The SELL Project: A Learning Tool for E-Learning Logic

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Abstract. The SELL project described here is the design and development of a tool for assisting the learning of Logic in the context of a wholly online CS degree using a web-based learning environment. This tool should provide guidance, interactive feedback, and continuous assessment for Logic course students, covering major topics in an introductory course (natural deduction, resolution and semantics in propositional and predicate logic). The process of the design, implementation, use and development of the resulting tool, coined Logic E-learning Assistant, is presented.

Keywords: introduction to Logic**,** online higher education, e-learning, intelligent tutoring system, e-tutor, web assistant, e-assessment.

1 Introduction

The UOC (Open University of Catalonia; www.uoc.edu) is a wholly online university having an e-learning student-centred educational model. The university offers a basic Logic course as part of the Computer Science degree, which is one of the most technical programs. There are more than 700 students enrolled each semester in this course, comprising the usual topics of an introductory Logic course in two possible languages (Catalan and Spanish). The traditional Logic course is an overview of propositional and predicate logic and special attention is given to formal semantics. Logic at this level is part of mathematical logic and the subject inherits the mathematical particularities that make it rather difficult for students to grasp.

Students enrolled in a Logic course have to acquire a set of skills and a small set of contents. The continuous assessment is very important in this kind of subjects, as a way to monitoring the progress in the learning progress of the logical skills. The instructor has also an important role when acquiring these skills and the concrete guidance and interaction with the teacher is a fundamental aspect of the learning methodology [5]. In an online scenario, students have the same interaction needs but they interact with the teacher only using their computer [11]. Furthermore, this computer-mediated interaction is usually text-based, providing a narrow scope to have feedback. Therefore, this can become a concern when learning the competences of Logic.

On the other hand, web-based learning and e-learning in general can allow individual training while being easily delivered to a wide audience via the Internet at a relatively low cost. Another important advantage of e-learning is that it is based on

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resources and activities that are accessible via a computer device, offering a high degree of interactivity and a more dynamic type of self-assessment or immediate feedback [3]. In particular, intelligent tutoring systems could be used to improve the learning process providing customized assistance and feedback to students [6,7]. In the context of e-learning, intelligent tutoring systems can help to overcome the absence of teachers while taking advantage of self-learning. In the UOC online model and in a subject like Logic, such learning tools should be part of the solution [14].

There are many learning tools for Logic [19] but they have no standard notation, rules, logical systems, etc. Thus, the existing tools are practically not reusable for a material created independently of that tool [10], in particular our UOC courseware for distant learning. We would need to create a new tool adapted to our courseware. Therefore, an innovation project placed in charge of the UOC was proposed in which a learning tool for Logic would be developed.

This paper is organized as follows; Section 2 describes the SELL project, the design and development process of the learning tool. Section 3 describes the characteristics of the resulting tool and its use in the virtual classroom. Section 4 describes the evaluation of the learning tool. Finally, Section 5 presents the conclusions.

2 Description of the SELL Project

The goal of the SELL (Monitoring E-Learning Logic, in Catalan "Seguiment E-Learning Lògica") project described here is the design and development of a tool for assisting the learning of Logic in the context of a wholly online Computer Science degree using a web-based learning environment. This tool should provide guidance, interactive feedback, and assessment to Logic course students.

The project team have comprised staff of the UOC that specified the functional needs of the project and an analyst-programmer who analyzed, designed and implemented the project in collaboration with the staff of the UOC.

2.1 Design

The project followed the UCD (User Centred Design) [13] process that includes three main phases: gathering user requirements, designing the product iteratively and finally, evaluating the prototypes of each design iteration [4]. In addition to these phases, the UCD process applied in the design and development of learning resources and tools has to follow the specific goals of the e-learning context: a) reduce difficulty in the teaching and learning process, b) improve the learning experience and c) integrate with the existing virtual learning environment. The key element of this approach is the evaluation and iteration of the design solutions. We had two sets of requirements:

- Institutional: e-learning tools which have to be placed in the virtual classroom structure should be accessed using a standard web browser and they should not technologically interfere with existing resources.
- Users: they will be the students enrolled in the course. Teachers will also be users but they will have more functionalities and views of the learning tool. An analysis was carried out with teachers and students to identify those requirements.

In addition to that, other information has been gathered during one semester by observing the continuous assessment process and the exams at the end of term. From a test with an existing tool for learning Logic in a comparable curriculum[1] [12] we learn that students do not use the tool since it only provides voluntary practice. This is because the students perceive the time and energy using the tool as an extra effort without any clear reward. Thus, an important finding was the need to integrate the learning tool in the continuous assessment model of the pedagogical strategy used [2].

Following that analysis, the main requirements for the Logic learning tool were: providing immediate feedback; fostering learning of the strategies and skills characteristic of Logic; to be integrated in the continuous assessment of the students; ease-of- use; to be integrated into the existing virtual classroom; and being multilingual (at least Catalan and Spanish).

2.2 Implementation

After testing the initial prototypes, the developing phase followed on. The coding of the tool took several months and was done by a web developer of the team. Other UOC members of the group supervised and commented on the process of implementation which was done in an iterative way. The architecture of the tool and other technical solutions were decided in order to assure the requirements would be taken into account. The tool would be designed under an approach based on architecture in three layers: interface, domain and persistence.

It is interesting to mention that the only user requirement in order to use the tool is to have a browser compatible with Internet Explorer 5.5 or superior or with Firefox 2.0 or higher. It is also necessary that the user has enabled Javascript (option by default of the browsers). The web pages that are part of the tool were developed using PHP for the programming in the server and HTML, CSS and Javascript. It is also interesting to mention that in order to store the data in a persistent way, a MySQL database has been used, which allows the managing of sessions in an efficient way. Finally, the development of this application requires liaison with the existing UOC servers to obtain the login information of the students. This functionality has been covered through a series of web services provided by the UOC virtual campus developers.

The final tool was simply named *Logic E-learning Assistant* or even simpler "The Assistant". There have been two versions of it. The first one is the result of the initial SELL project (2008, 2009); and the second one the resulting version of the enlargement of the project after the success of the first version (2009, 2010). The functionality available for users of the tool will be different depending on their profile "student" or "tutor". The first version set out the key lines of implementation: architecture, structure, functionality of each user and early automatic tutor support; while in the second one, the continuous assessment module was added.

3 Description of the Logic E-Learning Assistant

In this section the main features of the Logic E-Learning Assistant are presented. Technical and educational features and functions are described.

[1] Josep M. Humet: LSD (accessible a http://ima.udg.edu/~humet/lsdweb/index.php).

Access: Access to the tool is through the virtual classroom of Logic. There is a direct link in the first level. Students have been identified to enter the virtual classroom and this identification is to be used in all processes that need it.

Interface and Structure: There are four different modules that are easily identifiable in the interface: Language, Exercises, Assessment, and Help.

Multilanguage: The Assistant starts in one of the two possible languages (Spanish and Catalan). In the top right corner of any screen, one or the other language can always be selected. The system is easy extensible to other languages, by just translating s a list of vocabulary. As for the exercises and other content posted by the administrators, titles and explanations should be introduced in different languages. The formulas, through the universal language of Logic, do not need translation.

Exercises: The exercises are classified according to the topic. There are two major groups: Propositional and Predicate Logic exercises. In the Propositional case, there are three types: Natural Deduction, Resolution, Truth-tables. In the Predicate case, there are two kinds: Natural Deduction and Resolution. Exercises are easily identifiable in the initial screen. Each kind links to a different interface with a list of proposed exercises with the option to create their own exercises and with the students' own statistics. The option "Solve" leads to a new screen where the final real Assistant is eventually accessible in order to introduce algorithms to solve exercises, check them, obtain feedback and grade them in an automatic way. In fact there are five different Assistants, one for each of the five kinds of exercises. A database of exercises is filled up by concrete exercises, which are chosen and introduced by the teachers for further practice. On the other hand, students can easily introduce new exercises of any type in order to obtain immediate feedback while they solve them. There is a formulae editor to answer text questions.

Interactivity: When the learning assistant is accessed from the virtual classroom, five groups of topics of exercises are available. When solving an exercise, students have to introduce the rule and the result of the rule application. AELL responds to the student's actions by either applying the rule and going to the next step or giving an appropriate error message. AELL is never solving by itself at any step. Thus, the Assistant is mainly providing feedback of correction or error at any step of the algorithm. Error messages give standard information (depending on the error) to help the student find out what was the error. All the pieces of advice are dynamically generated and context sensitive. AELL has been enhanced to facilitate automatic marking for assessed coursework. As the students are always identified, a report can be produced for each student together with statistics for their teachers involving minimal human intervention.

Assessment: This module has been created to manage the individual work of the students (both voluntary and compulsory work). There are two possible interfaces, one for each kind of user (student or teacher). Students are always identified while working with the tool and the logs produced are stored. For any category of exercise, students can see the statistics of their voluntary work (the complete, incomplete, or pending exercises) and be able to access them. Through another part of the tool, students do and deliver the exercises of the compulsory work, where each test could have exercises that are automatically graded by the system and text exercises that are the only ones that the instructor has to individually correct. Students see their results immediately with respect to the automatically grade parts of the test. From the point

of view of the instructor, the assessment module is much richer. The instructor defines and introduces the different compulsory tests in an easy way. They have access to the individual or group statistics of many different elements: the average success of students, rules that were incorrectly introduced, frequencies of use, temporal distribution of the work, and as the system stores all the logs in a server of the university, many other statistics can be obtained. Most of the grading is automatically calculated by using the solving associated procedure and the time the teacher saves not doing the automatic part of the correction can be used in the providing of individual feedback and comments.

Help module: It consists of a collection of short videos (2 to 7 minutes) in both languages, showing how to use the tool for each category. A more complete documentation of the tool is being produced. Students can always ask the teacher for some help, if required.

The E-Learning Logic Assistant (Assistant E-Learning Logic, AELL, in Catalan or Spanish) is integrated in the courseware of Logic. There are other resources in that courseware and recommended timings and paths with a detailed guide of readings, examples, and exercises to practice. Style and notation in the Assistant is similar to the one in the rest of the tutorials, which makes it intuitive.

4 Evaluation

Until now, two versions of the learning tool have been used:

- The first version corresponds to the course 2009-10 (two semesters). The covered topics were natural deduction and resolution of propositional logic.
- The second version has been used in the first semester of the course 2010-11 (one semester). The covered topics in the previous version were enlarged through truth tables to be validated in propositional logic, natural deduction and resolution of predicate logic. The Continuous Assessment Module was also added.

The tool is completely integrated with the rest of the learning material and with the continuous assessment model of the Logic course. Students and teachers easily can track the learning progress since the tool provides statistics for each individual user, for the class group and also for the different groups. Students can see their progression level and both students and teachers can find the critic points of every stage of the learning process. At present, the tool is being used in the Logic course of Computer Science degree of the UOC. Using it in a real scenario provides a set of usage data that is being use to improve both performance and usability of the tool. We already have a first feedback from students that consists on positive comments about the tool and how it helps them to learn the course.

The initial small team has grown in terms of tutors of the ten or more virtual classrooms of each semester. They have participated as key users in the evaluation and improvement of the two versions. In particular, their involvement in the design of the continuous assessment module has been most valuable and their enthusiastic involvement went beyond professional limits.

During this time, we have evaluated the tool by using anonymous feedback forms and questionnaires, by studying the performance of the final face-to-face written

Table 1. Institutional satisfaction evaluation of general resources

Evaluation of the resources in Logic	Positive
2008-09	70%
2009-10 (first course with the Web Assistant – first version)	88%

exam and by evaluating recorded detailed logs. In the general satisfaction questionnaire drawn up by the university, we have the following results in the evaluation of the resources of the Logic subject.

We also have the following results in the specific satisfaction questionnaire.

Table 2. Specific satisfaction evaluation of the Logic Assistant

2009-10	
Useful in learning DN (propositional logic)	80%
Useful in learning Resolution (propositional logic)	70%
Useful in continuous assessment	76%
Useful in reducing study-time	42%
2010-11	
Useful in learning DN (propositional and predicate logic)	71%
Useful in learning Resolution (propositional and predicate)	77%
Useful in continuous assessment	87%
Useful in reducing study-time	52%

The results of the satisfaction questionnaires show that students find AELL easy and useful in the learning process of all the topics. They have also made useful criticism.

We have compared the results in the written exams with the semester using AELL and the other semester without the tool. This did not provide a clear advantage to students using the Assistant. The reasons for it could be many. The fact that the exam is in the old-fashioned paper-and-pencil style is one of the possible reasons for so little influence. Rates are still very low, as usually occurs in other mathematics subjects. However in the percentage of participation in the continuous assessment a little more success can be appreciated.

Table 3. Evaluation of the results, previous to and with the Logic Assistant

Course	Participation in Continuous Assessment	Passed the course
2008-09 (without Logic Assistant)	55%	39%
2009-10 (Logic Assistant – first version)	59%	38%

We are waiting to know the results for the present course with the second version of the Assistant covering the major part of the curriculum and implementing the continuous assessment module. It seems that participation is on the rise but at the moment of writing this version of the article, we do not have reliable data.

On the other hand, further work will be adding new modules to cover other parts of the Logic subject, improving the feedback system and functionalities, allowing comments and notes and building a mobile version, among others.

5 Conclusions

One characteristic of online universities like that of the UOC is its intensive use of technology to enhance learning, and this has been the initial impulse for the project. There are many other teaching tools for Natural Deduction or other Logic topics [1,9,15,17] but it seems that the current trend is the e-tutor paradigm [2,8], where intelligent tutors are integrated in a more general e-learning courseware environment. What we should add to this current trend is the use of e-assessment to support continuous assessment, like the one presented here. This kind of tool allows the automatic evaluation of some individual learning activities (in the case of logic, all those related to the methods of proving) and provides students immediate and personalized feedback and statistics of their progress. From the point of view of instructors, those tools enable automated tracking of performance and progress of students and free tutors from the routine of correcting many activities. The time and effort saved can be used to provide richer individual feedback and continuous improvement of the subject.

We know that there are people in other institutions working in similar projects [8, 16, 18] and we think that the possible community of practice of all these people will be a valuable framework towards more universal projects.

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