning environments (CLE) are systems specially developed to support the participation, collaboration, and cooperation of users sharing a common goal. In a CLE, the learner has to be active in order to manipulate objects, to integrate new concepts, to build models and to collaborate with each other. Additionally, the learner must be reflective and critical.

Learning environments should provide students with a sense of safety and challenge, the groups should be small enough to allow plenty of contribution and the group tasks should be clearly defined. Although several authors use the cooperative learning concept as defined by Piaget, our perspective follows the definition of Dillenbourg et al. (1995). Thus, collaboration here is seen as a joint work to achieve common goal, without the division of tasks and responsibilities.

Collaborative learning systems design should take into account social factors, (Vassileva, 2001) and (Cao et al., 2003). Vassileva and Cao et al. concluded about the importance of considering sociological aspects of collaboration to discover and describe existing relationships among people, existing organizational structures, and incentives for collaborative action. Hence, learning environments may be able to detect and solve conflicts, provide help for task performing and motivate learning and collaboration. In addition, Vassileva discusses strategies and techniques to motivate collaboration between students. Cheng and Vassileva (2005) propose a motivation strategy for user participation, based on persuasion theories of social psychology. In Cao et al. (2003), the goal is to find how people develop attitudes of liking or disliking other people when they interact in a CSCW environment, while in a collaborative-competitive situation. More precisely, the research investigates how they change their attitudes towards others and how the design of the environment influences the emergent social fabric of the group.

Prada and Paiva (2005) developed a model that supports the dynamics of a group of synthetic agents, inspired by theories of group dynamics developed in human social psychological sciences. Based on these theories, they considered different types of interactions that may occur in the group.

In a CLE, the learner has to be active, manipulate objects, integrate new concepts, build models to explain things, and collaborate with other people. The learner also has to be reflective and critical.

3. Computer-supported learning in medicine

Besides AMPLIA, we can highlight another learning environment or medical software that can be used in education. In Table 1 we selected several environments related to AMPLIA and we summarized their main features. Such Intelligent Tutoring Systems had been chosen because they are similar to AMPLIA in their application and student’s model.

A Bayesian network-based appraisal model was used in Conati’s work to deduce a student’s emotional state based on his/her actions (Conati, 2002). The probabilistic approach is also used in the COMET System (Suebnukarn and Haddawy, 2003), a collaborative intelligent tutoring system for medical problem-based learning. The system uses Bayesian networks to model individual student knowledge and activity, as well as that of the group (users connected in the system). It incorporates a multi-modal interface that integrates text and graphics so as to provide a communication channel between the students and the system, as well as among students in the group. COMET gives tutoring hints to avoid students being lost.
Medicus is a simple tutorial system that does not include collaboration aspects. It supports a single user interacting with the system and uses Bayesian networks to model knowledge (Folckers et al., 1996).

Table 1. Intelligent tutoring systems (ITS) comparison

<table>
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<tr>
<th>Systems</th>
<th>Objectives</th>
<th>Interaction tools</th>
<th>Tutoring</th>
<th>Student’s model</th>
<th>Strategies</th>
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<td>AMPLIA</td>
<td>Diagnostic hypothesis construction</td>
<td>Chat, Bayesian Network Collaborative editor</td>
<td>Socio-affective tutor to motivate collaboration and to join student in groups</td>
<td>Knowledge; Self confidence; Cognitive state; Take into account social and affective information to model individual and groups</td>
<td>From hints and quizzes to problems and discussions</td>
</tr>
<tr>
<td>COMET</td>
<td>Problem solving; Collaborative learning</td>
<td>Chat, Bayesian networks Medical images</td>
<td>It has an artificial tutor to help student learning</td>
<td>Individual and groups Knowledge and Activities</td>
<td>From hints to collaborative discussion</td>
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<td>I-Help</td>
<td>Personal Multi-agent Assistant (offer help to students)</td>
<td>Forums, On-line materials Chat</td>
<td>Personal assistant based on probabilistic reasoning</td>
<td>Student profile</td>
<td>Agents negotiation to find the suitable hint</td>
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<td>Prime Climb</td>
<td>Educational game to help students learn number factorization</td>
<td>Clicking on interface</td>
<td>Pedagogical agent that provides tailored help, both unsolicited and on demand</td>
<td>Bayesian network to infer students’ emotion</td>
<td>Emotional state leads to agent action choice</td>
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<td>Bio World</td>
<td>Problem solving</td>
<td>Text Frames Multimedia</td>
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Most of the above environments use knowledge-based models, like the AMPLIA system. Moreover, the strategies used consider the interaction between the user and the system. However, group interactions or group models were ignored. This functionality is observed in the AMPLIA model and it distinguishes our system from the similar environments shown in Table 1.

AMPLIA innovates by including a student model considering cognitive, social, and affective states (Boff et al., 2007). This model allows the evaluation of individual student profiles and, afterwards, the proposal of the creation of work groups. We envisage applying the system to promote the collaboration, through the web, of several students solving a clinical case together.

Additionally, AMPLIA takes into account self-confidence insofar as each group announces the confidence level regarding the proposed solution. Hence, driven by this confidence level, the tutor adjusts the most adequate strategy to guide students to the right solution. Therefore, AMPLIA’s features contribute to improve CLE design.

4. Group model

4.1. AMPLIA’s Collaborative Editor

The first version of AMPLIA’s editor allowed only one student to work with the system at a time (Vicari et al., 2003). Therefore, it wasn’t collaborative. According to learning theories in medicine
Based on problem-based learning (Peterson, 1997), the editor was extended to allow several students to operate it simultaneously in a collaborative fashion. Thus, besides the online editing support (see Figure 1), the system was provided with a group model designed through the Social Agent, whose main goal was to motivate collaboration and improve group activity. The collaborative editor is part of the AMPLIA Learner Agent. As depicted in Figure 1, BN editing is possible in the system through buttons available in the toolbars. There are menu options to insert nodes, arcs and probabilities.

Figure 1 shows part of the BN that is under development by a group of students. In the smaller window, on the right, we can see the Node’s Properties Editor, where the CPT (Conditional Probability Table) associated with variables (nodes) can be updated. At the bottom of the screen we can find collaborative editing options, including online users’ listing and a chat tool.

4.2. The Social Agent

The Social Agent is based on social psychology ideas (to support social aspects) and affective states. The main goal of the Social Agent is to create students’ workgroups to solve tasks collaboratively (Boff et al., 2007) in the AMPLIA system. Interaction is stimulated by recommending the students to join workgroups in order to provide and receive help from other students. The Social Agent’s knowledge is implemented with Probabilistic Networks. In the AMPLIA, each user builds their own BN for a specific pathology using the collaborative graphic editor. During this task, the Social Agent recommends other students that may participate in the BNs development.

The student feature set is based on the social and collaborative theories. The information collected to define a suitable recommendation includes: Social Profile, Acceptance Degree, Affective State (Emotion for Self and Emotion for Outcome), Learning Style, Personality Traits, Credibility and Student Action Outcome (Performance). The Social Profile and the Acceptance Degree were detailed in (Boff et al., 2007).

The socio-affective agent selects the action that maximizes this value when deciding how to act. The influence between nodes is shown in Figure 2. This network is made up of a decision node (rectangle), a utility node (diamond) and uncertainty nodes (oval).

The model of (Conati, 2002), based on the OCC Model (Ortony et al., 1988) is used to infer emotion. The affective states can be considered as an emotional manifestation at a specific time. Conati modeled a Bayesian network to infer emotions and consider the students’ personality, goals, and interaction patterns to reach emotions (Zhou and Conati, 2003; Conati, 2002), thus obtaining values for the states of Personality Traits and Affective State nodes.
The states of Credibility and Student Action Outcome nodes are informed by other AMPLIA agents.

![Figure 2 – Decision network of the student model](image)

The Student Action Outcome node represents a possible classification for the student’s BN model, which may take the values: Unfeasible; Incorrect; Incomplete; Feasible and Complete. Finally, the decision node Plan is responsible for recommendation, which is the suitable group for a student. Such plans are selected from a function of utility (node Utility). The Plan node states are recommend and do not recommend a student to join a workgroup. The Utility node selects the student that maximizes the recommend value.

4.3. Strategies for group proposal

The Social Agent uses different strategies to suggest a particular student to a workgroup. Students can join different groups whereas each group can work with different study cases, knowing that within medicine the teaching approach relies mostly on problem-based learning.

Participation in a group depends on the approval of the student by the members of the group. When the student is invited to join the group, he/she may also accept or decline the offer. When the student refuses to participate in a workgroup, the system may inquire him/her about the reason of the declination by presenting him/her with the following alternatives: (i.) I do not have interest in this subject; (ii.) I am temporarily unavailable; and, (iii.) I do not have interest in interacting with this group. The actions of the users are stored in the student model. This model is employed when the Social Agent looks for students to join a workgroup. The groups are dynamically formed, based on the task being carried out. The students can participate in several groups simultaneously, according to their interest. Each group must contain at least one student with the leadership role.

When a student acts actively in the learning environment, interacting and making contributions to the development of the BNs, the Social Agent records this information and verifies if he/she was not the one to collaborate more actively in the network construction - which can be reinforced when the student had his/her work modified the least number of times.
The Social Agent also tries to create groups with democratic profiles or sharing roles, where all team members are able to lead the team. This occurs when the responsibility for the operation of the team is shared – role-sharing – leading to shared accountability and competencies. The leader should focus on the process and keep the team functioning within a problem solving process.

When students overtly share the leadership or facilitator role, they are more attentive to team maintenance issues when they reassume a certain role, as they can get to know the team leader’s responsibilities (Peterson, 1997).

Some strategies can be useful to improve learning in groups, such as: working at giving good feedback, getting silent members involved, confronting problems, varying the leadership style as needed, working at increasing self-disclosure, summarizing and reviewing one’s learning from group experiences (analyzing the data to discover why the group was more effective or less so and providing final feedback to members on their contribution) and celebrating the group’s accomplishments.

The groups must also be formed by students with different levels of performance. Considering we have six people, for example, including students with performance categorized as excellent, average and regular, it is better to join two classmates of each level.

5. Experiments and Results

We conducted an experiment with AMPLIA involving a class of 17 undergraduate medicine students. All students were in the first term of their graduation and, therefore, they had not known each other for long. This experiment intended to assess the performance of the groups either spontaneously composed or proposed by AMPLIA, as well as the quality of group suggestions. Additionally, the students were inquired about their preferences regarding the type of learning (individual against collaborative).

First of all, the AMPLIA environment was presented to students to clarify the use of Bayesian Networks (BN) in the construction of diagnostic hypotheses. It is important to highlight that the class did not know BN concepts. The students organized themselves in 6 groups and they built a BN (using AMPLIA BN editor) to prove a diagnostic hypothesis. All groups worked on the same subject.

Then, the 6 groups were rearranged according to the suggestion of AMPLIA’s Social Agent and each group solved a new diagnostic problem (equal for all the groups).

At the end, the students answered two questionnaires. One of them assessed the use of AMPLIA as pedagogical resource. The other one aimed at analyzing the performance of the groups composed by AMPLIA.

As we expected, 82% of students preferred working with groups elected by them. However, 18% favored the groups composed by the AMPLIA system. On the other hand, 100% of students said that they liked the groups suggested by the Social Agent and that they would work again with that group formation.

When asked about the group performance (Figure 3), 58% of students pointed out that both groups (spontaneously composed and system proposed) had a similar performance. Only a single student affirmed that the group proposed by the system was much better, while 36% considered that the spontaneously formed group performed better (much better and slightly better).
The students approved the collaborative way of working. Only 6% of students commented that the group dynamic does not improve learning, while 59% of them affirmed that working in groups can improve learning and 35% of them corroborated that workgroups definitely improve learning.

Regarding the collaboration between colleagues, the students showed that most of them approved the group dynamic as an alternative to individual learning. In fact, 94% students declared that learning is improved when they work in small groups. The same percentage also affirmed learning was easier during the group activity, while only 6% felt ashamed during group interaction and considered that being within a group does not help the learning function.

Finally, when asked about the quality of the system’s group suggestion (Figure 4), 52% of students affirmed that probably the system suggestion can help the choice between available groups, while 12% of them corroborated that the system suggestion definitely helps their choice, meaning that 64% found the suggestions helpful. Only 24% thought that the group suggestion did not help them.

To summarize, students preferred to work in a collaborative way. All the students involved in this experiment stated that they would work again with the group proposed by the system. This reveals that, although most of the students preferred to work with people they already had affinities with, the system is able to produce a satisfactory distribution of students among groups. Concerning the groups’ performance, the majority declared that both groups were equivalent. The system produced suggestions that helped people choosing groups.
6. Conclusions and future perspectives

AMPLIA is a tutoring system to support medical students’ clinical reasoning. The editor allows the creation of virtual workgroups to solve tasks in a collaborative way. In addition, the AMPLIA environment contributes to the CLEs research area because it takes into consideration cognitive, affective and social states in the student’s model. We aim at reducing the teachers’ involvement, giving more autonomy to students.

The tutor recommendation mechanism explores the social dimension through the analysis of emotional states and social behavior of the users. In this direction, we aim to contribute to the design of learning environments centered on students’ features and collaborative learning.

Boff and Flores (2008) discuss previous experiments with AMPLIA. The AMPLIA’s pedagogical impact was evaluated, in 2005, by an experiment assessing how AMPLIA can help students, from the point of view of teachers, and from the point of view of students. The authors of this study also concluded that students are mainly concerned with learning to produce correct diagnoses, and with being confident in their diagnoses. In 2006, the pedagogical methodology used by AMPLIA and its potential use in Medical Education were evaluated through a major experiment involving 62 people: teachers, graduate and undergraduate students. Here, a new collaborative feature of the system is assessed.

By now, the system considers the profiles of the students, analyses them, and proposes group formations, using the Social Agent. Afterwards, each group is assigned to a given diagnosis problem and builds the corresponding diagnosis network. For the tutor, each group assumes the role of an individual learner. The group is given space and time to discuss their options and the solution is built through collaboration of the group members. The tutor evaluates the final group solution.

The experiment presented here is a starting point to indicate that the social agent reasoning can be used to make up groups with good performance. In fact, the results are rather promising as the majority of students, though preferring to work in groups of people they previously knew, confirmed that groups proposed by the system performed similarly or better. Besides, all students would work again with the AMPLIA proposed group, meaning that group proposals were adequate. So, we can conclude that the Social Agent’s model converges towards students’ expectation and reality. In the near future, we will conduct experiments to assess the performance of different groups suggested by the Social Agent and also analyze negative results that can be an interesting contribution to the research community.

AMPLIA is continuously being extended. In the near future, the system will be available for use on a Local Area Network (LAN), and, a Web version is envisaged.

Acknowledgements

This research has been partially supported by POCTI/ISFL/152 and CAPES/GRICES.

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