ARTEMISA: New techniques for Learner Modelling and Learner Adaptive and Intelligent Instruction
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Abstract

This project is part of a long-term research and development effort to build a new generation of resources that support the student in an e-Learning web based environment. The research goals include the definition of new components for automatic assessment, open learner modelling, and adaptive recommendation of learning tasks. The development goals are substantiated in the construction of web based applications and services that can be integrated in a mash up architecture to build an intelligent and domain independent learning management system.

Keywords: Learning Management Systems; Intelligent Tutoring Systems; Open Learner models; Automatic Assessment;

1 Project goals

The general objective of this project is the research and development of different domain independent and interoperable components that can be used in the construction of a web based intelligent learning management systems.

The intelligence is mainly based on a computational representation of learner knowledge and aptitudes (the learner model) and the adaptation of the learning process to ensure that learning really occur. To build up the learner model the system should be able to evaluate the learner actions, and assess their knowledge in a reliable way.

Many national and international research groups are working on this objective. Our research is focused on domain independent tools and interoperable resources. The problem arises when trying to generalize the resources and techniques to different domains. In particular, procedural domains in which the student is requested to accomplish a task are quite different from declarative domains. For instance, a classical test can be used to assess the knowledge in a declarative domain, but it fails to cover the wider range of abilities needed in a procedural domain. The objectives of the project

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are grouped in the following subgoals. These subgoals are accomplished by a set of tasks that had been defined at the beginning of the project and redefined during the project executions according to the results obtained:

1) Specification, design and implementation of a library of resources for open learner models construction and management.
   a) Study, specification, design and implementation of assessment techniques for declarative and procedural knowledge based on Computerized Adaptive Tests.
   b) Study, specification, design and implementation of techniques for the detection of conceptual errors.
   c) Study, specification, design and implementation of procedures and tools to accumulate different sources of information about the learner knowledge.
   d) Study, specification, design and implementation of quantitative open learner models.
   e) Study, specification, design and implementation of machine learning techniques for curricular structure.

2) Specification, design and implementation of adaptive tutoring techniques
   a) Study, specification, design and implementation of statistical models for the planning of pedagogical tasks.
   b) Study, specification, design and implementation of techniques of instruction based on self-evaluation tests.
   c) Study, specification, design and implementation of learning scaffolding and reinforcement management techniques.
   d) Study, specification, design and implementation of educational games.

3) Applications of the developed resources to real world domains.

The following table summarizes the actual scheduling of these tasks along the project duration:

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There were two additional subtasks that has been discarded from the project initial goals: (1e) Study, specification, design and implementation of machine learning techniques for curricular structure; and (2d) Study, specification, design and implementation of educational games. These subtasks have no effect on the overall objectives of the project. So they were postponed based on the time and budget available to take care of the implementations.
2 Project results

Project task results cover most of the goals proposed in the previous section. The different tasks are presented in this section using the same labelling structure as their corresponding goals.

Task 1a: Study, specification, design and implementation of assessment techniques for declarative and procedural knowledge based on adaptive testing:

The Siette system is a web-based environment for student knowledge diagnosis developed for several years (from 1999 until now) (Conejo et al., 2004), under the framework of several research projects, most of the financed by the Spanish Research Plan. It allows the construction and administration of Computer Adaptive Tests (CATs). A CAT is an assessment tool where the presentation of each question and the decision of ending the tests are adapted dynamically in terms of the student's ability, among other criteria. By means of a temporary student model, a CAT generates descriptive information about the student most relevant features regarding his/her learning process. Therefore, it makes easier the identification of students with learning limitations.

The Siette operating mode consists of a student knowledge inference probabilistic model based in the Item Response Theory (IRT) (van der Linden & Hambleton, 1997). The use of IRT guarantees invariant student knowledge estimation results; that is, whenever any type of learning does not take place between two test administration about the same subject matter, the estimation results should be similar.

Among the lacks of CATs, we could point out two which we have tried to overcome during this project. First the student knowledge evidence providers are mainly questions and accordingly it is difficult to use CATs when the exercises are procedural tasks such as problems. In the research field of ILEs, the most popular techniques of assessment involving procedural activities are:

- The Constraint Based Modelling (CBM) (Ohlsson, 1994), which focuses in representing what the student does not knows. The domain is composed of a set of constraints whose violation is used as a part of the student model. Following this technique, several ILEs have been developed such as SQL-Tutor (Mitrovic, 2003), Kermit (Suraweera & Mitrovic, 2002), etc.
- Model Tracing (MT) (Anderson & Reiser, 1985), based on a Knowledge General Theory ACT*, according to which, when a student solves a task, he/she follows a hierarchical structure. In the systems implementing this technique, e.g. LISP Tutor, Algebra Tutor (Anderson et al., 1995), the domain is defined by a set of rules, and the goal is to trace the student while solving a problem.
- Bayesian Networks have been also used for domain representation. They are used to code the rules that allow solving problems.

In general, the main problem of these proposals is that they do not use well-founded techniques, neither in the procedures they use for the student knowledge inference, nor in the initial assumptions used when they apply the diagnosis techniques. In this sense, we have developed a probabilistic model for determining the student knowledge level while solving procedural tasks. Our proposal is based in a combination of IRT and CBM. The evidences of a pilot study we accomplished in 2008 with undergraduate students of Telecommunication Engineering at the University of Málaga, suggested that the assessment made using our problem-based diagnosis model is similar to other carried out with a IRT-based test. It validates its well-
founded character and in addition requires much less problems than test questions (with a pair of problems we could achieve a diagnosis close to the one obtained with around one hundred questions). In this sense, under the framework of this project, we have already constructed two ILEs for two different domains: one for Object-Oriented Programming and the other for Linear Programming; and there are two others still under development (Project Management Fundamentals and Dynamic Programming Management). In addition, we are developed a generic framework for the student diagnosis through procedural tasks over the Siette system. This work was presented in the ICALT conference which took place in the summer of 2008 (Gálvez et al., 2008). Finally, we have to mention that this technique is the key idea of the Jaime Gálvez’s PhD thesis, still under development (Gálvez, 2009).

During 2009 we have extended the exercise library of Siette, including a new type, the composed items, which model more complex activities than the classical test questions. These new activities facilitate the implementation of exercises where the student provides simultaneously more evidences than a simple answer to a question. These evidences are modelled internally as, what we have called, virtual items, whose type maps to any other of the Siette item types.

The previous technique, even though is applied when using procedural tasks, does not assess procedural knowledge, but declarative. During the second semester of 2009, we have developed a technique for procedural diagnosis, which can be easily implemented through the composed items. Initially, from the results of a student population who solve certain procedural activity, we analyze the step sequences carried out by the students, using a semi-automatic procedure we have developed. For this purpose, we have used machine learning algorithms which infer temporal sequence patterns. Once these sequences have been obtained, we build the exercise resolution graph and, using it and the student population performance data, we construct composed items where each step maps to a virtual item where the set of possible answers are the actions the student can do. Using IRT, these items are calibrated and can evaluate procedural knowledge. Our goal is to apply these techniques to several domains during 2010, in order to explore its suitability.

**Task 1b: Study, specification, design and implementation of techniques for the detection of conceptual errors (misconceptions)**

ILEs base their intelligence on the adaptive instruction they supply. The use of student models in such environments has emerged as a consequence of the fact that these systems have to work with incomplete information about the students (Mayo & Mitrovic, 2001). A student model represents who is being taught, that is, what the student does (or not) know about the domain. Most learning environments construct this model from the student knowledge and the gaps in this knowledge. Using this information, they adapt the teaching process to the student’s need. The quality of this adaptation strongly depends on the accuracy of the student model. However, inferring the student model (and, in general, any user model) is a very difficult and costly process. Many researchers such as Self (1990), have highlighted the intractable nature of this problem. Nevertheless, researchers recognize that although student models may not be highly accurate, and may not be complete from the cognitive perspective, they are indeed useful. In the traditional classroom approach, teachers also use less accurate student models; however, the teaching process is usually effective.

Perhaps the most commonly used strategy in student modelling is overlay modelling. When a learning system is constructed with overlay modelling, one of the first tasks to accomplish is to identify the concepts involved in the domain. A human expert in the domain can relatively easily perform this process. However, there are other modelling techniques, such as perturbation models,
which also incorporate incorrect knowledge. Even though the inclusion of student errors in their model provides some benefits, it also entails some problems. Specifically, the main problem of this modelling approach is the construction and maintenance of the bug library. The elicitation of this library is a time-consuming task that requires an exhaustive analysis of expert-student interactions and, accordingly, requires an expert with considerable experience. Despite this problem, the research on misconceptions has primarily focused on its diagnosis and remediation more than on its elicitation.

In this project, we have developed a technique for semi-automatic misconception discovery, primarily for declarative domains. The main goal is to provide the teachers with a collection of potential misconceptions. Subsequently, they have to decide whether or not they are misconceptions. A data-driven procedure is carried out based on the performance of students who have completed assessment activities (such as exercises, problems or test questions) in a certain subject domain. Additionally, this technique also relates these misconceptions with the assessment activities (e.g. exercises, problems or test questions), which assess the subject in question.

Our proposal consists in the application of association rules for these misconception detection. It is based on the following hypothesis: when students take tests about certain domain, if several questions contain answers, which fit to a misconception, he/she will tend to select these answers. Taking this premise as a start point, our technique identifies the most frequent incorrect response patterns using association rules, makes a first filtering procedure in terms of some parameters and present these patterns to the domain experts, ordered according its frequency.

Preliminary studies we carried out in 2009 with undergraduate students of a Programming Fundamentals course, corresponding to the second semester of the first year of the B.Sc. in Telecommunications at the University of Malaga, suggest that this technique can help teachers to identify the domain misconceptions. These experiments and the technique are described in detail in a paper (currently under review) we have submitted to the 18th International Conference on User Modelling, Adaptation and Personalization (UMAP 2010) (Guzmán et al., 2010).

Once the misconceptions have been identified and related to the questions that provide evidences about them, the following step is to diagnose quantitatively, for each student, these misconceptions. To this end, we have designed a diagnosis model based in IRT that extends our work described in (Guzmán et al., 2007b). The main idea is that incorrect answers to test question provide evidences about misconceptions, the same way correct answers do about the concept knowledge.

Task 1c Study, specification, design and implementation of procedures and tools to accumulate different sources of information about the learner knowledge.

Our work related to web-based ILE has been focused for several years on the development of distributed architectures based on the integration and reuse of intelligent learning activities that manages its own student model. On the other hand, the web teaching/learning model evolves towards an auto-learning scenario in which students complete their training using resources located all over the web. In any case, we deal with students that are shared among different systems, each one of which stores part of the information about their knowledge, that is, the student model is distributed over the network. In this context would be interesting for a system “asking someone for references” when it has to work with a new student, in order to provide adapted instruction. This is the problem of student modelling for hybrid web applications (mashup).
Two approaches exist in this field: centralized (Brusilovsky, 1994) and distributed (Vassileva et al., 2003) models. The first ones are based on the use of model servers (Kay et al., 2002; Brusilovsky, 2005) and the last ones in agent architectures.

In this project SAMUEL, (Spanish acronym for User Modelling Accumulative Server for E-Learning), has been developed. SAMUEL allows the storing of student knowledge evidences about different domain concepts obtained from different sources. Besides the mark, each record contains information about the learning activity that provides the information. We have implemented and overlay model, but the evidence sources use their own ontology, so, in order to make inferences about student knowledge it becomes necessary to establish equivalences between concepts of different domains. For this purpose we have developed a tool to edit and integrate models that allows semi-automatic ontology mapping. It was presented in 2008 report.

At present SAMUEL offers eleven web services implemented with JAX-WS API. These services allow web learning resources both to register evidences and to obtain data about other user activities. They are estimated by means of diverse heuristics that infer student knowledge about a concept from the data provided by other systems the user has worked with.

In this project framework, ILE for different domains are being developed. The student model server will be used to compile student evidences coming from different systems. Moreover, it will help to compare the result obtained of applying the diagnosis techniques of each built ILE. Now SAMUEL is being used by two tools developed in other group projects: the test system SIETTE (www.siette.org) and the framework for ILE development MEDEA (www.lcc.uma.es/medea) (Trella et al., 2003; Trella, 2006).

Task 1d: Study, specification, design and implementation of quantitative open learner models.

The open learner models (OLM) are accessible and open models that extend the traditional ILE models to turn them into a visible and interactive part of the system (Bull & Kay, 2007). The OLM allow a student to inspect his model and to interact (edit or negotiate) with it. This kind of system stimulates student's reflection and helps them to plan and monitor their learning (Mitrovic & Martin, 2002). They are not just valuable for students but for teachers. Indeed, a graphical representation of the model can help teachers to carry out a course formative evaluation and to determine student's learning problems. Moreover, the model accuracy can be improved if the system allows students and teachers to collaborate in the modelling process. Broadly speaking, the student model has evolved from being a knowledge source for learning resources (closed system) to become an important learning resource for the student (open systems).

Two main type of OLM exist, those that are integrated in a tutor system or the independent ones (IOLM), which purpose is helping students to identify and to solve learning problems by themselves, without tutor system help, that is, to encourage metacognitive skills (op. cit.).

Following the line of resources integration we have developed a OLM (INGRID, Interfaz GRáfica Independiente del Dominio) through which students can see (via Web) user models of the various tools which they work and interact with. INGRID provides two views of student score, both based on the relationship topic / sub-topic from the domain concepts. The first is a hierarchical structure representing the issues by a graph, and the second is a table of topics and notes. The hierarchical view of the graph represents the nodes with a color code indicating the student's level of knowledge on this concept according to a particular source (SIETTE system, for
example). The table shows the same information but with bars indicating the note to a particular topic on a scale from one to ten, and it allows to sort the view according to certain criteria.

The important thing of this system is that it is generic and can represent data from any ILE. To achieve that, a number of web services have been identified, which receive as input a list of concepts and their notes, as well as the semantic network of the domain model (concepts and relationships) and are capable of representing it. Currently, it has been successfully tested with SIETTE and student models server, SAMUEL. Both tools use it, as plug-in, to graph the data from their students.

During this year we plan to continue working on various issues of this tool. Among them actions we plan to develop we can find the extension of the number of views, implement the part of editing that would allow both students and teachers to modify the data from the view and to research about negotiation techniques of the model.

Task 2a: Study, specification, design and implementation of statistical models for the planning of pedagogical tasks.

Shute (1995) claims that the intelligence of an ITS comes from the cognitive diagnostic (student modelling) and the adaptation of the instruction. Based on the information contained in the student model, the pedagogical module of an ITS applies different adaptation techniques and instructional planning, identifying at each point both the content and tasks more appropriate for a student. The accuracy and completeness of the model result in a more accurate adaptation of instruction.

In this line, we have begun work on developing a generic instructional planner for adapting the student learning process by recommending, based on the current knowledge, the pedagogical component that contributes most to improve their knowledge level. This planning model is based on statistical information of the behavior of students who have previously used the system and is characterized by being domain independent. Our goal this year is to perform experiments that allow us to assess the validity of this model.

Task 2b: Study, specification, design and implementation of instruction techniques based on self-assessment tests.

Practicing self-assessment tasks has been proved to be an appropriate way of learning (Guzmán et al., 2007a). The SIETTE environment is used both for actual assessment and for self-assessment. We have explored whether the self-assessment implies learning and implement two new features to SIETTE in order to improve their positive effects: (a) Collaborative tests, and (b) Tests based on the Leitner’s methodology of spaced repetition.

Collaborative learning scenarios should engage learners in cognitive and metacognitive activities to promote the conscious cooperative development of shared knowledge and to enrich their individual understanding of the world. Therefore, these scenarios should involve the learners in situations which require reflecting on their own knowledge as well as their colleagues’ in a grounding process (Baker et al., 1999) in order to get, as result of this process, more refined and mature knowledge by themselves. Collaborative testing has previously been done based on paper and pencil and face to face interaction. To our knowledge, this is the first computer based testing environment, available on the web, which supports collaboration. Some papers about the Siette
Spaced repetition is a learning technique that incorporates increasing intervals of time between subsequent review of previously learned material; this exploits the psychological spacing effect. Sebastian Leitner developed in the 1970s a simple implementation of this principle, where some pieces of knowledge (that are commonly known as flashcards) were reviewed at increasing intervals according to how well the learner know there content. [Leitner, 1984] This technique has been implemented in SIETTE as an alternative method of presenting questions to the learner. This feature has not been released yet, but is fully operative and will be deployed with SIETTE 3.5. We plan to study the effect of this technique on self-assessment test in the future.

Task 2c: Study, specification, design and implementation of learning scaffolding and reinforcement management techniques.

In order to enhance learning there are two potential actions from an intelligent system (a) Provide some hints while the learning task is being completed, and/or (b) Provide detailed analysis of the failures in the learner responses or meaningful explanation about how to get the correct solution. In the Artificial Intelligence in Education community, the first approach is known as Scaffolding and the second as Reinforcement.

Scaffolding techniques accommodates very well to self-assessment. In fact, this technique has been known as Socratic tutoring from the ancient past. Nowadays, computer based testing provide a workbench to measure and adapt hints. One of the best examples is the Assistment system, developed by Dr. Neil Heffernan and his group at Worcester University (Razzaq et al., 2005).

We implemented both Scaffolding and Reinforcement feature in the SIETTE system and analyzed the best way to select the most approprioted hint according to the learner knowledge level. Some preliminary results were published in (Conejo et al., 2007), and a new complete version for a journal is scheduled.

Task 3: Applications of the developed resources to real world domains.

The new ideas emerged during the project, have been substantiated in different applications. For instance, we have applied the collaborative testing techniques to different subjects like Compiler Construction, Programming Elements, (at the School of Informatics, Malaga University) and Botany (at the School of Forestry, Madrid Polytechnic University). In the same way, other techniques implemented in SIETTE have been used in different domains. These applications show that the techniques developed are really general and domain independent.

As mayor applications, we have constructed some ILE prototypes. However, despite the intelligent part of this tutors have been developed by the research staff, due to the budget restrictions, most of the interface programming tasks have been delegated to undergraduate students. This issue has lead to delay on our initial project plan.

Three different ILEs have been developed in the framework of this project:
a) An ILE of Object-Oriented Programming:

The first ILE with procedural tasks we have developed, focuses in the Object Oriented Programming (OOP) domain. This environment, called OOPS, has been used to evaluate the technique described in Task 1a and is composed of the following parts:

- A Web-based interface, through which the students can solve problems, applying the fundamentals of OOP, in an easy to use workspace and teachers can elicit problems. The students can insert sentences and declarations (by means a drag and drop mechanism). These problems should be written in a pseudolanguage developed by the teachers of the programming courses of the Telecommunication Engineering degree at the University of Málaga. Although the set of sentences supplied is a subset of the whole language, they are the most relevant to build object oriented programs.

- The domain model consists of a declarative representation of the information that maps to a OOP written in pseudolanguage. This representation has been made with a set of templates written in CLIPS that contains the information needed about the elements that are part of the problem solution. Each one of these elements (classes, methods, variables, sentences, parameters, etc.) will be represented by means of facts following certain template. Therefore, a program will correspond to a set of facts that, by means of references to elements, form a hierarchical structure. Each time a student performs an action through the interface, such as the addition of a new method, one or more facts are added (which map to the declarative representation of these elements) to a inference engine.

- For the student modelling, we have used the CBM, described before in Task 1a. The student model, according to this technique, stores the actions carried out by him/her. This information with the violated constraints, will be used, by the pedagogical module, to determine his/her knowledge lacks and, therefore, to act in consequence to fix it. In addition, the model stores an estimation of the student knowledge level which be used to decide the most suitable problem to be presented. This knowledge level is computed each time a student who is building the solution to a problem, compiles his/her code.

- The pedagogical module assists the student during the assessment/learning process in two different ways. First, selecting adaptively the exercise that should be solved; and once the student start a problem, detecting his/her lacks by applying CBM.

The constraint (or errors detections) in the domain model is an essential part in CBM. In this ILE, several types of constraints have been defined, in such a way that the student lacks could be detected: syntactical constraints (grammatical rules violation), visibility constraints (which comprise errors due to the lack of knowledge about scope rules of classes, methods, variables, parameters, etc.), type constraints (seek for incoherencies between the types of operations, parameters, etc.), constraints about the name format (names of local variables, parameters, methods, etc.), and constraints about missing references (as a consequence of deleting some variable, attribute or method, previously used in the code, and thus existing a reference to a code piece which does not exists). A total of 71 constraints have been collected: 15 of visibility, 13 of syntax, 9 of types, 21 about the name format and 13 of missing references.

This system cannot be only used as a way of student knowledge assessment, but to help the student to learn the OOP concepts using a constructivist learning strategy. Combining assessment with learning, we obtain what is known as assessment for learning, which differs from the classical approach of assessment of learning. In March of 2008, we carried out a study that tested this learning feature. The students used the OOPS tutor as a learning way. Therefore, each time a student makes an error, the system will supply a feedback. The students took a pre-test before the
learning process and a post-test after it. In comparison to a control group, data suggested a significant learning. This experiment was described in detail in a paper published (Gálvez et al., 2009) in an special issue about Blended Learning of the Knowledge-Based Systems Journal, indexed in the ISI JCR.

In addition, two other papers have been published about this system: the first one describing its architecture and its operating mode (Gálvez et al., 2007) and other about the suitability of the technique described in Task 1a (Gálvez et al., 2009c).

b) An ILE of Linear Programming:

One of the main goals of this environment was to assess the abilities required to solve any kind of linear programming problem by means of the Simplex and two-phases methods. These abilities can be structured hierarchically to discover dependences between the different types of problems and the abilities needed to solve them. This ILE has been used as a complement in the classes of several subjects about Computational Techniques on Operative Research in the School of Computer Science Engineering at the University of Málaga, during the academic courses 2007/08, 2008/09 and 2009/2010.

This system also combines IRT and CBM, although in order to trace the student action in the different stages of the problem solution procedure, we have also used some principles of Model Tracing (explained before). We have decided to use both MT and CBM, in such a way that the ILE behaviour was modelled by means of a state transition diagram, where each state represents a step in the resolution of the optimization methods, which provide evidences for the student knowledge diagnosis. Furthermore, inside each step, CBM is applied.

The system has a Web-based interface and shows different types of problems to the student and a the whole set of actions he/she can perform during all the process. The domain model has been implemented using JBoss Rules from the Drools project. This engine implements the RETE algorithm in Java, allowing the addition of sentences of this programming language inside the inference rules. Thanks to this feature, the representation can be made by means of Java beans, which makes easier the direct use of data management structures in the inference procedure. The domain model consists of a set of Java beans, used to store the information related to the problem.

We have accomplished several experiments with this system which were published in a full paper in the International Conference of Artificial Intelligence in Education (AIED 2009) (Gálvez et al., 2009b).

c) An ILE of Dynamic Memory Management:

We have a first prototype of this ILE which allow the students to assess their knowledge about dynamic memory management. It applies the techniques described in Task 1a.

d) An ILE of Project Management Fundamentals:

This ILE is still under development, we hope to have available a first prototype by the next summer.
3 Project achievements measures

Project achievement can be measured from different points of view. They have been presented in detail in the previous section according to the project tasks. In this section we summarize those contributions following the given guidelines:

- **Achievement of initially scheduled objectives.**
  Most of the goals initially proposed have been completed successfully, and are implemented in web-based applications that can be accessed through Internet. See previous section for a detailed description of tasks achievement.

- **Soundness and originality of the results.**
  The project has contributed to the Artificial Intelligence in Education community with completely new and original ideas about:
  - Use of IRT for scaffolding while self-assessment.
  - Collaborative testing.
  - Use of well-founded techniques (IRT) for declarative and procedural knowledge assessment using procedural tasks.
  - Extension of a learning purpose methodology like CBM for assessment purposes, also giving it soundness.
  - Data-driven Domain Misconception elicitation and diagnosis.
  - Development of a data-driven technique for instructional planning.
  We have also tried to reproduce and compare results previously obtained in this field by other groups:
    - Integration of different resources of information in a common learner model
    - Advantages of using open learner models

- **Scientific and technological results.**
  From the scientific point of view, we have achieved the following results:
    - Use of testing for student collaboration.
    - Development of a technique for assessing declarative and procedural knowledge using Item Response Theory.
    - Development of a technique for data-driven misconception discovery.
    - Extension of a probabilistic diagnosis model for student misconception estimation.
    - Development of a probabilistic technique for instructional planning.
  Moreover, from the technological point of view, we have achieved the following results:
    - Development of a web-based open learner model which is able to integrate different sources.
    - Development of four ILEs.
  Finally, to disseminate the result of the project some contributions has been submitted to scientific journals and conferences (see references at the end, in the subsection "Project references")
• **Application of the result.**

Most of the results of this project have been implemented as new features of the systems SIETTE (http://www.siette.org) and MEDEA (http://www.lcc.uma.es/medea). Both systems are accessible through Internet, but some features are restricted to registered users. SIETTE is currently integrated with Moodle, and it is offered as a general-purpose activity in the Virtual Campus of Malaga University. There is a growing community of teachers and students that use SIETTE as a tool for assessment and self-assessment, most of them at Malaga University, but there are also regular users from the Schools of Forestry at the Polytechnic University of Madrid, and from some High Schools teachers that are evaluating the system and creating for their students. SIETTE access has been also requested from other research groups worldwide. Currently there are more than 120,000 completed test sessions, and around 24,000 registered users. The SIETTE collaborative testing environment has been successfully used during the last two years for different subjects at the University of Malaga and the Polytechnic University of Madrid. Over 500 students have taken collaborative tests. The use of MEDEA is evolving slower, because some of their features are still under development and not fully integrated in the widely used LMS.

As mentioned before, during 2009 we conducted several experiments with two of the tools developed during 2008, i.e. with the Object Oriented Programming and Linear Programming tutors. The experiment results for the first tutor have been published in a journal indexed in the ISI JCR. The results of the Simplex tutor have been published as a full paper in the International Conference on Applied Artificial Intelligence in Education (AIED 2009). Since the second half of 2009, we have begun to analyze data from well-known tutoring systems developed by the Intelligent Computer Tutoring Group (ICTG), a research group leaded by Professor Mitrovic, such as SQLTutor (Mitrovic, 2003) and KERMIT (Suraweera and Mitrovic, 2002). This analysis has allowed to obtain different results we expect to publish during 2010.

• **Human resources.**

A young software engineer has been contracted to develop some of the implementations required by the project. The project has served him as an introduction to research in this area and as a way of acquiring expertise in new programming techniques for web applications.

• **Cooperation with other national and international groups.**

After our attendance to the AIED 2009 conference, where we presented part of our experiment in which we showed the viability of using our methodology for assessment, we had the opportunity of collaborating with prof. Tanja Mitrovic from the University of Canterbury in New Zealand. Professor Mitrovic leads the ICTG, which has driven the development of the CBM. The tutors developed in this research group have thousands of users worldwide. Cooperation with Tanja Mitrovic, has supplied the data of such users for further studies with large user populations.

As a consequence of this collaboration, Jaime Galvez, Ph.D. student under the supervision of Ricardo Conejo and Eduardo Guzmán, has been invited to stay in New Zealand to work directly with members of the ICTG in order to integrate methodologies and share experiences. Besides, prof. Mitrovic has expressed her intention to continue working on this collaboration and extending future work with another stay in our university.
• **Project management.**

Project management has been done according to the University guidelines. The main problems we have faced were the search and contract of the right person for the project, that delayed the realization of some of the implementation tasks. A web page has been developed to improve project management and disseminate the results: http://albireo.lcc.uma.es/joomla/artemisa/

To sum up, we think that the project has achieved a good degree of completion of the initially proposed tasks. We have done a humble contribution to the field and that has been recognized in the community and has promoted good relationships with other international research groups. The project results are substantiated in web applications that are currently used by a growing community.

4 **References**

4.1. **Project references**


4.1. Other references


