A Virtual Learning Environment as a support to the Formal Methods courses: Languages Theory, a case of study

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Abstract: The way of teaching specialized courses about formal methods of Systems Engineering –in face-to-face modality- has remained unaltered for a long time. This article presents a report about the experience in designing and implementing a Virtual Learning Environment (VLE) as a support to the Language Theory (LT) course, offered by the Computing and Systems Engineering Department (CSED) at Universidad de los Andes (UA) during year 2003.

Keywords: Virtual Learning Environment (VLE), simulation, experimentation, Language Theory (LT).

1 Introduction
The way of teaching specialized courses about formal methods of Systems Engineering –in face-to-face modality- has remained unaltered for a long time. The experience in one of these courses -Language Theory (LT) in the Computing and Systems Engineering Department (CSED) at Universidad de los Andes (UA)- showed students having great difficulty to take possession of the basic concepts associated to regular languages and context free languages (in general) and of regular grammars and finite state automata (in particular). The consequences of this situation were the expected ones: high dropping out, serious problems when trying new approaches to compiler and interpreter theory and construction and –probably one of the most important – conscious rejection to using formal methods in Systems Engineering. Identifying these problems has lead to point a specific educational need, which has served as a benchmark for designing and developing a Virtual Learning Environment (VLE) which can be used as a support to classroom work and which encourages personal experimentation and the possibility to criticize a classmate’s job, opening in this way the chance for group learning.

This article presents a report about the experience in designing and implementing the virtual environment as a support to the course, during year 2003. The second part describes the classical structure of a LT course stressing the teaching methods associated and highlighting virtues and defects when possible. In the third part the VLE project is presented, emphasizing the methodology used when analyzing the course and offering the results from such analysis. The fourth section presents the proposed changes to the LT course. These changes include modifications to the pedagogical model as well as the design and implementation of a virtual support system. The fifth section presents the results obtained from the project and the sixth part presents conclusions and options for future work in this area.

2 Language Theory (LT) course - Characteristics

2.1 Content and structure
A LT course, in general, is offered to students at an intermediate level in Systems Engineering; it means it is a course taken in the third of five years the career lasts. This location in time implies students between 19 and 22 years old, who have some knowledge about information and communication technologies (ICT), virtual communication tools and web navigation and who also, have certain formation in programming methodologies and techniques. Although the majority of students belong to Systems Engineering, the thematic of this course might encourage the participation

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of students from other programs in engineering (electronic and industrial) and science (math and biology). The particular conditions at UA lead to LT courses with about 40 students.

After evaluating the didactic material and the thematic presentation proposed in several universities it is possible to conclude that a typical LT course studies abstract mathematic models for known computing devices, and by using these models tries to establish limits to computing. The core of the course is composed by two topics: computing models (automata or machines) and languages and grammar. In this classical approach grammar is understood as tools which generate symbol chains and automata is understood as tools which process such chains. According to De Castro ([DC04], 2004), “since the appearance of Hopcroft and Ullman influential texts ([HU69], 1969) y ([HU79], 1979), a basic course of computing theory has been focused in studying automata and grammar”\(^3\). In UA, as well as having in mind this approach, the LT course includes topics related with operational and denotational semantics which purpose is to introduce students to compilers construction.

In this way, a LT course can be divided in three big thematics:

- Regular languages: Deterministic Finite Automata (DFA) and non-deterministic (NDFA), regular grammar (RG), Regular Expressions (RE), Properties and limitations.
- Context free languages: Stack automata (SA), Context free grammars (CFG), Properties and limitations.
- Semantic: LL(k) and LR(k) analysis, Operational and Denotational Semantic.

The theoretical content is larger in the first two parts of the course, which take about eight weeks during the first half of the semester, while the third part focuses in problem solving.

2.2 Methodology at UA

The teacher presents the course topics trying to join them with the previous knowledge students have. Several kinds of exercises take place –such as presentations, individual exercises and group workshops – which aim to generate discussion and explore how to apply the new concepts. As it has been pointed, these concepts require a good abstraction level from students. In the second part of the semester, students can use a computing tool (javaCC) which lets them create and study different solutions to problems presented.

The face-to-face discussions are sometimes complemented with virtual discussion forums in order to go deeper in some topics. These virtual forums are a strategy to maintain a discussion level which might be lost due to the increasing number of students taking the course.

The teacher-student interaction is open and horizontal. The teacher is aware of rising questions and leads students to get the concepts as clear as possible. In order to achieve this, he generates questions and counter-questions about exercises developed in class. It can be said that the teacher is an expositor as well as a facilitator. When it comes to students, it is possible to identify a group of students who take active part in the class and suggest exercises to the teacher, who evaluates how pertinent they are.

The teacher usually assumes a dynamic role, going from expositor to facilitator or guide. Which of these roles he takes the most will be determined by the objectives of the learning process.

The evaluation of the course aims to observe development and progress in students by making two periodic and a final exam. Besides, there are quizzes, homework and workshops which value corresponds to 40% of the final grade (this aims to highlight the students’ everyday work and make possible a follow-up to their learning process). The periodic exams are graded on a 100 points basis and include one or two extra questions which represent a 25 points extra bonus; that is why some students get grades over 100. This evaluation is summative mainly. The teacher corrects the evaluation in class, so students can see their most common mistakes or good shots.

According to what has been exposed above, an unavoidable question rises: Why do students have difficulties to take possession of the concepts of the course?

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\(^3\) Original in Spanish: “desde la aparición de los influyentes textos de Hopcroft y Ullman ([HU69], 1969) y ([HU79], 1979), un curso semestral básico de teoría de la computación se ha centrado en el estudio de automatas y gramáticas”
The hypotheses are:

a. The presentation of concepts and facts belonging to an abstract, self-content theory can leave the student unable to react toward it. The student does not take part in the concept building or the facts discovery, but is only a passive, distant spectator. This passivity, worsen by the distance requires a bigger abstraction from students in order to have access to their secrets.

b. The necessity to go inside the theory to discover its applications can leave the student without apparent justification to get down to studying. Once again, there is the distance between theory and reality for the student. The only way to overcome this situation is by promising a future usefulness in a short term.

c. The impossibility to interact with abstract entities in a direct way can close the door to students to the construction, development, facts and applications of theory. This effect increases the distance mentioned above.

3 The Virtual Learning Environments (VLE) project

3.1 Context and methodology

The Academic Provost office at Universidad de los Andes, through the Research and Development Laboratory about Informatics and Education (LIDIE), started in year 2003 a process in which teachers from all knowledge areas are invited to live a process that intends to improve face-to-face classes by using ICTs. This process is determined by a methodology organized in four steps, according to Salazar et al [Sal03]:

Educational Analysis: This phase starts with an initial reflection by teachers about their courses and the way they have taught them previously, in order to identify problems and educational needs that can be solved by using virtual elements as support; this process has in account the previous experiences of teachers using these methods, the target population and the advantages and pertinence of virtual support for the identified need.

Educational Design: This stage is based over the results of the previous one, so orientations, contents and skills of the pedagogical model are a natural consequence of the necessity to be solved. In this stage the specific data of the aimed environment come to light, based on the definition of general and specific objectives and strategies to achieve them. The organization of activities and their integration with face-to-face sessions give rise to identification of spaces that will be part of the Virtual Learning Environment (VLE). For designing, is necessary to keep in mind the pedagogical guidelines established in the educational analysis stage, since it is fundamental to make resources and technological tools conditional to be coherent with the instructional model and objectives (micro worlds, simulators, drill and practice tools, etc). Furthermore, in this step the learning evaluation system is designed as a feedback and reinforcement model with motivating elements which can be used to support summative, formative or diagnostic evaluations.

Communicational Design: In this stage is designed the interaction between the user and the virtual environment in development, through the interface. The navigation and the graphic design are specified according to the philosophy or learning model identified at the beginning.

Computational design and development: Simultaneously with the Communicational design, the functional and technical requirements are defined in order to develop the virtual environment and the software resources associated with them. These include the logic structure and procedures required by the environment to be able to meet the principles and functions defined previously. Once this has been achieved, the development, integration and installation of computational elements composing the VLE take place.

There are two stages that complement and give feedback to the previous four:

Pilot test and adjustment: A representative sample of possible users uses the environment designed for a period of time -a semester-, under normal operative conditions. This test leads to determine whether the environment matches
the initial objectives, and also to identify the necessary adjustment to make it an effective solution to the defined necessity.

**Evaluation:** The process is accompanied from the beginning by an evaluation component whose purpose is to evaluate from an objective point of view the real impact of the VLE use in the course. In order to achieve this, is necessary to compile historical information of the course (dropping out and failure statistics, grades average, evaluations to previous versions of the course, etc) at its beginning; during the analysis, design and construction stages take place *in situ* observations of the teaching practice as well as interviews with students and teachers about how they are perceiving the course. These resources become the baseline which gives information about the course before and during the intervention.

During the pilot test, a new observation of the teacher’s job is made, as well as interviews to students, monitors and professors and analysis of VLE use indicators. All of these become the exit line which leads to a comparison with the initial data; from this, conclusions can be made about the real impact of the use of the Virtual Environment. In the particular case of the LT course at UA, the different stages lead to weaknesses identification, concrete educational needs definition and an educational proposal to satisfy them.

### 3.2 Weaknesses and educational needs identification

The analysis of strengths, opportunities, weaknesses and threats of the course helped to confirm the opinion expressed by students in the initial surveys, about how important is to have a space to experiment which leads to construction and interaction with the basic concepts from theory. The lack of this space was identified by all people taking part in this LT course as one of the biggest generator of difficulties to take possession of concepts from students. On the other hand, the big number of students in the course added to the abstraction grade required was identified as an inhibitory factor in the process of group construction of knowledge.

Based on the LT course objectives as well as on the information obtained from different sources (interviews to students, monitors and teachers; statistics; non participant observation) and on analysis and reflections made after that, two primary educational needs were identified:

- To maintain spaces to discuss and create concepts in group. These concept and discussion spaces were endangered due to the group size.
- To have a space which allow students experiment with some of the elements of the course.

### 3.3 Solution strategies and educational proposal

The strategy proposed to attend the problems exposed included four main objectives:

- Keep the face-to-face character of the course and keep on giving priority to this component.
- Design a VLE which facilitates interaction between all the people taking part in the course. It is necessary that this environment stimulates in the students the constructive critic and the confrontation with their classmate’s job.
- Design a tool which allows interaction between students and concepts and objects of study. This tool can be associated to the VLE, but its installation and use should be possible without it. It was decided that, as a first instance, this tool must cover all topics related to regular languages (DFAs, NDFAs, RGs and REs).
- Improve the written material for the course by making an electronic book associated to the VLE and which presents the different approaches to the topic.

In this way, the virtual environment designed includes a tool which enables experimentation with the mentioned concepts. The use of this tool is framed in a methodology that intends for students to experiment by solving practical problems about concepts developed in class. It is important for students to compare the proposed solutions with their partners’ and promote in this way the critical analysis based on the achievements, differences and difficulties they find.

The following spaces for information and interaction in a VLE were defined:
• **Navigation guide**, which shows students the purpose of existing spaces.
• **Tasks**, which includes assignments to be done by students.
• **Grades**, where you can find the grades obtained by the students.
• **Course topics zone**: divided into two big sections (*language and semantics*). Every one of these presents exercises about construction, modeling and operations, which are solved by the students who are supported by a virtual laboratory of automata construction and regular grammar.

The core of the VLE, where the biggest interaction of the student takes place, is focused in the course topics zone and in using the automata, grammar and regular expressions simulator: ALGRES (Automata – Languages – regular Grammars – Regular expressions – Educational Software). Is also in this zone where the student takes part in moderated forums about each topic of the course.

The three kinds of exercises available for the student in the course topics zone have specific educational purposes:

- The *construction* exercises are problems with different levels of difficulty which allow student to practice the operative approach to concepts (the typical entry of one of this exercises is “build an automata which accepts the language...”).
- The *modeling* exercises are problems where specific challenges are solved which allow students to practice the first clear applications of theory (e.g. It is proposed to the student to design a DFA which permits to verify automatically whether an addition is correct or no.)
- The *operations* exercises guide the student in exploring the theoretical proprieties of topics studied in class (a typical entry for these exercises includes one or more questions about theoretical facts the student must find out: Is the intersection of two regular languages a regular language?)

In the sequence of activities proposed, the teacher presents different kinds of exercises to the students. The solutions given by the students to the suggested exercises are published in a discussion forum where the group criticizes and evaluates the different results. The teacher gives feedback to the given solutions, encourages their publishing and also criticizes them. At least one of the exercises proposed is evaluated (this means that at least one of the exercises has a fix percentage of the final grade). Additionally, students get points according to their participation in the forum.

### 3.4 ALGRES\(^4\) and its role in the LT course.

ALGRES\(^5\) is a simulator for deterministic and non-deterministic finite automata, which allows users to see the existing relations between these, the regular grammar and regular expressions. Besides, it also allows users to explore the algebraic proprieties in the regular language family and in the computational model underlying the finite automata theory.

In the LT course the use of ALGRES becomes the way to make abstract concepts real; a support tool to minimize the distance between theory about formal languages and the reality faced by students. All of this is done at the *hands-on* laboratory which can be used in three different levels corresponding to three learning stages:

- Basic level: students have the first contact with the object of study; make operations with them; know and understand the way they work and what they mean.
- Intermediate level: students establish relations among the objects of study and make this evident by justifying the result of their operations.
- Objective level: students use consciously the objects of study and their proprieties to solve specific problems within and out of the theory.

\(^4\) See [http://sugamuxi.uniandes.edu.co/algres](http://sugamuxi.uniandes.edu.co/algres)

\(^5\) Educational Software developed by Francisco José Cháves (e-mail: fchaves@uniandes.edu.co) and Juan Pablo Quiroga (jquiroga@uniandes.edu.co), Computing and Systems Engineering Department (CSED) at Universidad de los Andes.
4 Results

The VLE of this course has two big objectives: offer the student a space to experiment and manipulate concepts with an abstract nature, and also provide spaces to discuss and conceptualize them. The simulator obtained from the process meets the proposed objective, since students have the possibility to use the tool to test their hypothesis about design and to verify the automata and grammar correction.

Additionally, the VLE opens a possibility to have discussions about the solutions obtained by students to proposed problems. This activity of evaluating and criticizing each other’s job allows students to verify how strong is their comprehension of the concepts and, in this way, they build learning by giving and receiving comments. All this process complements the dynamic of the face-to-face class and helps to keep conceptual discussions going -which were endangered by the rising number of students in the course-. Last but not least is to say that the proposed exercises are designed so students can evidence their usefulness and their relation with previous knowledge (in other areas). Summarizing, using the VLE designed for the LT course was useful to delve into the topics of the course; generated interaction between students based on theory and widened communication channels between the people taking part in the course. It also promoted collective building of knowledge by using analysis, reflection, critic and debate; promoted evaluation in pairs and autonomy in the learning process.

5 Conclusions and future work

The proposal to be used as a guide in future work includes periodic reevaluation of educational needs in order to identify the ones that will show up in a near future. In the same way, given the success obtained, it is important to develop an improved version of ALGRES which gives similar support in topics related with languages independent from context. On the other hand, this work can be extrapolated to other courses related to formal methods in systems engineering. Currently some work is being done in an editor of demonstrations in equations logic which must be used to satisfy –by using virtual support- an educational need identified in this kind of courses. In a broader context, with the particular experience in the LT course it is possible to confirm that “when students have proper learning tools which are also coherent with the objectives of the course, the chances to accomplish these increase.”[AS04]. This is an important supply for the expansion stage of the VLE project which currently is being done in the different academic programs in the university.

6 Bibliography


6 Original in Spanish: “en la medida en que los estudiantes disponen de herramientas de aprendizaje apropiadas y coherentes con los planteamientos del curso, las posibilidades de lograr los objetivos del mismo aumentan”