AMPLIA LEARNING ENVIRONMENT
A Proposal for Pedagogical Negotiation

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Abstract: AMPLIA supports training of diagnostic reasoning and modelling of domains with complex and uncertain knowledge. It focuses on the medical area, and it helps a learner to create a Bayesian network for a certain problem. A pedagogic negotiation process (managed by an intelligent *Mediator* Agent) aids handle the differences of topology and probability distribution between the model the learner built and the one built-in in the system. The negotiation process occurs between the agents that represent the expert knowledge domain and the agent that represents the learner knowledge. As a consequence, the learner visualises the organisation of his/her ideas, creates and tests hypothesis, and discuss them with the system .

1 INTRODUCTION

AMPLIA (Vicari et al 2003), primarily designed as an extra resource for the education of Medical students, aims to support the diagnostic reasoning development and modelling of diagnostic hypotheses in the medical field. It employs Bayesian networks for knowledge representation and reasoning about some case study or illness.

We are developing this Learning Environment for the research on negotiation and argumentation in agents' societies.

Negotiation is a complex interaction process between two (or more) agents that want to reach a common agreement over a certain situation. There is a wide range of possibilities, depending on the situation and the agents involved. Negotiations may happen, from the solution of conflicts between competitive agents up to task division among co-operative agents. In the present work, we considered negotiation basically as a process of decision that serves to solve conflicts that may arise from the interaction among agents. Thus, the process of pedagogic negotiation is defined as the solution of conflicts that may happen among agents involved in a teaching-learning environment, exclusively using strategies with a pedagogical profile for the solution of these conflicts.

For a real application, this definition is still incomplete because it doesn't specify the kind of agents that take part in a teaching-learning process, what is the result expected, which conflicts may arise and, finally, which pedagogical strategies should be adopted to solve these conflicts.

There is not an exchange of economic goods in any pedagogical negotiation process. We may suppose that negotiation mechanisms derived from Games Theory and Market Theory (Sandholm, 1999) (Jennings, 2001), would not be useful for this kind of negotiation. However, these mechanisms were generalised to operate with more abstract versions than economic values, such as utilities and preferences. We examine their applicability, checking whether the notions of preference or utility are appropriated in a process of pedagogical negotiation.

2 MULTI-AGENT ARCHITECTURE

AMPLIA provides the possibility of integrating the resources that an ITS offer and the learning resources related to the domain being studied. This could lead to courseware or to a human partner (either teacher or student) who may help the student to solve a problem.

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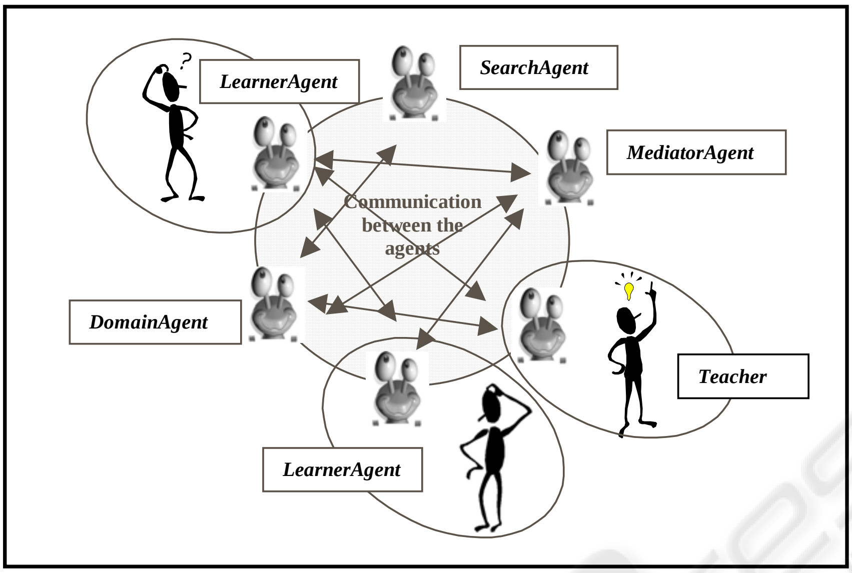

Figure 1: Multi-agent Architecture of the AMPLIA Environment.

A diagnostic component is compulsory to be there, for the development of an individualised teaching. The human agent may take part of this process, helping to identify the problem the student is facing when the software agent fails. This way, an architecture based on agents provides a natural synergy between human beings and software agents (diagnostic components, pedagogical agents, on-line help systems, intelligent web searching based on the semantic selection of support material)

This is the scenario we intend to reach with AMPLIA. The Figure 1 presents an outline of the AMPLIA Environment's Multi-agent Architecture. The starting point of our efforts is to set a co-ordination mechanism among the agents that inhabit this society. The interactions that occur between the personal agent, which represents the student in this society, and the diagnostic agent are seen as a pedagogic negotiation process, in which conflicts are solved with the aid of a pedagogical agent whose function is to set the discussion topic as the student's modelling task advances. The autonomous agents represent users (students, teachers and applications), and take part in a social interaction based on objectives in which they communicate, co-operate and negotiate between themselves.

Each agent has two different user's models that represent: (1) the objectives' model to be reached, either from the human user or from the application (in the case of human users, the user's objectives and preferences), and (2) a model of available resources of each user and/or application, which in the case of a user includes his/her cognitive resources (knowledge domain models, registers of experiments and skills). These models make possible that the agents argue about their objectives and plan their actions (e.g., suggesting to the student to search for help from other users).

A personal agent (the one that represents the user in the virtual environment) knows about the current objective (or preferences) and the user's resources level (knowledge), when it is evaluated by some diagnostic component specific of the application, or interface based on the task. In AMPLIA, such diagnostic application is represented by an expert agent (*DomainAgent*) and the personal agent (*LearnerAgent*) that may negotiate beliefs about knowledge. If the student argumentation skill is not enough to convince the diagnostic application, the personal agent asks for help of a pedagogical agent (*MediatorAgent*), able along the negotiation process. This pedagogical agent could search and contact a specific agent from the application domain (in order to make support material available to the user) or even contact an expert user to provide a description of the problem and to give help to the learner.

Once the user's objective and cognitive resources status (the Bayesian model of the case study proposed and the log of the user actions) are diagnosed, the *LearnerAgent* decides how to help the user to reach his/her objectives. Let's suppose that the *LearnerAgent* finds that the user it represents is trying to reach an objective (modelling a case study) using an incorrect tactics, for example, a cyclic graph (this means that the user lacks some resource, in this case, knowledge about the Bayesian network definition). The *LearnerAgent* may decide to teach the student using the pedagogical support the *MediatorAgent* has suggested.

The *MediatorAgent* could send a message to the *DomainAgent*, or to the intelligent search of web-based material agent, or can suggest a visit to a FAQ directory (or to a discussion forum) or contacting the personal agent of other user to ask for human help. The *LearnerAgent* decides to ask for pedagogic advice about which is the best pedagogic strategy. For that end, it contacts the *MediatorAgent* that helps in the pedagogic negotiation process between the user and the *DomainAgent*.

In AMPLIA environment, besides real students, there are the following artificial agents that are essential to the pedagogic negotiation:

- *LearnerAgent*, responsible for representing the student within the system, and acting in favour of its interests. This agent undertakes the student's role in the setting that is being discussed up to now.
- *DomainAgent*, responsible for representing the expert in the domain. This agent has the knowledge the student must study.
- *MediatorAgent*, responsible for mediating the teaching and learning process between the Domain agent and Learner agent. This agent partially undertakes the teacher's role, within the scenario that has been being discussed.

In terms of pedagogical negotiation the *LearnerAgent* represents the student, gathering all concrete evidences about the status of its learning process, registering the self-confidence level declared and trying to infer its confidence with relation to other agents of the system.

The *DomainAgent* and *MediatorAgent* share the teacher's role. The *DomainAgent* incorporates the knowledge base on the theme to be studied and, therefore, it has the higher confidence level about the topic. The *MediatorAgent* incorporates negotiation mechanisms needed to solve conflicts of this process, that is, teaching pedagogical strategies that can be used in pedagogical negotiation.

There are two major aspects in the accomplishment of such multi-agent system: (1) implementing the interaction between student and *LearnerAgent*, and (2) implementing the interaction among other agents.

2.1 The Interaction between the Student and the *LearnerAgent*

In AMPLIA, the student makes its argumentation by modelling a Bayesian network. (Rolf & Magnusson, 2002) affirms that the practice and teaching of reasoning and argumentation are adequate for the use of schemas. The student's manner of expressing him/herself occur through a graphic editor, where arguments are formed by nodes and links among them. Rolf & Magnusson classifies three levels of software that can express arguments through graphic structures. This classification takes into account the calculus used. Belvedere system, for example, does not have any calculus, constituting the first level; Athenas and Reason!Able systems are in an intermediate level, having some numerical naming and rules for filtering the best arguments. AMPLIA is at the third level, having an advanced mathematical theory, based on Bayesian inference. All these systems, except AMPLIA, do not present a mediator in the learning process.

The procedures analysis of the student's during the network building is also a function of the *LearnerAgent*, which infers the credibility (expectation) that the system has on the student. A high expectation or credibility is computed, if the student effectively demonstrates autonomy and confidence in his/her actions.

Three credibility degrees are defined.

- *Low Credit*: attributed in indecision and low confidence cases, for example, when the student constantly erases and puts nodes again.
- *Medium Credit*: when the student uses the system help spontaneously, or when he/she builds a network model which is less efficient than the previous one.
- *High Credit*: when the student builds his/her model autonomously, using even resources out of the environment, as for example, web-search mechanisms.

The credibility that the *LearnerAgent* infers is translated, by the *MediatorAgent* point of view, with more or less autonomy to the student, not directly interfering in the strategy, but in the tactics that leads the student to a more active or passive action.

2.2 The Interaction among Agents

The negotiation process follows the following protocol.

(1) The *DomainAgent* presents a case study for the student. The *LearnerAgent* only takes notes on the example and passes it to the student.
(2) The *DomainAgent* made available the case studies from where the student models the diagnostic hypothesis. The student models the diagnostic hypothesis, and sends (through the *LearnerAgent*) his/her model to the *DomainAgent* to be evaluated. This evaluation refers to the importance of each area in the model (trigger, essential, complementary...).
(3) Based on the result of the *DomainAgent* analysis and on the confidence level (declared by the student) supplied by the *LearnerAgent*, the *MediatorAgent* chooses the best pedagogic

strategy, activating the tactics suitable to a particular situation.

(4) The student evaluates the message received from the *MediatorAgent* and tries to discuss the topics which considers important, by changing its model. At this stage, the student may also decide to give up the learning process.

The AMPLIA's negotiation process occurs in a dynamic choice of strategies. The parameters considered are linked to student's beliefs, to the evaluation carried out by the *DomainAgent* and to the observations registered by the *LearnerAgent*.

In this negotiation process, both the student and the *DomainAgent* have the possibility of giving up the interaction. The *DomainAgent* only leaves the negotiation process when the student presents a solution, whose performance is equivalent or better than its model. The *DomainAgent* may come to accept the student's modelling, although it does not correspond exactly to its model, but the student uses the arguments to solve the study case problem presented to him.

3 PEDAGOGICAL NEGOTIATION

Pedagogical negotiation requires we know its key role along a teaching-learning process, namely which are the final objectives of this process and how negotiation may help to reach them.

In traditional negotiation processes, based on the Economic Theory, the result is the maximisation of gains expected by the agents. We expect to find a solution that maximises gains of agents in relation to all possibilities of solutions to the current negotiation. Gains are measured through a *utility function* known by the agents The problem lies exactly on the presupposition that an agent knows how to determine the utility in a given situation, as well as in situations derived from its actions (Sandholm, 1999). This does not happen in a teaching and learning process, because, it is difficult to realise how a student generates all his/her preferences.

The same is valid for the teacher. Simply, it is not reasonable to presuppose that the teacher has total knowledge on all situations that may happen in a teaching-learning process. Students can present results so that, even they are not in accordance with the teacher's expectations, they can be perfectly acceptable in terms of teaching objectives intended.

We observe that results of a pedagogical negotiation should be related to the final objectives of teaching-learning process, as well as the concept of preference or utility for an agent are not enough to characterise results expected in the pedagogical negotiation. As a solution for these problems, we adopted some simplifying presuppositions, based on the common sense, with which we expect to contribute to elicit more this issue.

A primarily presupposition is not to approach the teaching-learning process directly as a *knowledge transference* process. Characterising the process in this way implies to consider the need for solving classical epistemological issues that do not have concrete answers: what is knowledge? How could it be transferred to another person? How to measure a person's knowledge? To this claim we add the discourse of pedagogical models supported in the Piaget's genetic epistemology (Piaget, 1970), where the subject builds knowledge through interactions.

We will use the notion of confidence that an agent can have in relation to another (or about itself) analysed aiming at maximising this relationship as the process evolves. We will adopt the notion of confidence based on the expectation of future behaviour of an agent in relation to another (or to itself). The idea is that the "expectation of future behaviour" may be evaluated more precisely than the perception of "how much this agent knows on theme".

Considering the teacher-student learning scenario, a first step in the characterisation of the teaching-learning process is to attribute distinct objectives for each role. In a constructivist point of view, the teacher role is to mediate the interaction process in such a way that the student can explore and ask questions about facts, think about them and formulate hypotheses. In this case, certification can be translated through the confidence level that the teacher has on the student, when he/she is in known, and mainly new, situations, where knowledge assimilated and already set or new reasoning and hypotheses are required.

Relating to the teacher's role, as a mediator of the teaching and learning process, it should be considered not only the relationship of confidence between teacher and student, but it is required an inverse analysis, that is, the relationship of confidence between student and teacher. Thus, there are two important characteristics to outline in the student's behaviour. (1) The student is confident on the teacher's appraisal capacities during the development of contents. This statement does not imply necessarily that the confidence level is complete, i.e., that the student should blindly trust the teacher. What is said is that there should be a reasonable level of confidence, and that it should be undertaken so that the teaching and learning process can be accomplished. (2) Definition of what the student expects as a result of the teaching and learning process. The simplifying presuppositions is to undertake that the student expects to reach a level of knowledge that makes possible to understand and solve situations or problems within the area or discipline that is being studied. The point is not exactly what the student intends, but how we could have concrete evidences that this objective was reached.

The teaching-learning process could be seen as a way of reducing the initial asymmetry of the confidence relation between teacher and student and the topic studied, maximising the confidence of all. Putting this into a scheme:

- Beginning of the teaching and learning process:

Teacher:
(IP.1) High level of confidence in the capacity of value the topic approached.
(IP.2) Low level of confidence in the student's capacities to deal with this topic.
Student:
(IA.1) Low level of confidence in the capacity of value the topic approached
(IA.2) High level of confidence in the capacity of value the topic approached.

- End (expected) of the teaching and learning process:

Teacher:
(FP.1) High level of confidence in the capacity of value the topic approached
(FP.2) High level of confidence in the capacity of value the topic approached.
Student:
(FA.1) High level of confidence in the capacity of value the topic approached.
(FA.2) High level of confidence in the capacity of value the topic approached.

Conditions **(IP.1)** and **(FP.1)**, as well as **(IA.2)** and **(FA.2)** should not change, being only bases for an adequate beginning, development and end of the process. The effective result of the process would be the increase in the confidence level of the teacher in the student: **(IP.2)** for **(FP.2)**, and of the student in himself/herself: **(IA.1)** for **(FA.1)**.

3.1 Formalising these objectives

There are several ways of analysing the confidence among agents, and it is possible to characterise several important aspects of this notion. According to (Castelfranchi & Falconi, 1998), trust relations among agents depend on mental states and, therefore, only agents with mental attitudes (beliefs, desires, intentions, etc.) can trust one another. We assume a weaker notion of trust towards an expectation of future actions of an agent, similar to the confidence notion defined by (Fischer & Ghidini, 2002). Their notion of confidence is based on a modal logic of beliefs and abilities, which is intuitive, according to the idea that we trust somebody when we know how this person will behave in certain situations.

Some comments should be made, comparing modelling outlined above for the teaching and learning process and the formal notion of confidence defined in the work by (Fischer & Ghidini, 2002), which is given in the formula $B_i \Diamond_j \varphi$. In this formal expression, there is not space for a "level of confidence", or the agent i believes that j will eventually make φ, or not. A possible approach to deal formally with this incongruous feature is to undertake this kind of belief, everything or nothing, and try to structure the belief object, formula φ, splitting it into sub-formulas φ1, φ2, ..., φn logically related to φ, in a way that φ1, φ2, ..., φn necessarily imply φ. Another way would be to deal with probabilities linked to a logic formula explicitly, using, for example, the PROB(φ) operator, defined in the work (Rao & Georgeff, 1991), which attributes a probability $PROB(\varphi) = \alpha$ that the formula φ is true in a certain possible world.

In the present work, the last approach will be used having in mind the notorious drawbacks of defining a generic method of structuring some formula in terms of its most important components (a problem similar to the knowledge structuring). For example, supposing a scenario composed of an agent **p** professor, an agent **a** student and a proposition φ, that states the answer to be required. When facing a questioning on the theme being studied, we have that propositions **(IP.2)** and **(FP.2)** may be formalised as:

(IP.2) $B_p\ PROB(\Diamond_a \varphi) = \alpha$

(FP.2) $B_p\ PROB(\Diamond_a \varphi) = \beta$ where $\alpha \leq \beta$.

Coefficients α and β are probabilities used to indicate the confidence level or expectation that the student a eventually hits the answers asked in φ (or that he/she states the entire proposition φ complete, which is the same). In the beginning of the teaching-learning process, the teacher has a low expectation α that the student gives the correct answer. After this process, the expectation should increase to a new coefficient β. It is important to highlight that, from the formal point of view, effects of negotiation in a teaching-learning process can bring two kinds of changes in the formulas given above: they may both change the logic proposition φ related to the topic approached or change the final expectation β (or even the α initial value) of this process.

3.2 The role of pedagogical negotiation

Although the teaching-learning activity can be considered a process of "equalising" confidence levels, we can not presuppose that it has a linear, monotonic and continually increasing behaviour, also, we can not guarantee that this process will increase a certain confidence level step-by-step (linear), without interruptions (monotonic) or drawbacks (continually increasing) until it reaches the required level. Evaluation conflicts between teacher and student are common, and so it is needed to adopt a negotiation process in order to solve them through argumentation mechanisms, with the aim of strengthening the confidence relation between teacher and student. The expected result will be to increase the confidence level among all agents.

Another important issue is the definition of with teaching and learning strategy should be selected. The present work undertakes the constructivist approach, which is being introduced into AMPLIA system (Seixas et al, 2002), where the student will have an active role in the learning process and the teacher will be the mediator and motivator of this process proposing reflection strategies in problem solving. The main pedagogical strategies adopted are positive strategies turned towards student's motivation, and not only negative ones to identify student's "mistakes" and "problems".

3.3 A hypothetical pedagogical negotiation process

The Figure 2 above intends to represent a hypothetical pedagogical negotiation process, step by step, in AMPLIA.

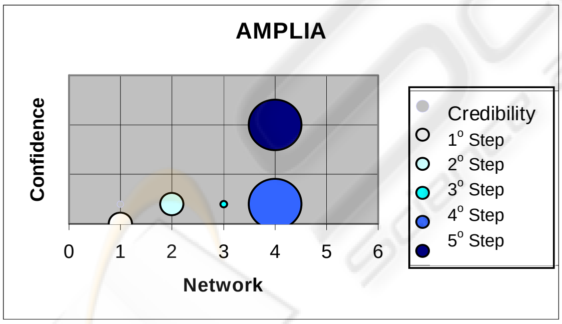

Figure 2: Hypothetical pedagogical negotiation process

The vertical axis represents the confidence level the student declares (self-confidence). (Just for representation reasons, three confidence levels are shown). The system understands this as the students attitude towards the negotiation process. So, if the student declares a *high confidence*, the system interprets that the student feels him/herself very secure and he/she doesn't want to do meaningful changes in the model. On the other side, in a *low confidence* situation, the system believes the student will be open to receive help, because he/she feels secure about his/her model. So the second student will be more ready for a negotiation process than the first one.

The horizontal axis represents the students network evaluation results, carried out by the *DomainAgent*. The network is tested for its qualitative and quantitative aspects and according to it, the *DomainAgent* classifies the network as *not feasible* (the network has cycles or not oriented nodes), *incorrect* (there is an excluder node), *incomplete* (absence of important nodes), *feasible* (it is not the same as the specialists model, but it satisfies the study case) or *complete* (it is identical with the specialist model).

The size of the circles on the graphic represents the credibility (expectation) the *LearnerAgent* infers, based on the students actions during the network construction process. Three credibility degrees are defined, presented in the section 2.1.

The graphic represents five steps of a negotiation process. At first, the student has informed a low confidence in his/her model. This model was evaluated as incorrect, and the credibility the system has inferred is medium. The negotiation process is directed to the network construction and to the students self confidence. Now, in the second step, the student declares a medium self confidence level, and the model, although it is not incorrect, is not feasible. The credibility the system has inferred remains as a medium value. The negotiation process is once more directed to the network construction and to the students confidence. After that, now being the third step, the student declares his/her confidence as medium level, the network is incomplete and the credibility the system has inferred is very low. So the negotiation process is carried out, involving the network construction, the students self-confidence and the students autonomy too. At the fourth step, the student still states medium confidence in his/her network, but it is evaluated as feasible and the system infers a high credibility. At this moment, the negotiation process is focused on the student's self confidence, which has to be enlarged. At the fifth and last step, the student's confidence is high, the network is evaluated as feasible, and the system has a high credibility in the student's actions. At this moment the system considers the negotiation process is finished, because the confidence degrees between the student and the system were levelled, the student's model is feasible and the system believes the student can act autonomously.

4 FINAL CONSIDERATIONS

In intelligent teaching and learning environments pedagogical agents take different kind of roles. These agents adapt the environment to the needs of the student, based on the student profile that is composed by information provided by the student or inferred by the agent, as in (Souto et al., 2002). Pedagogical agents can also assume the role of “tutors” that, based on the observation of the student activity, show hints or make suggestions to the student, attempting to conduce his/her actions toward the solution of some problem, like ADELE (Johnson & Shaw, 1997), ANDES (Gertner et al 1998) or SE-Coach (Conati, & VanLehn, 2000).

In AMPLIA, the pedagogical agent works like a mediator in the knowledge construction process, acting directly in the interaction between subject and object, through a “dialogical” relationship that can be called “negotiation”. Negotiation is directly linked to the pedagogical way of how to make a student to develop his diagnostic reasoning, refining his/her learning ability

The set of ideas described until now, show our point of view of how to analyse, interpret and model the complex phenomena that occurs in the teaching-learning process, at least in some very restricted domains of graduate level medical education. The validation of these ideas and the generalisation of them to new educational domains or other areas can only occur with time and with real world application and testing. So we need to set-up experimental evaluation courses and effectively use AMPLIA in these courses.

We have taken a two-level evolutionary strategy to project and build the AMPLIA environment. In the basic level, we first develop prototypes for our three types of agents, then we specify an initial model for their communication and finally implement the communication tasks in each kind of agent, extending their abilities to cope with new needs derived from communication (that is create new prototypes of the agents). At this point we can return to the specification of the communication modelling adding new elements to it and returning to the prototyping phase or we can proceed to the next level. The following level takes place in a real teaching environment, that is, in this level we proceed with one experimental course, evaluating at the same time the positive (and negative) effects of the AMPLIA environment and taking note on any lack of feature or resource of the environment and also trying to figure out how it can be improved.

Currently we are in the final phase of development of the individual agents and already have made the initial modelling of the communication. Indeed we are starting to implement the communication acts in some of the agents. To this purpose we have assumed a strong commitment to current standards of communication languages and protocols between agents, that is, we are committed to restrict the communication of our agents to FIPA standards, provided that they exist to the application we need. For example, currently all communication is carried by standard query-ref, query-if, request, propose and similar acts, following standard query, request, propose and other interaction protocols. The content language adopted to exchange information and knowledge between agents is FIPA-SL.

However, we already have detected an important problem in FIPA content language standard. Simply there is no support to represent probabilistic information. So as it can be easily seem in sections 2 and 3 our agents do not only exchange probabilistic information but they need to negotiate, argue and discuss intentionally over probabilistic propositions. To solve this problem we have taken an pragmatic approach, by extending FIPA-SL to support Bayesian networks contents and incorporating an operational semantics to these inserted probabilistic propositions in the agents.

To easily integrate AMPLIA with current Internet infrastructure, we have chosen to use only HTTP protocol to transport FIPA communicative acts. This kind of transport solution is not only completely sanctioned by FIPA, but has the beneficial effect of allowing the communication between agents pass through firewalls, filters, routers and other network devices, which is a important advantage when we start to use AMPLIA in a WAN environment as distance learning tool.

We intend to start to evaluate the AMPLIA with experimental courses in the second quarter of 2004. The first courses will occur in a LAN environment, to allow the direct observation of the effects and results of the application of the environment on the subjects (students) and the fine-tuning of the AMPLIA. Only after these first local and carefully observed tests we have the intention to evolve our environment to work in a WAN (distance learning) context.

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