AMPLIA: A Probabilistic Learning Environment

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Abstract. This paper introduces AMPLIA, an intelligent learning environment employed as a resource in medical students’ training. The development of AMPLIA raised several research topics, due to the convergence of Artificial Intelligence (AI) and Learning Environments. The core topics are: probabilistic diagnostic learning in the medical area, application of teaching strategies based on Pedagogical Negotiation (PN), construction of cognitive student models with probabilistic beliefs, and application of interoperability methods for pedagogical agents, and tutoring systems integration. An important aspect of AMPLIA is the utilization of PN as the main form of interaction. The impact of this approach on the system dynamics and on the student’s learning is presented in detail. Considering the importance of cooperative work during the learning process, we describe how AMPLIA is used to enable cooperation. The description is based on experiments carried out with AMPLIA and its users. The main results of these experiments are reported as well.

Keywords. Intelligent learning environments, pedagogical negotiation, education and medicine

INTRODUCTION

The goal of the present paper is to describe the main features of the AMPLIA learning environment (Vicari et al., 2003). AMPLIA is a Multiagent System (MAS) designed to work as an extra resource for the education of medical students. It supports the development of probabilistic diagnostic reasoning and modeling of diagnostic hypotheses. AMPLIA is the most recent software application
designed and developed by our group in Intelligent Tutoring Systems (ITS) research. Our approach involves cognitive models with practical reasoning-style architectures resulting in useful examples and applications. We have been using the concepts of agency and mental states for a while, as abstractions to describe, design and build ITS systems. The approach used to handle these tasks is straightforward. The goal is to analyze and propose cognitive models that present: viable computational interpretations, clear epistemological and psychological foundations and precise formal specifications. Cognitive models should be computational, at least from the theoretical viewpoint; otherwise the approach cannot be considered an application of computer science. Concepts used in these models should be based not only on naive intuition or common-sense psychology, but rooted on explicit epistemological and psychological foundations. The formal specification is the answer to avoid excessive anthropomorphism: the formal definition of any concept is independent of subjective belief, perception or emotion about this concept, even when the concept that is being formalized is the concept of “subjective belief”, “perception” or “emotion”.

The technological focus of our research is to design and develop ITS systems using pedagogical agents and MAS as software engineering tools. By using agents’ technology to design, represent, and execute the student model, it becomes a pro-active model which is more similar to the real student being modeled. However, as agent and MAS architectures are quite implementation oriented, only providing schemas to build agents and systems, they are inadequate as analysis tools. In the case of pedagogical agents, it is not easy to respect the pedagogical theoretical foundations that are the basis for such agents while building them. Formal models showed to be the best option as we are interested in both describing and analyzing the autonomous behavior in ITS.

Following these principles, AMPLIA was built to explore pedagogical strategies, cognitive student models, and interoperability methods for ITS integration. The function of AMPLIA is to support the development of diagnostic reasoning and hypotheses modeling in the medical area, by using probabilistic mechanisms for knowledge representation. Student activities comprise the representation of a diagnostic for a clinical case in a Bayesian Network (BN) model. The student’s network is compared to that of an expert on the domain stored within the environment. Differences between networks are managed through pedagogical strategies based on the constructivist theory. BNs have been widely employed in the modeling of uncertain knowledge domains, such as medical diagnoses. Uncertainty is represented through probabilities and the basic inference is the probabilistic reasoning, based on the hypothesis that physicians implicitly perform a probabilistic reasoning when diagnosing. This is supported by reviews of medical study cases (Heckerman et al., 1992).

The main functions of learning environments (explanation, education, diagnostic) are traditionally implemented as one-way mechanisms; this means the system has total control over interactions. AMPLIA attempts to treat them as bilateral processes, which means that a diagnostic model is built collaboratively, and there are some negotiation moments. It is clear that for the establishment of a negotiation, there must be a level of latitude available to agents, otherwise nothing can be negotiated. This negotiation takes the form of a Pedagogical Negotiation (PN), which is defined as the solution of differences and conflicts that may happen among agents involved in a teaching-learning environment, using strategies with a pedagogical profile. Hence this work represents a step towards a PN.

Research from the PN perspective has represented a welcome attempt to broaden critical interaction arguments (Baker, 1992) in knowledge negotiation context (Moyse & Elsom-Cook, 1992). Baker’s works establish a set of requirements for the design and implementation of models for sustaining dialogue in ITS, which incorporate mechanisms for negotiating cooperative teaching and learning goals. Baker’s work is centered on the “KANT” (Critical Argument Negotiated Tutoring)
system, which incorporates negotiation mechanisms within the framework of a general model for dialogue. KANT bases its decisions on what to negotiate on a set of parameterized dialogue goals, in combination with a method for controlling dialogue. Otherwise, AMPLIA works with the idea of a negotiation space (see the Formal Model section) generated by the logical and probabilistic model used to represent the negotiation process.

Moyse’s work proposes an interaction that takes the form of a mixed-initiative dialogue, in which one student can challenge or count the arguments of the other and open up different avenues of discussion, where there is no right or wrong answer to the issue under discussion, and no pre-determined end point of the interaction. In the AMPLIA system we are also negotiating knowledge, but our approach is based on an explicit initial point and a final point for the negotiation process (see the Negotiation Process section).

Another characteristic that differentiates AMPLIA from similar learning environments and medical software that can be used for education purposes, like BioWorld, COMET, Medikus, and Promedas, is the fact that AMPLIA considers cognitive and social states to build the student model, following an epistemological theory. Most of these environments use knowledge-based models and one of them (BioWorld) considers the self-confidence level. However, the strategies used in these systems do not consider interactions between user and system based on cognitive models nor do they consider group interactions or group models.

Summing up, AMPLIA was a successful test bed for several experiences that allowed us to explore: an interesting learning domain with a new pedagogical negotiation model of interaction, the limits and generalizations of cognitive student models, showing how to combine subjective (bayesian) probabilities with cognitive (Belief, Desire and Intention – BDI) student models, reusability of pedagogical knowledge and interoperability with other pedagogical agents and ITS systems, and collaborative work among students based on a constructivist pedagogical framework.

This paper is organized as follows. The next section will show the theoretical basis of the paper, followed by a section that shows the architecture of the AMPLIA system. The next section presents how Pedagogical Negotiation processes are used in AMPLIA and shows the intuitive and formal model of these processes accompanied by a PN example. The Collaborative Work section will show how collaborative work among students was incorporated in the AMPLIA system. The last section shows final considerations about the work.

THEORETICAL FOUNDATIONS

The application of formal approaches to understand or conceptualize issues of educational processes is a relatively new area, at least in the sense of the formalization of ITS. Self’s work (Self, 1992, 1994) presents solid foundations on how to apply formal methods and models, particularly logical models, to the analysis of the student model in ITS, showing that there is a deep relationship between several areas of AI, like machine learning, cognitive agent modeling, and ITS. His work provides a theoretical and computational basis for student modeling, which is psychologically neutral and independent of applications. The corresponding formal model is derived mainly from various areas of theoretical AI, particularly from the epistemic/doxastic modal logic (Knowledge/Beliefs logic) and from BDI logic used for agent’s cognitive and communication modeling. This is the main interface of Self’s research and our own work, as we start from a similar formal model. However, due to the nature of the knowledge learned in the AMPLIA environment and to the probabilistic modeling of the reasoning
processes used in the agents of AMPLIA, it was necessary to generalize the purely logical BDI model to support probabilities. This was done through a new probabilistic logical model that keeps the theoretical basis and is compatible with the logical formalisms used as the foundation of BDI models (Gluž et al., 2006).

In related work, Dillenbourg and Self (1992) describe an abstract formal framework that shows how basic entities of an ITS, such as the tutor/domain and the student model modules, can be organized in several abstraction layers, the relationships among elements in each layer and the kinds of knowledge related to each one of these relationships. The abstract layers of the framework are based upon the computational distinction between behavior, behavioral knowledge, and conceptual knowledge. The entity sub-classification forms of the framework define the existence of three entities: the “system”, “the learner”, and “the system’s representation of the learner” (student model).

The AMPLIA architecture extends Dillenbourg’s framework, because it needs to identify the entity responsible for the teaching mediation process and the entity responsible for the learning domain knowledge. In addition, the main focus of AMPLIA resides not in the detailed analysis of the student model, but in finding out the properties of the interaction among the student and the entities of the system. We consider these interactions the most important elementary units for the analysis of the teaching and learning process phenomena. They are handled as negotiations of a pedagogical nature that take place among the participating agents.

Discussions about the use of negotiation mechanisms in learning environments are not recent. According to Self (1992), there are two major motivations for the use of negotiation in ITS: it makes it possible to foster discussions about how to proceed, which strategy to follow, which example to look for, etc. in an attempt to decrease the control that is typical of ITS, and it provides ways for discussions that yield different viewpoints (different beliefs), considering that the tutor is not infallible. Indeed, the approach of PN can be applied to knowledge areas that share some characteristics such as incomplete knowledge, and different views or even domains where there is no “knowledge” – considered in its classical definition, in which knowledge is always something true – but a set of justified beliefs about what someone can argue and debate. These characteristics foresee the transformation of viewpoint, both from the system and student, into beliefs instead of knowledge. This implies a special type of teaching dialogue, considering that an interactive change of justified beliefs is a simplified definition of argumentation (Schwarz et al., 2001). It is a complex process that involves the student’s autonomy, the symmetry of relations between teacher and students or among agents, and the levels of flexibility which requires the agents’ level of freedom to perform their actions. The requirement is that the interaction among agents shares a common goal, so that an agreement is reached according to the negotiation object. Different dimensions of the negotiation object will be negotiated simultaneously. The initial state for a negotiation to take place is the absence of an agreement, which can include a conflict or not. In the case of a teaching and learning process, a point of conflict is the relation of self-confidence and mutual confidence among teachers and students, besides their own beliefs about the knowledge domain. A process of teaching and learning is a way of reducing the asymmetry between the teacher’s and the student’s confidence on the topic studied.

These considerations bring our research directly to what has been studied in negotiation protocols for MAS. According to Sandholm (1999), there are strong correlations between agent negotiation protocols research and well established negotiation theories from the economic sciences. The problem is the great influence that Utility Theory has on this kind of research. This theory makes good sense in economical terms, but there are not clear indications of how it can be interpreted or used in a pedagogical context. Our approach considers PN as negotiations that occur in a classroom and relies
strictly on pedagogical strategies to achieve agreements. No economical or monetary means must be used in these agreements.

Nevertheless, theories and models used in agent negotiation protocols research, as seen in (Jennings et al., 2000) are valuable and we apply these techniques to our problem. We overcame the problem of using Utility or Preference Theory, by considering a basic concept for the educational process: the concept of confidence relationships that can and must be established during the evolution of the educational process. Of course, there are several questions related to how to make good assessments or estimation of this confidence and our work should be considered only as a formal approach to this issue. However, we have a positive answer to this question, at least in the AMPLIA domain, based on the idea that these assessments are probabilistic in their nature. Using probabilistic modeling of the reasoning process related to these assessments we achieve good practical results.

AMPLIA’S ARCHITECTURE

AMPLIA’s MAS architecture is shown in Figure 1. The Learner Agent represents the student, gathering all concrete evidence about the status of his learning process. Based on this evidence, the Learner Agent elaborates and updates the student’s model, inferring the credibility (expectation) that the system might have on the student, and also registering the self-confidence level declared by the student. The Learner Agent interacts with students through a BN graphical editor. This editor is the main form of interaction between AMPLIA and its students, presenting clinical cases, and allowing students to model and submit their diagnostic hypothesis (the BN model represents the hypothesis) to the system. The editor can also work in a collaborative way, allowing the BN to be built interactively by several students.

![Fig.1. AMPLIA’s Architecture.](image-url)
The Domain Agent stores knowledge of the medical domain and evaluates the knowledge the student is modeling. The result is sent to the Mediator Agent in order to coordinate the interaction process. The interactions between the student and AMPLIA are seen as a process of PN, in which the Mediator Agent solves differences using teaching pedagogical strategies. These strategies are selected according to the confidence and credibility levels, and to the classification of the diagnostic hypothesis given by the student for the clinical case. The Mediator Agent incorporates negotiation mechanisms needed to solve differences and conflicts in this process. This agent makes decisions on how and when to interfere during the student’s solution model construction process. It will select the most appropriate pedagogical strategy to query and aid students during their learning processes. For details about the AMPLIA architecture see (Vicari et al., 2003).

These three agents form the core of AMPLIA. They know the learning domain and are responsible for the learning activities, and pedagogical strategies to be applied in the interaction with students. However, considering the possibilities for group and teamwork offered by the collaborative editor, it was necessary to integrate another agent into the AMPLIA agent’s society, the Social Agent (Boff et al., 2007). This agent acts as a mediator among students that establish social relations. The goal of the Social Agent is to stimulate students’ interaction based on social and affective data collected about their use of the system. Each user builds his BN for a specific pathology. During this task, the Social Agent will recommend students to help other students.

The communication among agents follows a cycle of interactions which obey the following protocol:

1. The Domain Agent presents a case study to students. The Learner Agent only takes notes on the example and passes it to students.
2. The Domain Agent makes available the case studies from where students model the diagnostic hypothesis. Students model the diagnostic hypothesis, and send (through the Learner Agent) their model to the Domain Agent to be evaluated.
3. Based on the result of the Domain Agent analysis and on the confidence level, which is declared by the student and supplied by the Learner Agent, the Mediator Agent chooses the best pedagogic strategy, activating the tactics suitable to a particular situation.
4. The student evaluates the message received from the Mediator Agent and tries to discuss the topics, which he considers important. At this stage, the student may also decide to give up the learning process.

In step (3) the Mediator Agent should also consult an external agent called the UP (User Profile) agent about student’s profile information (see footnote 1). It also should interact with the Social Agent to promote pedagogical strategies based on group activities. The Learner Agent also should interact with the Social Agent to coordinate collaborative activities.

The communication of these agents is based on FIPA (Foundation for Intelligent Physical Agents) communication standards (FIPA, 2002). AMPLIA’s agents communicate among themselves through a

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1 The architecture presented in Figure 1 shows only the AMPLIA agents and their pedagogical roles in the system. In a real learning environment these pedagogical activities need to be complemented by other management tasks. For instance, the management of information related to students’ profiles is delegated to the User Profile (UP) Agent, which is an agent developed in the PortEdu Project (Nakayama et al., 2005).
combination of two FIPA agent platforms\(^2\). However, FIPA standards required an extension of these standards because the probabilistic knowledge, usually represented through a BN model, is a format not supported by any content language standardized by FIPA. The inference process of Mediator Agent, Domain Agent, and the Social Agent are modeled using BN models and these agents need to exchange probabilistic information among themselves, and also with Learner Agents. Although, FIPA’s Agent Communication Language (FIPA-ACL) offers a wide range of communication acts, it does not provide communicative acts that make it possible to inform or question the value of a probabilistic proposition or variable. To solve this problem a new communication framework was proposed which extends FIPA standards, and is able to represent and communicate probabilistic knowledge among agents (see (Gluz et al., 2006) for details).

**TOWARDS A PEDAGOGICAL NEGOTIATION IN AMPLIA**

PN processes model all interactions that occur in AMPLIA. The negotiation among agents is characterized by: the negotiation object, the negotiation process from initial to final state; the role of agents in this process, and the formal model of PN.

**The Object of Negotiation**

The object of negotiation in AMPLIA is the belief on a diagnostic hypothesis outlined for a clinical case. The student’s diagnosis hypothesis is a BN model built through a collaborative graphical editor. Students can build and observe their BN, and test their hypotheses through BN models.

The teacher’s beliefs are also modeled through an expert’s BN model, which is stored by the Domain Agent. As these beliefs are concerned with an uncertain domain, the expert’s BN model can be incomplete. Therefore a base of real cases, which is continuously updated, is used to validate the expert's beliefs. A belief expresses how much one believes \( x \), or how much \( x \) is considered right. From this viewpoint, the students’ and teacher’s confidence are two parameters comprised in negotiation. The participants of a negotiation process use the resource of argumentation to persuade other participants to change their beliefs. In AMPLIA, the argumentation resources are represented by the teacher’s actions, translated into the selection of a strategy that is more adequate to convince the student. The student’s argumentation is represented by the modifications (or not) of his BN and by the level of confidence he is asked to declare. As the object of the negotiation is a BN model, it is probable that there will be problems both in its topologic structure and in tables of conditional probabilities. The problems identified in the student’s BN model are classified as Not Feasible (network that does not satisfy the definition of a Bayesian network), Incorrect (network whose model is conceptually incorrect), Incomplete (network that presents the lack of some nodes or relations considered important, whether they are diagnosis or findings), Satisfying (network different from the built-in model but it satisfies the case study proposed to the learner) or Complete (identical to the model built by the expert).

\(^2\) AMPLIA is composed of a set of Java agents and a set of non Java agents. The Social Agent was implemented in Java and uses the FIPA-OS agent platform. Other agents were implemented in Object Pascal, and also use an agent communication platform based on FIPA that was specifically developed for the AMPLIA project. There is a module, called ComServer (not depicted in Figure 1), which provides the communication gateway between agents implemented in Java and non Java agents.
The Negotiation Processes

The pedagogical negotiation in AMPLIA can be seen as a way of reducing the initial asymmetry in the confidence relation between teacher and student concerning the topic studied. Such a negotiation is intended to maximize the confidence of all participants.

Intuitively, the initial state can be characterized by four conditions: the teacher has a high level of confidence in his own knowledge about the study topic (IP.1), and a low level of confidence in the student’s knowledge about this topic (IP.2). The student, otherwise, should have a low level of confidence in his own knowledge (IA.1) and a high level of confidence in the teacher’s knowledge about the study topic (IA.2).

The main goal of a PN process is to provide and establish a high degree of confidence among the participants of the process. Thus, in the final state of the PN process it is expected that teachers can keep the high level of confidence in their own knowledge (FP.1) and that they can establish a high level of confidence in the student’s knowledge about the study topic (FP.2). It is also expected that students develop a high level of confidence in their own knowledge about the study topic (FA.1), and keep the high level of confidence in the teacher’s knowledge (FA.2).

It is important to note that here we are not talking about a generic confidence, but about a specific and objective one, associated with the abilities the student demonstrates when dealing with the learning domain. The degree of belief on an autonomous action is an important component of confidence that will take place in this teaching and learning process, that is, how much the student’s actions are guided by trials or hypotheses. This variable corresponds to the system’s Credibility on the student’s actions and it is inferred by the Learner Agent. Self-confidence (the confidence the student has on his BN model) is another variable used in the pedagogical negotiation, as the student must be confident of his hypothesis, or at least increasingly trust them, as he builds his knowledge. The quality classification of the BN model is the third variable considered in the negotiation process, as the student must be able to formulate a diagnosis that will probably be compliant with the case. Pedagogical strategies are selected upon this classification, and Self-confidence. The Credibility represents the “fine tune” and determines which tactics will be applied to the student. The tactics are meant to be the way in which the strategy will be displayed. These variables are part of the Learner Agent.

Figure 2 shows the main elements of the negotiation model: initial state, final state, the negotiation object, and negotiation process. The negotiation object is represented by circles and indicates the status of the student’s BN model. Status is labelled as Main Problem, which is identified by the Mediator Agent. The initial state is defined in terms of specific elements, student’s and system’s individual and mutual goals and beliefs. The only element required is the mutual goal of agreeing on some negotiation object. The final state will be reached when a symmetry between the student’s (Self-confidence) and the system’s (Credibility) confidence is reached, and when the student’s BN model reaches the status Satisfying or Complete, with a similar or even better performance than the expert’s BN model. The negotiation process has the purpose of achieving the final state from the initial state. The inverted triangle of Figure 2 is meant to indicate convergence towards this final state.

In the initial state, the object of negotiation – the student’s BN model – is not built yet; therefore, there is no negotiation. The pedagogical strategy used in this case will be to guide the student: the tactics are used to present a problem or suggest that the student check his BN model again and look for conceptual problems. In the following level, in which there is a mistake in the representation of the object, the Mediator Agent disagrees with the student’s BN model. In these first levels, the focus of
the Mediator Agent is on a concrete object (BN) and does not include the student’s confidence on his BN model. In the following levels, the negotiation process starts: the objective of the Mediator Agent is now to make the student reflect and enhance his diagnostic hypothesis represented by the BN model by including lacking nodes and indicating the relationship among them. When the student’s BN model starts to enter the satisfactory level (as compared to the expert’s), the Mediator Agent starts to warn the student that some adjustments in the a priori and conditional probabilities of the BN model are required. Meantime, the student’s BN model is submitted to the database of real cases for the evaluation of performance. The expert’s BN model is also submitted to this base. The database is continuously updated, so that the Mediator Agent is able to accept BN models built by students that are better than BN models built by experts. It is worth saying that the conditions (FP.1) and (FA.2) are the basis for this process to take place.

![Fig.2. Negotiation process in AMPLIA.](image)

Even if the student’s BN model is classified as Complete but the Learner Agent detected low credibility, or if the student declared a low confidence, the Mediator Agent will use different strategies, such as demos or discussions, in order to enhance the model. These actions correspond to the (FP.2) and (FA.1). While this status is not reached, the Mediator Agent does not consider that negotiation has come to an end.
The Role of the Agents

The Learner Agent is able to assess if the student has a hypothesis to guide his actions or if he is making combinatorial trials that can hit a diagnosis. The decisions made by the Learner Agent are modeled by the BN shown in Figure 3(a). Empty nodes represent variables inferred from the student’s actions log. Grey-filled nodes represent observed variables (dotted nodes will be implemented). The goal is to infer probabilistically – such as a teacher would do – the levels of grasp of consciousness of the student, after the observation of student’s actions. This inference will result in the credibility levels used in AMPLIA. These variables are the conditional nodes of the BN and are informed to the Mediator Agent.

![Diagram](image)

(a) Learner Agent Credibility Assessment Bayesian Network

(b) Mediator Agent influence Diagram for Pedagogical Tactics Selection

Fig. 3. Probabilistic reasoning.

The main role of Domain Agent in the PN process is to analyze and evaluate the student’s BN model. This analysis is not a simple comparison between the student’s and the expert’s knowledge, as it happens in the traditional overlay, differential and perturbation models. These traditional models are strongly based on the expert’s knowledge, assuming that the student’s knowledge is either a subset of it or it is compared against a set of errors, foreseen by the expert. This is avoided by a Domain Agent through the concomitant assessment of the student’s and the expert’s BN model performance, when compared against a database of real cases. The student’s BN model is also evaluated on its feasibility, correctness and completeness properties when compared with the expert’s model. The Domain Agent makes a qualitative evaluation (the network topology) and a quantitative evaluation (the conditional probabilities tables). The distribution of conditional probabilities among the variables is analyzed when there is no evident progress in the student’s BN model. In the quantitative evaluation, the student’s BN model is submitted to a database of real cases. The goal is to check if the BN model can provide a correct diagnosis even with the chosen nodes. At the end of the process, the Domain Agent provides a list of problems found in the student’s BN, which will be managed by the Mediator Agent.

The role of Mediator Agent is to mediate the interactions between the student (represented by the Learner Agent) and the tutor (Domain Agent) at each cycle of the BN model construction. This agent uses an Influence Diagram to select the tactics that will display the best utility in different moments of the interaction (see Figure 3(b)). The parameters used are the results of the BN model evaluation; the level of the student’s declared confidence, and the credibility. The Mediator Agent aims to make it possible to represent the dependence relations among these parameters and assimilates the need of incorporating the constant changes that take place in the learning process.
An Example of Negotiation

As an example of how AMPLIA interacts with students, a study case focused on the diagnostics of Dengue Fever will be presented. The interaction starts after the student logs in to AMPLIA, and selects, through the Learner Agent, a study case from the database of available medical study cases. The Learner Agent presents the introductory material (text and pictures) corresponding to the study case and the student, after reading it, is able to start the construction of the BN model for the diagnostic of the study case. The Domain Agent also presents a list of all nodes that can be related or not to the current case. Figure 4 presents the Dengue Fever expert’s diagnostic model.

The nodes “DC-S” (Classic Dengue Fever - Suspicion), “DH-S” (Dengue Hemorrhagic Fever - Suspicion), “SCD-S” (Dengue Shock Syndrome - Suspicion), “DH” (Dengue Hemorrhagic Fever - Confirmed), and “SCD” (Dengue Shock Syndrome - Confirmed) represent a definitive diagnosis for the case. The student’s challenge is not only to discover the diagnosis for the case (Dengue), but also...
to classify such pathology according to the different degrees of severity. Nodes are classified as diagnosis and/or findings ("triggers"). The findings are of the type trigger, essential, complementary, or excluder. Trigger finding singles out the diagnosis as a potential solution to the problem, when present. Essential finding must be present to assure the diagnosis identification. Complementary finding might be present to increase the probability of the diagnosis. Excluder finding indicates the diagnosis is improbable (i.e. it has a very low probability), if present. Of course, some diagnosis variables can be considered to find other diagnosis variables if the first are potential causes of the latter. The Domain Agent will use this classification together with the domain built-in model to inform the Mediator Agent about the differences between the learner solution and the domain model. As an example of the “trigger” node, see the “APA” (No Blood Pressure) in Figure 5.

![Fig.5. Network with a single trigger node.](image)

A positive evidence for this node is enough to indicate a later “positive” “SDC” distribution of probabilities (one diagnosis and evidence node). The nodes “FEB” (Acute fever of not more than 7 days), “MME” (Smaller events) and “AED” (Contact with Aedes Aegypti) from Figure 6 represent “essential” nodes in this network.
They are deemed essential because they are fundamental (all of them must be present) so that the final diagnosis of “DC-S” can be reached. Note that the node “MME” represents an “abstract” logic node, with a “positive” probability only when two or more of its parent nodes are also positive. According to the definition of the Health Ministry, a notification of classic Dengue Fever suspicion can only be made when the patient has acute fever for up to seven days, followed by at least two of the following symptoms: “CEF” (Headache), “DRO” (Retroorbital pain), “MIA” (Myalgia), “ART” (Arthralgia), “PRO” (Prostration) and “EXA” (Skin rash). Besides, the patient must have been in an area of Dengue transmission (AED). Note that the nodes “CEF”, “DRO”, “MIA”, “ART”, “PRO” and “EXA”, are examples of “complementary” nodes, because they help to set up a belief in other nodes (the MME node in this case).

As an example of an excluding node note the entity “FEB-S15” (High fever for 15 days or more) presented in Figure 7. The Domain Agent includes such variable in the list of nodes as a means of testing the student’s degree of confidence towards the topic. A patient with fever for over a 7-day period highly reduces the probability of Dengue. In such case, even with the complementary positive nodes MME and AED, the Domain Agent expects (according to the net above) that “DC-S” always has a negative a posteriori probability of distribution. After the learner models his/her network, the input of evidence is carried out based on the textual diagnostic investigation, according to the learner’s own interpretation.
Figure 8 shows an example of negotiation that occurred in one of AMPLIA’s experiments. The graph presents the evolution of a student’s performance during the experiment. The agreement attributes are presented as vertical columns in the graph. This graphic is generated on the fly by the Mediator Agent making it possible to visualise the student’s BN model construction. In each cycle of the interaction, defined by the BN model submission, the left column indicates the student’s Self-confidence, and the right column indicates the inferred Credibility. The horizontal line represents the BN model classification, from the lowest (Not Feasible) to the highest point (Complete).

In the first cycle, Self-confidence is Low, Credibility is Medium, and the network presented by the student is Not Feasible because it is not even a bayesian network (it has cycles or disconnected nodes) The tactic is to ask the student to identify the problem – presence of cycles or disconnected nodes. The student makes some changes, has no difficulties (High Credibility) and declares High Self-confidence, but the problem persists as the following cycle shows. The tactic suggests that the student should check the BN model again. Up to this point there are no negotiations, only different orientations, once there is not a BN.
In the third cycle, the student reaches a satisfactory BN model and his self-confidence decreases. The BN model is considered satisfactory because it does not lack any essential nodes (see Figure 6) and does not contain excludent nodes (see Figure 7). Figure 9 presents a hypothetical BN model presented by the student that is considered satisfactory.

All signals and symptoms from the clinic case are in the network. After inference tests, the Domain Agent checks if all the a posteriori probability of the diagnostic nodes are correct. The example, however, shows a common problem when the student’s and the expert’s model is compared: the presence/absence of “abstract” nodes. Note that the “APC” (Capillary Permeability Increased) is missing. This is a logic node that the expert created to summarize the presence/absence of parent nodes (in Figure 9, the student included only one such parent: AHT – 20% increase in the complete blood count – because it is the only one mentioned in the clinic case).

Pedagogical negotiation starts at this point: the first tactic selected is to raise hypothesis providing material, which can increase the student’s self-confidence, as it effectively happens in the fourth cycle when high Self-confidence and high Credibility are achieved and the student model continues to be satisfying.

In the fourth cycle the student BN model has not changed. This is an expected result of this tactic in the sense that, by reading the suggested material, the student started to trust his or her model. The Mediator Agent then starts a new pedagogical negotiation cycle in order to enhance the BN model quality until it is considered Complete (and the student maintains his or her high Self-confidence state). A student BN model is considered Complete when it has a good performance when compared to the expert’s model and to a database of real cases. That is why the student’s BN model does not need to be exactly the same as the expert’s, it may be even better.
The Mediator Agent uses complex heuristics to handle problems like the one presented in Figure 9. In the first step the agent looks for missing nodes. However, if the parents of these nodes are found in the student model (that is the case in the Figure 9 example), the Mediator Agent checks (using sensitivity analysis) if probabilistic results that are coincident with the specialist model still can be observed in the student model. Because all diagnostic nodes are present and still have acceptable \textit{a posteriori} probabilities, the Mediator Agent can assume that the student’s credibility is high, and then apply a more direct tactic displaying a list of lacking nodes so that the student can check what is missing.

The result of this tactic appears on the fifth cycle, when the BN model proposed by the student is considered \textit{Complete} by the Domain Agent. At this point the NP process can be finished in a successful state, because the BN model is \textit{Complete} and the student maintains his or her high \textit{Self-confidence} state and the system also believes in this (high \textit{Credibility} state).
Formal Model

The study and proposal of formal models for the PN process is an ongoing goal of AMPLIA’s project. This goal is related to the most general research purpose of AMPLIA (and other projects of our research group), which is to serve as a tool for the analysis and study of cognitive models that present viable computational interpretations, clear epistemological and psychological foundations and precise formal specifications. The formal specification is the answer to avoid excessive anthropomorphism: the formal definition of any concept is independent of subjective belief, perception or emotion about this concept, even when the concept that is being formalized is the concept of “subjective belief”, “perception” or “emotion”. The initial approach to formalize PN processes was based on the modeling of the communication interactions related to these negotiation processes. The semantics of these interactions were formalized over the probabilistic modal logic SLP (Gluz et al., 2006). This logic is an extension of the SL logic originally used to formalize the semantics of FIPA-ACL language (FIPA, 2002). SLP incorporates probabilistic $BP(a, \varphi)$ terms that denote subjective probabilities (degrees of belief) of a given sentence $\varphi$ to be true. Using these terms it is possible to represent BN models and probabilistic inference directly in the SLP logic.

The knowledge to be shared between AMPLIA’s agents form a hybrid ontology composed by several distinct propositions that represent the logical or the probabilistic beliefs these agents need to communicate one to another. Student or expert solutions for the study case are modeled by BN. Logical knowledge shared by AMPLIA agents is represented by four different logical propositions: $\text{StudyCase}(\text{CoS}, \text{L}), \text{Sol}(\text{CoS}, \text{L}, \text{S}), \text{Class}(\text{CoS}, \text{L}, \text{S}, \text{C})$ and $\text{Tactic}(\text{CoS}, \text{L}, \text{T}_t)$. These propositions represent, respectively, study cases (CoS) shared between the system and student L, the solution S that student L thinks will solve problem CoS at time t, the classification C, for pedagogical purposes, of the student solution S, and the new teaching tactics $\text{T}_t$ to be applied to help the student in the next cycle of pedagogical negotiation $t+1$. The probabilistic knowledge shared by AMPLIA agents is directly related to the probabilistic inferences made by these agents. The proposition $\text{Conf}(\text{CoS}, \text{L}, \text{S})$ expresses the degree of confidence that the student L had that his model S is the correct solution for the study case $\text{CoS}$ and $\text{Cred}(\text{CoS}, \text{L}, \text{S})$ expresses the degree of credibility that the Learner Agent assigned to the solution S made by the student L.

PN processes model all interactions that occur in the AMPLIA system. The main goal of a PN process is to set and reinforce a high level of confidence among its participants. It is not a generic confidence, but a very specific and objective one, related to skills the student has reached and shown with relation to the learning domain. The notion of confidence used in AMPLIA is directed towards an expectation of future actions of an agent, derived from the confidence notion defined by Fisher and Ghidini (2002). However, unlike the approaches taken by these authors, in AMPLIA it is allowed that these expectations have degrees, represented by subjective probabilities. The $\text{CF}(t, s, \theta)$ operator denotes the degree of confidence of teacher t that student s will do some action to solve a problem $\theta$. This operator is formalized as follows:

$$\text{CF}(t, s, \theta) \equiv \text{def} \text{BP}(t, (\exists e)(\text{Feasible}(e, \theta) \land \text{Agent}(s, e)))$$

By using $\text{CF}(t, s, \theta)$ it is possible to formalize which conditions it should hold at the initial and final states of PN processes, from the point of view of the system (see Flores et al. (2005), and Gluz et al. (2007) for details):
are modeled using BNs as they are based on uncertain knowledge. For more details see (Boff et al., 2007).

The COLLABORATIVE WORK IN AMPLIA

The main goal of the Social Agent is to stimulate student interaction. This agent creates workgroups to solve tasks cooperatively. The agent uses the strategy of initiating a BN construction to motivate students to interact with the environment, through the collaborative graphic editor. The network is built collaboratively, and there are some negotiation moments. Based on Conati et al. (1997) the agent’s preferences over world states are expressed by a utility function, which assigns a single number to express the desirability of a state. In order to infer the students’ personality traits the Social Agent uses the model proposed by Paiva et al. (2005), based on the OCC model (Ortony et al., 1988). For more details see (Boff et al., 2007).

When the student is invited to join the group, he or she may also accept/decline the offer. The groups are dynamically formed, based on the task being carried out. Each group must contain at least one student with the leadership role. Students with different levels of performance must also form the groups.

The Social Agent’s reasoning is based on individual and group features. Both reasoning modes are modeled using BNs as they are based on uncertain knowledge.
The individual level is represented by the features of each student. The information collected to define a suitable student for recommendation is: Personality Traits, Affective State, Acceptance Degree, Sociability Degree, Net Credit and Leadership.

The Sociability Degree (SD) or Social Profile is built during the students’ interaction through a synchronous mechanism. The following information is collected during the students’ interaction: number of times that a student had the initiative to talk with another; number of times that a student answered a communication request; individuals with whom the student interacts or has interacted, number of interactions and individuals with whom the student interacts regularly, and the total number of interactions.

Based on Maturana and Varela’s ideas (1998) we defined the Acceptance Degree (AD), which measures the acceptance between students. Such data is collected through a graphical interface that enables each student to indicate his acceptance degree for other students. As the AD is informed by the students themselves based on their affective structures, the value can indicate different emotions, such as effort, persistence, etc.

After a helping session, two questions (‘How do you classify the sociability of your class fellow?’ and ‘How do you classify the help given by your class fellow?’) are submitted to the student who got assistance, in order to collect information about AMPLIA’s performance. The questions are based on concepts from Social Networks and Sociometry (Moreno, 1953), and may be answered by qualitative values: “excellent”, “good”, “regular” and “bad”. So far, students have shown a strong interest to participate in the research project, answering all these questions, and even providing useful suggestions and comments. The answer to the first question along with the average of the ADs of a student, form his SD that indicates how other individuals see the social capability of this student.

The agent’s preferences over world states $S$ are expressed by a utility function $U(S)$, which assigns a single number to express the desirability of a state. For each action $a$ available to the agent, and for each possible outcome state $S'$ of that action, $P(S'|E, a)$ represents the agent’s belief that action $a$ will result in state $S'$, when the action is performed in a state identified by evidence $E$. The expected utility of an action is computed as defined in (5).

\[
U(a) = \sum_{S'} P(S'|E, a)U(S')
\]  

(5)

The Social Agent selects the action that maximizes this value when deciding how to act.

In order to infer the students’ personality traits we are using the model proposed by Paiva et al. (2005). The affective states can be considered as emotion manifestation in a specific time. Conati et al. (1997) modeled a BN to infer emotions. This research uses both models to give us states values to PersonalityTraits and AffectiveState nodes, see Figure 10.

The StudentNetCredit node represents a possible classification for the student’s BN model and is received from AMPLIA’s Mediator Agent (Not Feasible, Incorrect, Incomplete, Satisfying or Complete).

The Leadership node represents evidence indicating the students’ capacity to lead: a student that helps other fellow students, a student that gives his opinion during the execution of a task, or a student that makes several changes in the BN built by his group.

The group level takes into account the cohesion and the confidence the students have in their workgroup. The Social Agent’s reasoning is modeled in a BN, where the confidence node influences the cohesion node, indicating that group cohesion is based on the confidence of individuals in the group. Confidence is defined as the belief of the agent in attributes such as trustworthiness and honesty. When agent $a$ does not have any direct interaction with agent $b$, or it is not certain about the
trustworthiness of $b$, agent $a$ can make decisions based on the reputation of agent $b$, which may be obtained with other agents. After interacting with agent $b$, agent $a$ can establish its confidence about agent $b$ based on its degree of satisfaction in the interaction.

![Fig.10. Social Agent reasoning BN.](image)

![Fig.11. AMPLIA’s BN diagnosis process.](image)

The collaborative work is made by the group of students using the collaborative editor. The process of a Bayesian model construction is always followed by the system, which allows for an intervention whenever it is necessary. Figure 11 shows in the first window screen the student’s construction of the diagnostic hypotheses and the Mediator Agent explanation, that presents the
diagnosis result analyses from the students BN. The second window presents the BN built by the expert.

The argumentative resources, pedagogical strategies and tactics, intend to make the student reflect upon his actions, aiming to improve his diagnostic hypothesis. It is important to highlight that, although the learner’s and system’s arguments are different, the interaction language is the form of bayesian networks, whose meaning is commonly understood by the student and by the system.

EXPERIMENTS AND RESULTS

The first experimental phase of AMPLIA used seven medical students and eleven resident physicians from Hospital de Clínicas de Porto Alegre (HCPA), who attended study sessions from May to June 2005 in a course about probabilistic medical diagnostic. This experiment was supported by twelve medical professionals, all of them teachers from the Medical School of UFRGS.

The first set of experiments aimed to validate the pedagogical contents and strategies to be used in the course. The health professionals enrolled in the experiment came from different medical areas such as: surgery, anesthesia, psychiatry, endocrinology, cardiology, internal medicine, and nursery. To each area there is one BN that covers the pedagogical content to be studied (the expert knowledge). The objective of this first set of experiments was to validate if the BN used by AMPLIA is correct and adequate from the pedagogical viewpoints. The experiments were divided into two parts:

- The first part was focused on pedagogical resources, theoretical concepts on uncertain domains, probabilistic networks, and knowledge representation.
- In the second part, the teachers built the expert’s networks that were incorporated into the Domain Agent knowledge base.

The course goal was to show the AMPLIA learning environment to the medical teaching community. The goal was not only to validate the environment, but to make physicians aware that such a tool can be used as an additional tool in the qualification of young physicians.

Such an interaction and collaboration methodology has a fundamental role in the development process of the project, which allowed the constant evaluation of the environment features in several aspects (formal education, competences, preferences, etc.).

The observation of the student’s knowledge construction was based on the following variables: the quality of the student BN model, the student self-confidence in his BN model, the Learning Agent credibility about the student BN model, and the strategies and tactics used by the Mediator Agent to teach the student. The evolution of the first variable is registered in the Domain Agent’s log, the next two variables are registered in the Learning Agent’s log, and the strategies and tactics used by the system are registered by the Mediator Agent. Based in these variables we define the methodology used to observe the experiments. The observation of the AMPLIA experiments followed two methods:

**Method I:** unsystematic observation where the objective was exploratory and to point out eventual operational problems in the system.

**Method II:** direct observation through surveys constructed according to Marconi and Lakatos (2002). The objective was to observe and register student’s opinions and attitudes about the system. The observable parameters were selected based on the PN process. Data were collected using a model of opinion and attitude measurement. Attitude is meant to be the mental willingness associated with potential action and opinion is meant to be a conscious manifested mental position about something or
someone. Parameters were supported by indexes used in the assessment of the learning process in medical education, such as, skills, judgment capacity, knowledge application (Cleave-Hogg & Morgan, 2000), or related to academic development, such as self-regulation of their learning, cognitive and autonomous behavior. Also, there were observed points of the student academic performance (learning self-regulation, cognitive behavior and leaning autonomy).

The method II was implemented through six measurement instruments formed by surveys that collected data related to the initial and final state of the PN processes:

**Instrument 1:** a survey about the students’ learning model, to be answered by the teacher. This instrument is composed by two parts. The first contains personal and academic information about the teacher (name, sex, age, etc.), the number of years that the teacher works in this area, number of classes, subject of these classes, number of students in each class, and didactic resources that the teacher regularly used in his classes. The second part was an exploratory study of the student’s model for clinical diagnosis defined according to Meyer and Cleary (1998). The objective is to obtain data that allows the construction of the students’ learning model, from the teacher’s viewpoint. This survey makes the assessment of the PN state (the (IP.2) condition).

**Instrument 2:** a survey about the students’ learning model, to be answered by students themselves. As in the previous survey, the first part is composed by student personal data. The second part is the same one as in the survey 1, but now with the purpose of collecting data that allows the construction of the initial students’ learning model based on the student self-evaluation. It corresponds to the estimation of the PN state (IA.1) condition.

**Instrument 3:** a survey about the physician’s professional profile according to the students’ opinions. The goal is to collect the student opinion about the physician’s professional behaviour and about the actual academic curriculum design concerning ethical behaviour in the medical area. The survey also contains questions related to the student behaviour as a future physician. It corresponds to the estimation of the PN state (IA.2).

**Instrument 4:** this part of the data collection is specific about AMPLIA and tries to assess the impact of the system on the learning process, from the viewpoint of students. This survey was answered by the students after each AMPLIA work section. It is composed of questions about the student’s objectives during the work with AMPLIA such as: ‘What changes where caused by the contact with the system knowledge?’ These data sets provide information to assess the PN states (FA.1) and (FA.2).

**Instrument 5:** this survey collects the student evaluation of AMPLIA concerning the system interface, AMPLIA’s pedagogical strategies and the content. This part of the evaluation process corresponds to qualitative opinions that will provide the information necessary to make the system more adequate.

**Instrument 6:** this survey evaluates the teacher opinion about AMPLIA as a pedagogical tool. It provides data about the PN state (FP.2). Also in this phase, the teacher answers questions concerning his opinion about AMPLIA’s influence on the clinical diagnosis elaboration comparing it with the traditional resources used in the medical formation classes.

We also used the indirect observation method that corresponds to the analysis of the log files generated by AMPLIA’s Learner and Mediator Agents. With the Learner Agent logs, it is possible to observe information about the period of time that a particular student worked in the environment and the student actions during the BN construction. Through the Mediator Agent log files, it is possible to observe the student BN model each time he submitted it to the Domain Agent evaluation, the student BN classification made by the Domain Agent, the student self-confidence about his BN model, the
Learner Agent credibility level for the student (or group of students) BN model, and the pedagogical tactic selected by the Mediator Agent for each student. AMPLIA provides graphics, such as the one presented in Figure 8, which allows an on-line observation of these logs that shows the PN process in action.

The pedagogical impact of AMPLIA in the HCPA experiment was estimated by instruments 4 and 6. In order to define the questions that implement instruments 4 and 6, it was assumed that the common goals of all students that look for training were considered to be: professional competence qualification and assessment directed towards such a goal. As Glavin and Maran (2002) suggest, competence assessment should be based on Miller’s pyramid. From bottom up, it is composed of the following levels: knowledge (knows), followed by competence (knows how), performance (shows how), and action (does). The two first levels can be assessed through traditional oral or written tests, the following level through practical tests, but the last one can be assessed only through actual performance in habitual practice. On the other hand, competence assessment also encompasses cognitive skills, such as decision taking, problem solving, observation and planning. Apparently, the confidence level the student declares is related more to the student’s background than to actual and current competence. In AMPLIA, competence is defined as a diagnostic reasoning with a high probability of being correct (as compared to the expert’s model or to the database of real cases), associated to high confidence and autonomy.

The instrument 4 was implemented by two sets of questions (a) and (c) intended to elicit the goals students have when using AMPLIA, and evaluate AMPLIA’s help from the point of view of students. The questionnaire (a) was based on the translation and adaptation of the work by Meyer and Cleary (1998) in an exploratory study of student models for clinical diagnoses. This questionnaire contains four assertions about what are the student’s goals when using AMPLIA: to know how to make a diagnosis, to understand a diagnosis, to be confident to make a diagnosis, and to make a correct diagnosis. Students were asked to classify these assertions using a Likert’s scale. Students were also asked to respond to another questionnaire (c), using the same four assertions, but this time asking them to categorise AMPLIA’s help.

The goal of instrument 6 is to evaluate how AMPLIA can help students, from the point of view of teachers. This instrument was implemented by questionnaire (b), which used the same set of four goals of questionnaire (a), but this time asking the teacher to evaluate, using the Likert scale, how the use of AMPLIA as a pedagogical resource should help students to achieve these goals.

Figure 12 presents a summary of results of questionnaires (a), (b) and (c) in the HCPA experiment. From data presented in Figure 12(a) it is possible to see that the majority of students suppose that their main goal is to learn how to make, to understand and to be confident in their diagnoses. A closest near goal is to make correct diagnoses. Figure 12(b) shows that the majority of teachers also agree that AMPLIA helps students in these four tasks. They differ probably due to their professional experience as teachers or as physician doctors. Some teachers also evaluate that AMPLIA can positively influence students to learn how to make diagnoses. Data from Figure 12(c) show the viewpoint of students and there is also a reasonable match between student’s goals and help from AMPLIA. However, some students are not so sure that AMPLIA really helps them to make correct diagnoses, and to be confident of them. Although a little incongruent, these results were expected due to the constructivist, not directive, nature of AMPLIA. The PN process intends to make students think about what they are learning. This process is not intended to give them easy assurances about study cases.
Fig. 12. Results from experiments in HCPA.

(a) Students Goals when Using AMPLIA

(b) Teacher’s Evaluation of AMPLIA’s Help

(c) Student’s Evaluation of AMPLIA’s Help

Fig. 13. Results from Experiments in 44th Brazilian Congress in Medical Education.
A second set of experiments with AMPLIA was conducted in a Workshop at the 44th COBEM (Brazilian Congress in Medical Education) that took place in September 2006, where AMPLIA was used for the development of diagnostic reasoning abilities. The methodology to observe, collect data, and evaluate this experiment was the same as was used with the HCPA experiments. However, due to the short period of time of this experiment and large number of participants, only instrument 6 were measured, by checking how participants were evaluating: (a) the pedagogical methodology used by AMPLIA, and (b) the potential use of AMPLIA in medical education.

The results presented in Figure 13 correspond to the answers of 62 workshop participants, evaluating different aspects of potential applications and the pedagogical use of AMPLIA. The participant’s profiles were: 14% teachers, 7% graduate students, and 79% undergraduate students. Teachers and graduate students declared a medium level of computer use experience. Undergraduate students declared a higher level of experience in the use of computers.

Data presented in Figure 13(a) indicate that all participants believe that AMPLIA has a clear influence in the way students think about diagnostic processes, encouraging them to think about diagnoses starting from evidences. Figure 13(b) shows clearly the potential of AMPLIA to be used in autonomous study as an additional resource for medical education. Secondary tendencies show an expected use in virtual communities, most due to the recent inclusion of collaborative features. There is also a reasonable expectation of impact of AMPLIA in the relationship between teachers and students.

Pedagogical negotiation was also under observation through indirect instruments during these experiments (as seen in Figure 8). The work (Flores et al., 2005) presents main results of these experiments.

The experimentation of AMPLIA and its recent integration with the Social Agent are still under observation. However, the results obtained from these experiments had shown a reasonable convergence with the observations carried out by teachers who followed the students during the process of the network construction. This means that teachers probably would use tactics and strategies similar to those selected by AMPLIA, to mediate the learning process. Summing up, results obtained in these experiments have shown that our agents already achieved a considerable ability to handle educational goals.

**FINAL CONSIDERATIONS**

The paper discussed the PN process involved in the implementation of a real learning environment. It focuses on the formal aspects of the negotiation process, trying to abstract general features of this process. In AMPLIA the goal of the negotiation model is to increase: the performance of the diagnosis model developed by the student; the confidence that the tutor has in the students’ ability to diagnose cases; the students’ confidence of their own ability to diagnose cases; and the students’ confidence of their own ability to diagnose diseases.

During AMPLIA experiments we have been studying if the use of BNs as a pedagogical resource would be feasible and if they would enable the student to model his/her knowledge. Also, we have been observing agents making inferences using BN and selecting pedagogical actions for each student at each moment of his knowledge construction process. During the experiments all tactics provided in AMPLIA were used several times. The average for the student’s approval by AMPLIA was 4.6 (0 to 5) considering HCP and COBEM experiments. The number of declining students was only 11.
Through the addition of a Social Agent, AMPLIA also supports collaborative working, and promotes pedagogical strategies based on group activities. The combined system of AMPLIA and Social Agent already passed integration tests, and this integrated system is being used in experimental Medical courses offered by the Medical Faculty of UCS (University of Caxias do Sul). Presently we are analysing the empirical data collected during the experimental courses offered in 2007, trying to evaluate the impact of collaborative work and social pedagogical strategies on the learning process.

As future works we intend to make AMPLIA available over the Web. The student’s self-confidence declaration can also be approached, focusing the student’s emotions, which were not considered in the present phase. We believe that motivation is a relevant affective state in human learning and that it can be monitored and captured through observable features in student’s behavior when interacting with the system through communication interfaces. This acknowledgement is accomplished through constructions derived from a human agent’s observable behavior in specific contexts. Observable features are composed of parameters that can model the student’s motivation.

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