On the use of a constructivist framework to support Collaborative Learning in Teacher Life-Long training in Technical Areas[1]

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Abstract *— Brazilian math assessments are an important social problem nationwide. The teachers´ skills are one of the most important variables to consider in this situation and the use of educational technology contributes significantly to improve the students´ achievement. Moreover, if we can provide distant courses, we can reach a broader range of teachers. AMADeUs, our project, is based on the principle that a multi-dimensional learner evaluation is very important to build a better picture of students' development and participation. Design decisions are taken based on experiences with matematica.net; pilot studies are been conducted to orient the design processes and a methodology for this type of courses.*

Index Terms — Teaching, Learning and Assessment Strategy in Virtual Classroom, Intelligent Training Technology.

INTRODUCTION

Nowadays, computational environments for Distance Education (e.g. BlackBoard, WebCT) are mostly generic tools that allow for course creation without any link to the domain in question. Furthermore, they do not offer any specific support for neither the student nor the teacher.

A common way of designing and implementing environments is based on instructionism, which considers that good presentations of knowledge are enough to guarantee learning. This suffers from a serious limitation: little or no consideration for the learner's needs. Works in AIED (Artificial Intelligence in Education) have been striving to solve this problem for a long time.

As far as distance learning goes, there is a gap to be filled with the application of higher-level educational environments, which, not only provide better tools for the teacher, but also that provide adequate support for the learning process. As far as teaching is concerned, we should aim at providing support not only for the teacher to follow the learning of specific concepts, but also for him/her to follow the evolution of competencies such as organisation, group interest, and communication. Thus, methodologies for multi-level evaluations are of great interest.

The computational system we are proposing not only incorporates evaluation techniques, but also caters for the processes of negotiation (amongst learners, and learners and teacher) and mediation. This is achieved by the use of intelligent support agents that will help users. In its first application, our platform will be used for teacher formation.

The AMADeUs solution stems from the necessity of implementing an architecture that took the domain specific needs into consideration. The first domain was elementary math teacher continuous formation and computer science undergraduate students.

This paper is organised as follows. The first section describes our motivation. Then we present some environments used in teacher formation. The third section introduces a model for a collaborative learning support system including both traditional collaborative tools and content guided tools. The fourth section describes the intelligent support in development. We then describe a proposal for a multi-level assessment technology and present a user centered design approach. Finally, we present our conclusions and references to future work.

MOTIVATION

There are important assessment problems associated with maths learning in elementary levels [48]. In general, students finish secondary courses with minimal knowledge, (i.e. with competencies to solve primary maths problems). In the last three years of school, no more knowledge is acquired. The same report indicates that assessments improve significantly when educational technology is used in learning.

In this light, we can see that there is a clear need to better form maths teachers. Actually, formation courses occur in various ways, the main distinction being the number of teachers and distance from formation centers. In the first case, if the number of teachers is too large, administration prefers to organize single, short-duration events. In the second case, teachers are trained by private consultants. The interventions are usually brief and non-systematic. Graduate professionals, with short pos-graduate formation, conduct those courses. In both cases, teacher participate in short time courses without continued evaluation.

Many authors indicate that teacher's formation should be organized as a continuous process. Information technology can be an alternative solution to make it feasible. In our project, teachers are engaged in communities of practice and were accompanied with mixed methodology. Virtual and classroom activities are combined and distributed in a long-term formation program. Post-graduate tutors assisted the teachers. Also, teachers were able to work

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and challenge peers from the same school and far from those work place.

SOME POSSIBLE SOLUTIONS

The socio-constructivist approach to learning [18] suggests that the learner is part of a social group, and, as such, should be able to question, discover and understand the world in which he/she is inserted. The boom of communication technologies has made it possible for us to implement computer environments that take advantage (and encourage) group interaction. Such environments are known as Computer Supported Collaborative Learning Environments (CSCLE). Amongst the various possibilities for CSCLE, we want to focus on the tecnology based on projects. The idea is to teach based on discovering solutions for real life problems. According to [39], knowledge and ideas emerge from situations where we need to learn from meaningful experiences. Boud, Keogh e Walker [25] define reflection as being the act of mulling things over, and trying to understand our own experiences. This is a fundamental skill in learning, and is also the one we lack most. When talking about reflection, we cannot leave out the process of articulation. Self, Karakirik, Kor, Tedesco and Dimitrova [33] define articulation as being the act of verbalising our thought processes. Amongst the main benefits of this are the fact that verbalising might help us develop our thought processes; articulating something brings its weaknesses to light, and may generate interesting discussions on the topic.

As a general rule, collaborative learning is more productive when participants are engaged into open-ended problem solving. A possible way of constructing these learning situations is to propose projects involving learner groups and to provide intelligent support that reinforces the ideas of reflection and articulation.

A project can be defined as a process that is divided into stages, related to one another, forming a flow. Each stage can be evaluated through the execution some tasks. The environment we are building is based on the idea of workflows – which allow us to visualise and evaluate the work being done in the different stages of the project. The idea is to provide tools for evaluating tasks, monitoring group interaction and evaluating the learning process.

THE AMADEUS USER CENTERED DESIGN

The AMADeUs´ initial architecture was based on a literature review together with the participants´ experiences in various areas. The AMADeUs team is multi-disciplinary, consisting of teachers, Educational specialists, Psychologists, and Computer Scientists.

The interface design is centered on users´ actual practices in a user centeder design routine [35] [36]. As the design progressed, we incorporated tools for intelligent support and group monitoring and formation. Part of our new insights came from the case studies we have carried out – as described below.

Case studies

We have carried out a first course to observe the parameters that could orient the interface and architecture design processes. The syllabus focused on maths´ teaching and learning with educational software. Ten (10) teachers from a public school in Recife participated in the study.

The course was focused on the use of educational technology in maths education. We organized interleaved sequences of theoretical meetings and experimental classes with educational software sessions. Both were conducted at the school. The course had six modules: introduction to educational technology in mathematical education, additive structures teaching and learning, multiplicative structures teaching and learning, fraction teaching and learning, function structures teaching and learning

We adopted a mixed methodology encompassing local and distant seminars. The course was programmed to last one year. The local meetings were conducted twice a month, lasting three (03) hours at a time. Those meetings were interleaved with virtual discussions through both synchronous and asynchronous communication tools. By observing the activity in the discussion list environment, we have concluded:

- This first experience was very hard. Teachers were really skeptic about distance learning.
- Participants´ engagement during chat was modest. Discussions were difficult to mediate and anonymous contributions confused participants.

User Needs and User Centered Design of Teaching Support Environments for E-learning

In order to investigate solutions that aid educators in their educational practice in e-learning environments, this paper presents the analysis of some of the Educators' activities to understand their tasks in executing their jobs. Thus, the complexity of the tool's appropriation tends to be reduced, centering the development of the whole design in the users, their needs and their tasks. We have chosen three teaching activities to start with: course planning, teaching materials creation and delivery and evaluation/tutoring. This choice is based on the fact that there is a shortage of tools to support these fundamental (and yet non trivial) tasks.

This work argues that Educators need to modify their activities in order to fit with some existing tools in e-learning environments. This sometimes promotes a restriction of what could be accomplished and limits the Educator´s creativity, thus entailing possible failures during the course development.

Questions such as: how these environments support real teachers' activities, which activities are exercised in these environments and whether the support available is carried out efficiently and in agreement with the educators' practice, are more and more necessary to aid educators to teach in a reflexive way, making their tasks more flexible and dynamic.

Based on a questionnaire that investigated teachers' procedures in planning, delivering and tutoring, we interviewed twenty Brazilian Educators experienced with e-learning environments and performed a qualitative data analysis with a software named NUD_IST (Non-numeric Unstructured Data Index Searching and Theorising). The reason for choosing NUD_IST was the difficulty classification and analysis of not structured data used in this research. This resulted in a classification of teachers' tasks which was used to build prototypes of tools to aid teachers in planning their courses, delivering their materials and tutoring the students. As argued in [35] [36], we believe that understanding users´ needs is a success factor in product development. This motivates us to use User-Centred Design (UCD) to guide our task on developing the tools´ prototypes.

At the time of writing we are specifying our systems use cases based on [35] [36], considering the user needs and requirements. The use cases elaborated in the specification will be validated in an e-learning environment named AMADeUs (Microworld Agents and analysis of the development in the use of instruments). The objective of AMADeUs is the construction of an e-learning environment based on the microworld concept [2], methodologies and tools that allow a significant progress of the reflections on teaching technologies [44] and an improvement in the use of those technologies in the teaching-learning process.

The planning and creation course use case resulted in set of procedures that would be performed by teachers, which include the elaboration of a course program, with its objectives, activities, bibliography, calendar, evaluations and communication tools. The teacher materials creation and delivery use case resulted in elaborating teaching materials guide and also in a set of procedures to complete the delivery according to their needs; and the results from the tutoring use case based on the task that students activities may be traced, driving the best way in their learning, aiding tasks execution and obtaining subsidies for its evaluation to define systems' tools.

User-Centered Design of Workflows in E-Learning

The socio-construtivist learning approach [18] suggests that the learner must have the initiative to question, discover, and understand the world through his interaction with the other elements of the historical context of which he is part. In this philosophy, we singled out the use of technology in cooperative learning based in projects [50], whose objective is not only to incorporate up-to-date access to information, but mainly to promote a new learning culture through the creation of environments that foster the making and exchange of knowledge. The method based in project was devised to teach through the discovery of solutions for real.

The development of a project can be defined as a process, divided in stages related one to another, forming a Workflow. Each stage is evaluated through the execution of one or more tasks that must fulfil certain objectives, and generate some products.

Some of the features of cooperative learning based on projects are [14] [15]: consider the expectations, potentialities, and needs of the students; build the necessary space where teachers and pupils have autonomy to develop the cooperative learning process with reciprocity, responsibility, and honesty; develop the ability to work as a team, make decisions, facilitate the communication, and formulate and solve problems, develop the ability to learn how to learn in such a way that each one may rebuild the knowledge through the integration of abilities according to his universe of concepts, beliefs, and values.

We believe the most natural way to promote the teaching based in projects in a web-based learning environment – using workflow technology as its base [Georgakopolous1995]. However, the existing Workflow (e.g., StaffWare [www.handysoft.com], LotusNotes [www.lotus.com], BizFlow [www.handysoft.com]) Management Systems were not conceived with educational environments in mind, which is why they do not satisfactorily tackle actions such as teaching, evaluating, and orientating. On the other hand, the majority of Virtual Learning Environments (VLE) (e.g., Blackboard [www.blackboard.com], LotusLearningSpace [www.lotus.com], WEBCT [www.webct.com]), don't offer management and automation tools for educational workflows. Generally, it's up to the teachers and students to externally plan a cooperative project, and to propose support mechanisms to make it feasible. Special instances are VLE with Workflow Flex-eL ([www.flex-el.com]) [44], and VLE based on Zebu Projects [14].

Our proposal aims at creating a virtual project-based learning environment whose cooperation process is promoted by the integration of comunication functionalities with an educational workflow. This environment, named AMADeUs [46], is a generic framework offering adaptative teaching tools centered in group work. Tools to allow the implementation of a constructivist evaluation proposal taking into account all the stages of the workflow are in the process of being developed. The basic idea is to create a structure to stimulate the emergence of the right distance-teaching actions through the most representative users, which are, teachers, pupils, parents, content-makers, coordinators, and managers.

The development process for this system takes into account methods and tools for the ethnographic analysis of formation activities [38] [40]. We used a Software Engineering undergraduate course as a use case. The first part presents a social analysis starting from data collected from transcriptions of interviews and dialogs between teachers and pupils in the presence of observers, and an e-mail list used to facilitate the communication between members of the group [45]. The first requirements are then produced from the classification of the information collected using Nud-Ist. In the second part, the system modelling using scenarios [37] and UML diagrams that embed qualitative information in each task to perform [35] begins.

Initially, we adopted a component-oriented development technique using JAVA and XML (eXtensible Markup Language) in a three-layered framework (adaptative interface components, workflow components, and communicaton middleware) [1] [42]. New ethnographic analysis is performed for the study of the structure of the activity using the new tool. The development cycle ends when the study of the social activities points to a satisfactorily employment of the tool by the user.

THE AMADEUS ARCHITECTURE

One of the main novelties about our project resides on our use of constructivism to allow the implementation of an assessment system that permits a continuous evaluation and diagnosis of the learning process, differently from most on-the-market learning environments. Furthermore, we also intend to promote effective collaboration by organising participants´groups in project teams, and guiding their interaction [31] in accordance with the guidelines for effective collaboration defined in [34]. We have also taken special care while designing the interface – we have used user centered design techniques [referência aqui] and taken users´ awareness into consideration.

Our initial model consists of several agents, three of them directly concerned with intelligent support. The idea is to evaluate the entities´ performance during construction of the first prototype. The results obtained then will show us whether we need to modify agents' funcionalities. The system's architecture is shown in Figure 1.

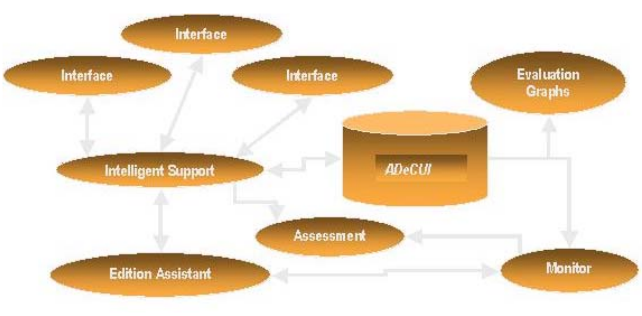

FIGURE 1
THE AMADEUS ARCHITECTURE.

Since we want AMADeUs to be as generic as possible, we have been also thinking about a way of using its core with computer science applications. To us, one of the best ways to do it is to build a tool for collaboratively carring out projects. According to [14] such environments must provide tools for: defining processes to account for collaborative process; selecting and implementing tools for performing project-related tasks; storing and retrieving information about past projects; using the internet as its basic platform. Thus, we will be incorporating tools for guiding the collaborative process in the AMADEUS framework [56]. One of the most effective ways of doing so is to incorporate intelligent support agents that help participants interact, reflect, and thus reach more refined solutions.

Cooperation Components

In AMADeUs, there are several environments students (and teachers) can interact in. We have provided environments for individual learning (interfaces, email box, pigeonhole), for group interaction (lists, chats, foruns, evaluation central, common workspaces) and so forth. We have paid special attention to group formation and negotiation issues and evaluation.

We have also provided space teachers to interact with one another and to find better ways to perform their activities (planning of courses, tutoring, evaluation). In fact, we are working on finding out a methodology to design tools for the teacher to use.

Awareness Interfaces

The first results obtained during a pilot study have indicated that asynchronous user component web interfaces are too complicate for use. Maths' teachers, as a significant number of teachers in elementary education, are not familiar with information technology. Our main intention concerning the interface is to create extremely simple web interfaces that approximate, as much as possible, users' models concerning cooperative learning to teach. Another principle adopted in web design was that signaling co-presence could improve cooperative initiatives and facilitate the users´ conceptualizing process [23].

Our aim is to create, through the interface, awareness of social participation, with specific roles and objectives, but interdependent with each other through social contracts.

The group's coordination, as promoted by expert tutors, intends to facilitate group conscience emergence. As we have already mentioned, the intelligent support provided will aim at reinforcing good collaboration – and that certainly involves group participation from all members. The main semiotic principle is the limited number of elements and signs in the web interface. The interface is also used to communicate co-presence in the web site. Participants can follows peers and tutors navigation through little signs on the pages.

User Software Component

The most important collaborative component is a middleware component, a shared workspace. Its architecture is open, what allows the use of different contents-oriented educational software in training situations.

Considering that one of the most important features of any educational groupware is the set of resources that deal with the interaction between the participants, and that the mere transmission of contents through the Web is not enough to the teaching of Mathematics; we propose to expand the notion of interaction to one that includes actions.

Since AMADeUs is an environment designed to educate teachers to teach Mathematics using computational tools, it is necessary to take into account a different interaction paradigm (frequent in games played on-line): interaction through action, which is based on the concept of micro-worlds. This interaction occurs through the use of virtual shared environments also called User Software Component, USC. These components allow the creation of more than one level of interaction, promoting situations fundamental to the teaching proposed by the environment. This component complements the proposal for communicative interaction through texts in communication tools.

There are two ways to instruct in VLE: directly and indirectly. In the first case, lessons are presented by the instructors who also pose questions and wait for the answers, give feedback, and evaluate the results. This makes a VLE independent of the type of contents in an generic environment. The second type adopted is synchronous and visual. Our proposal aims at increasing the possibilities of interaction through shared action. In this case, instead of following rules, the students explore the relations actively and cooperatively. Our idea is to overcome the limitations of the existing educational environments, combining the properties of intelligent tutors and micro-worlds through cooperative systems or tutored discovery. Besides, it was observed that the tools and environments should amplify the teachers´ abilities to produce situations and proper follow up to the pupils´ learning.

In the AMADeUs environment, the tools associated to the development of indirect instructions are non-web applications of the shared environment type, named user´ software components. These components are launched during the surfing of the environment, and support the shared use of up to four people, teachers or pupils. The advantage in using this type of collaboration tool is that the pupils use different strategies leading to the emergence of different kinds of knowledge [47] [49]. In previous studies, we have shown how the use of different interfaces determines the emergence of different properties of concepts. Users profited by participating of direct and indirect instructions [VBK1999].

The micro-world environments are conceived to favor the students´ activities. These systems seem to be the best adapted to the learning in situations of classroom mediation or in educational IT lab conditions, where pupils work in pairs, and are oriented by the teacher.

The notion of interaction through the Internet is related, in many cases, to processes mediated by text and image communication. The interaction can take place through other forms of action. From the point of view of cognitive development it is interesting to combine textual with imagistic and manipulative forms. In this case, we propose that the interaction between the actors of a learning group takes place through actions performed in the same shared workspace. An image tells more than a thousand words. Words are frequently ambiguous. However, sometimes, the meaning of a discourse is enhanced by some actions and vice versa.

The USC interface displays three parts: a map at the upper right corner, an educational software environment at the center, and a chat at the lower right corner. The game machine is shared among several educational applications. The machine has communication resources between applications, access resources to the server to send and receive information about the pupil´s development or about the interface quality, communication resources through chat, and the interface local control (statecharts). There are three layers of software: interface, mathematical modelling, and interface control.

The USC have two main parts. The first one is a client into each are that incorporated a communication component (chat), a coordination one that permits participants to program the time sharing strategy. The third part is educational software (micro-worlds) that are plugged and shared with the other students. There are three user software components under development: two in the domain of the teaching of Mathematics and another for Physics teaching.

Multi-Level Evaluation

Evaluation in e-learning is organized according to different strategies. Systems' design is typically guided by a priori effectiveness comparisons of different evaluation strategies. In this platform, our aim is to coordinate the positive contributions of specific evaluation strategies, taking advantage of the best features of each of them.

Our design principle is that comparing and combining different actors' points of view can substantiate evaluation results better that using single strategies. The idea is to take different strategies that focus on single actor's (students, tutors or graders) points of view and combine their results in order to produce a better picture of our users. In this light, we have proposed a combination of four strategies, namely: open-end evaluation (the traditional evaluation of production, exams or papers), continuous participation evaluation (grades, tutors and staff continually evaluating contributions on chats rooms, forums and e-mail list services; interface agents following and grading students activities, and intervening in the interaction), self-evaluation and peer-evaluation.

For each strategy, we have designed specific environments and support agents. All those points of view are integrated, processed and represented in simple reports and graphs. Results from different sources are compared and combined to produce a coherent and usable student evaluation. In this way, we are able to produce more consistent results. Active and passive units and environments compose this specific architecture.

Student's participations are monitored in chat rooms, discussion forums, e-mail lists, individual e-mail to tutors and teachers. Intelligent interfaces in user software components are responsible for modeling and evaluating students learning in action. Peer points of view are captured in specific environments where peers are invited to evaluate colleagues and judge their production.

We use the evaluation task as opportunities to promote learning. All material delivered is then adapted from the aspects students had learned and those they are still having problems with. All adaptative content is constructed dinamically and presented in the right time to studentes.

COLLABORATIVE LEARNING SUPPORT

Aiming at supporting more effective colaboration, AIED research has been trying to better understand the collaboration process and to build systems that support it. Learning collaboratively implies achieving solutions that would not be found otherwise and negotiating shared knowledge [26]. Dillenbourg [28] [29] argues that we can support collaboration by (1) fixing initial conditions; (2) constructing scenarios; (3) supporting productive interactions, by structuring the dialogue and (4) monitoring and regulating the learning process. In our platform, we intend to support collaboration in these four levels. The idea is to follow Dillenbourg's guidelines and structure the interaction (via tools that facilitate communication and agents tha monitor the dialogue) and through the presence of mediators (either the teacher or artificial ones).

Intelligent Support

As far as intelligent support goes, we have several agents working on different levels. In the following, we present each of them. In fact, in order to account for a multi-level evaluation and (subsequent) support, the student modelling component our system consists of a multi-agent society, whose members are described below.

A1 – Action Modelling Agent

This agent is initialised every time a new student logs onto the system, and follows him/her until the end of the interaction. A1 is basically responsible for collecting (and analysing) students´actions. When the agent finds out that the learner is having some difficulties with the syllabus, it sends the teacher a notification. A1 reasons about the actions following 3 criteria: (1) possible misconceptions; (2) correct actions and (3) strategies used for solving the current problem

A1 can also learn tutor´s actions, and can take the initiative with the tutor´s permission. That includes suggesting new learning situations and interacting with learners.

A2 - Student´s Production Agent

This agent analyses students´records (their production and teacher/instructor´s evaluations) in order to suggest the strengths and weaknesses of each student. It also uses information from A1. As we determine students´competencies, A2 accumulates a learner model. Besides performance and quality of production, the following parameters are also included: (1) can help in topic; (2) needs help in topic.

When it deems necessary, A2 asks A3 to form groups based on the contents needed by learner *x*.

A4 - Rithm Monitoring Agent

Sometimes, students in distance learner courses indicate their lack of motivation/ understanding by not doing their activities, and not logging on the system. Thus, A4 uses this information to try to assess whether there are problems and where they are, and thus inform the learner models. It can try to solve it by forming groups, sending communications to the leaners and informing the tutor that there are problems.

A5 – Interface Agents

This agent analyses users activities in the microworlds interfaces, and will try to help its charge by taking local decisions (which situation to present now? Does the interface need to be adapted?) It will base its decisions on a library of past situations faced by previous students of the system. A5 also provides feedback for the learning monitoring system A.De.C.U.I.. It also has functionalities to interpret situations and feedbacks.

The agent that monitors the microworld interfaces is responsible for monitoring whether the student has already seen all the available situations. It also helps the tutor to identify and propose new problem situatiosn for the students and to reinforce learning by assessing what has been done in each microworld. The first part of this agent design was recentelly obtained thur the identification of adequate learning algorithms best adapted to those specifique data strucuture **[ref reic ana emilia isbn**].

A6 – Editoring helper

This is responsible by helping the teacher to create new learning situations for the students. The teacher consults the production knowledge base and conceptual maps graph in order to assess what would be most beneficial for the student. The teacher can also see other teacher´s work for similar situations.

A7 – ADeCUI´s data Analyser

This agent will analyse the data present in A.De.C.U.I. in order to give feedback to the interface agents about what the learners know and what are their weaknesses. Data mining techniques are being applied here in order to guarantee that the relevant information will be available to the agent or to the teacher in due time.

Group Agents

A3 - Group Monitoring Agent

This agent works with information from A1 and A2 in order to form groups to learn given topics. When A3 needs to form a group, it asks the agents A2 to inform which learners could fit the profile, and sends them messages inviting them to join a group. Agents A1 and A3 then negotiate in order to find activities that are beneficial for all the group members.

Agent A3 also monitors the group interactiong, trying to keep the group motivated and collaborating effectively. In order to do so, A3 keeps track of the social roles played by group members, identifying the following: collaborator, tutor, competitor, leader, reflective, shy and idea generator.

A3 also has the following responsibilities: a) motivate members that are not participating as much, and trying to reinforce the guidelines for consensual decision making [34]; b) mediating possible conflicts; c) reminding participant of options not explored yet. A3 also keeps a group model, which includes a detailed log of the interaction, not only for users to see and reflect upon but also for the teacher to consult.

CONCLUSION AND FURTHER WORK

In this paper, we have briefly presented AMADeUs, our project of a computational distance learning platform that tries to address the deficiencies found in most on-the-market distance learning products: we provide mechanisms for multi-level evaluation; intelligent support that addresses not only the needs of the learner but also the needs of the teacher (in dire neglection these days); we take issues like motivation and effective collaboration into consideration.

We also have members working on methodologies to design environments that are adequate for the teachers´ pedagogical activities; we are also working on group formation and negotiation. Even though our project was conceived with maths in mind, we have already seen that it can be used in other domains. Our next idea is to adapt it to be used in Computer Science Education. The idea of collaborative projects can be widely used in computer science (for designing software, for example).

In the very near future we intend to carry out a couple more case studies to validate our design methodology. We also intend, as soon as we can, to put the system to good use, in order to evaluate it, and modify it accordingly.

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