A hands-on course for introducing freshmen for Electrical Engineering

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***Abstract*—This work describes the experience 2013-2017 of the course Tallerine, a hands-on freshmen course of the Electrical Engineering program of the Universidad de la República, Uruguay. Its objectives include introducing Engineering and the degree program to the students, facilitate their socialization, and promote teamwork and the acquisition of communication skills. This paper summarily describes the experience with an emphasis on the methodological point of view and a first evaluation on its impact on the program.**

Keywords—hands-on freshmen course. project-based learning. electronic projects.

I. INTRODUCTION

Uruguay faces a strong scarcity of Sciences and Engineering graduates, in all areas and levels, which constitutes a bottle-neck for the country plans aiming to develop the production, the culture and the knowledge. This scenario is not, of course, exclusive of Uruguay, [1]. Uruguay graduates 400 engineers each year, equivalent to a graduate per 8000 people. This figure is sensibly inferior to the region's rates (6700 for Argentina, 6000 for Brazil, 4500 for Chile and Mexico) and very inferior to the rates in developed countries, near to 2000. Engineers' and technicians' unemployment is zero and the demand is often unsatisfied with adverse economical and social consequences.

A distinctive characteristic of the Uruguayan educative system is the absence of formal limitations to the access to the public universitary system in most areas, including Sciences and Engineering. Any student completing the secondary cycle is free to access the public University. However, the number of freshmen students of Engineering almost does not increase and the indices of evasion are quite high. The freshmen feminine population is about 20% evidencing a strong opportunity to increase the admission and diminish the genre discrimination by trying to change the existent cultural bias.

The EE program nominally lasts 5 years and has a generalist, credit-based, flexible curriculum. It accomodates several professional lines in EE (telecommunications, power systems, electronics, signal processing, etc.).

The program has received twice the official Mercosur accreditation in 2006 and 2011 and is currently on a new accreditation process. Background on Physics and Mathematics is mostly concentrated in first 4 semesters, common for most of the engineering programs. Until 2013, the organization of the program basically delayed the first technological contents to the 5th semester, delaying also the first project-based learning activities. The whole scenario resulted in:

- a scarce freshmen visibility of the EE program, among all the Engineering programs;
- serious difficulties with student motivation, social integration and evasion;
- number of freshmen EE students descending from 240 to 120 in seven years.

Freshmen students face a quite rude scenario: massive classes and a social environment very different from the previous one often implying a change of residence. Most of them experience also serious academic difficulties with a secondary underground not fully suitable for universitary studies. This situation motivated the offer of the freshmen course Tallerine by the first time in 2013. Tallerine (acronym of Introduction to the Electrical Engineering Workshop and also a pun in Spanish) is an active learning activity where the students develop team projects in several EE areas. The main goals are:

- motivate the students,
- estimulate their creativity;
- integrate socially the students;,
- that the students identify themselves with the University and the program,
- let the students know the objects, topics, methodologies and actors of the EE program.

The methodology includes team work, the offering of five different, ludic, projects or challenges to be chosen by the students, communication activities, etc. The projects offered in the period, more than 15, included applications in audio and image processing, analogical and digital electronics, energy, control, robotics, etc.

The results are very positive. The students perception on the course, very good and sustained along these years, is similar to the results of the first year, documented in [2]. Later, the school performed an evaluation, summarized in section III of this paper, of the impact of the course on the students performance along the EE program.

The paper is organized as follows. Section II describes the methodology of Tallerine including a brief description of main projects. Section III relates the 2013-2017 experiencei ncluding the main results of the evaluation of the impact of the course on the students performance. Section IV wraps up the paper with some concluding remarks.

II. METHODOLOGY

The total group of EE freshmen is about 150 students. Five independent tracks are offered to them, each one of 30-36

places. The students in each track are organized in work teams of 4 to 6 students. The teams work on the same project independently along the 15 weeks of the semester.

Several (usually five each year) EE projects are offered, one by track, whose main attributes are: imply the building of a prototype; are representative of the main applications of EE and have ludic and motivating aspects.

The projects are exposed in a final public event, and by the elaboration and publication of a short video. The videos of the experience 2013-2017 can be seen at [11]. Some of them are included in references below.

The students work in interaction with teachers and with EE students that play the role of teacher-assistants (T.A.) who participate in the experience voluntarily. The interaction with the T.A. (young students like them, but with some experience with the school and the program) is a good stimulus for all of them.

The course schedule includes some initial classes, introductory to the basic objects to be manipulated (basic electronic components, programming, electronic devices and tools, etc.) and a schedule of intermediate deliverables. The grading is individual although, of course, take into account the team performance. It is based on the deliverables (written reports, presentation, prototype), class observations and co-evaluation.

Key tools of the methodology are discussed next.

Motivation. It is the main objective to achieve and also the main educative tool. Motivation was closely monitored by the daily teacher-student contact and through surveys specially designed with this objective. Motivation was also the main tool to organize the team of teachers and voluntary teacher-assistants.

Team work. Our previous experience with active learning in Engineering, see e.g. [3,4] suggested a number of 6 students per team. It provides redundancy, enough work force to achieve some interesting technical goals, and the basic cell for social interaction and communication. The fair distribution of tasks between the team was observed by the teachers in each instance and by the co-evaluation, described later.

Challenging projects. The proposed projects were frankly challenging for the students, given their previous background. This fact is strongly motivating when properly handled. The lack of background was circumvented by several teaching tools: introductory material, tutorial exercises, black boxes in electronics and software, etc. The objetive was *to work with* these devices instead of *to analyze* them or *to model* them.

Closely controlled course. Teachers had to be careful with several details potentially able to frustrate students along the course. One aspect that deserved a lot of attention was the level of difficulty of the different tasks in order to be reached by the students with a heterogeneous and partially unknown previous background. The projects and the tools provided were thought in a modular way in order to tune their extension and difficulty during the semester. Some projects were extended because primary objectives were surprisingly reached very fast.

Technical communication. The student teams were asked to present their advances at least twice, with computer presentations and prototype demonstrations. These instances provided feedback about the ongoing projects for students and teachers. Written reports were also asked and the elaboration of a video per team. The videos had two guidelines: a hard limit of 5 minutes and the warning that they will be public on Internet. Considering that the elaboration of the video was the last activity of the semester, they were advised to relax ad enjoy the experience to publish their work on the net.

Tallerine communication. During the course, two on line tools are used. The University education site (https://eva.fing.edu.uy/course/view.php?id=405) was employed for formal communication and news, and also a Facebook as a repository of pictures, videos and a way to maintain the students motivation.

Coevaluation. At the middle and the final of the semester a mandatory on line form has to be filled by the students. The questions asked the student about the punctuality, the attitude, creativity and the respect for the team agreements of each member of the team. These data were processed very fast and the feedback, student by student, was put in knowledge of the teachers. The average rate received from their colleagues was also communicated to each student. This tool was very helpful to encourage the right attitudes in a work force and prevent an unfair distribution of tasks and responsibilities inside the student teams. The co-evaluation form was designed along references [5,6,12]. The co-evaluation was not done in teams with less than 4 members.

The projects offered in the period were:
Analogic sinthesizer ("Sintetizador"). Each team must build a electronic musical instrument, departing from schematic diagrams and basic principles of different modules: oscillators, amplifiers, filters, modulators, etc.. Each team had to:
design the layout and build the printed circuit board (PCB);
build each circuit (to cut and drill the PCB, welding the components);
test and debug each circuit;
synthesize a sound chosen by the team (e.g. the sound of a motorcycle, an alarm, etc.).
Finally, each team had to design and build a sound controller, e.g. a controllable device that helps to play the sound. The controllers built were different devices ranging from an optical harp to a kind of a guitar based on a linear resistance. We discovered the art skills of several of our students.

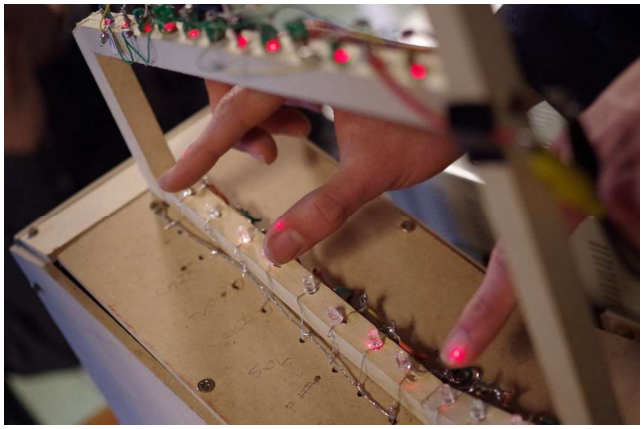

Figure 1:" The harp", 2013: an instance of Sintetizador project.

Othello game ("Otelo"): Each team had to program a small micro controller Arduino in order to manage a led matrix, communicate with a similar device and implement a strategy to play the Othello game. The harware (Arduino card and a PCB with the led matrix and associated circuitry) was supplied. The students work was entirely on the game strategy and the programming. The routines provided by the teachers implement the basic manipulation of the led matrix, the PC-Arduino communication and a routine that returns the possible places for the next move.
Teachers provided a first benchmark player that simply chose the moves at random. A second benchmark, more competitive, was provided later. Students investigated on Internet and designed game strategies to play against the teachers' players and other opponents. The project ended with a competition between the students teams and the teachers' strategy.

Cell phones with Android ("Android"): the teams implemented routines for the management of the basic peripherals of a smart phone (camera, display, audio, device attitude) to play with them and implement basic games. The teams began making programs to implement different games (bouncing balls, mazes, etc.) and signal processing routines. The final projects, at the end of the semester, include an interactive maze (the user can draw a maze on a paper, take a picture and use it to play on the cell phone), programs that directly upload pictures on Internet and several kind of games based on the attitude sensor and the tactile display.
This project was the most challenging from the technical standpoint. Some teaching procedures and materials were later revised in order to turn easier the first approach for students lacking previous experience on programming.

Solar energy system ("Solar"): the teams had to build a battery charger fed by a photovoltaic panel.A 6V battery and a 17V, 12W photovoltaic panel was provided, as well a schematic diagram of a linear voltage regulator that can charge the battery from the solar energy. The project included an initial set of very interesting workshops about renewable energy, the design and construction of the PCB and the testing of the final circuit. This project, the most technically simple, was as effective as any other to keep the students motivation all along the project.

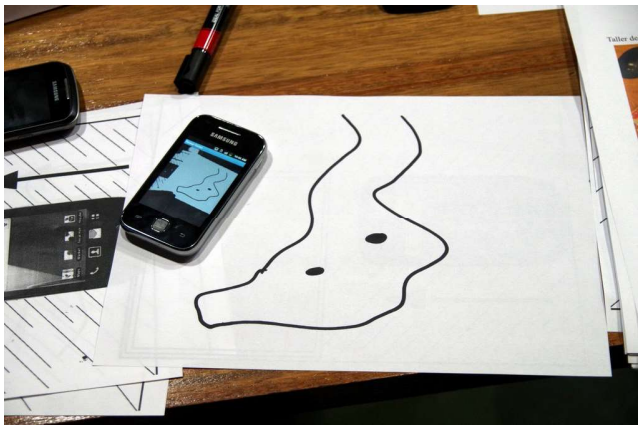

Figure 2: " The maze", project Android 2015.

Figure 3: An image of the robots used for Tallerine Robotico, 2015.

Robotic ("Robotico"): an autonomous robot provided with two driven wheels, infrared and proximity sensors is to be programmed by the students in order to follow some floor references and respect certain restrictions. The robots are equipped with an Arduino micro-controller and communications cards Xbee. The final competition one year consisted in driving the robot by a small city designed on the floor; other years was a sumo game.

Simon game ("Simon"): Students implemented the classical game with an electronic plaque of configurable logic, the Terasic's DE0. The blocks of logic were very simple and the introduction of the students to this technology was made very efficiently with a set of three tutorials. The implemented game was based on three colors and switches, instead of the four of the classic game. A VGA output allows to observe the game on a computer monitor.

Leds on wheels ("Leds sobre ruedas"): The challenge was the construction of a display based on the persistence of vision (POV) with an array of leds mounted on a beam of a bicycle wheel. The control was done with an Arduino micro-controller and some additional basic digital electronics.

Digital audio effects ("Efectos Digitales de audio"): Several classical audio effects (Distortion, Delay, Flanger, etc.) were implemented by using free hardware y software (Linux/GNU, Puredata, Arduino, Raspberry, etc.) . See, for instance, video [10].

III. THE 2013-2017 EXPERIENCE

The first experience was, *a priori*, plenty of uncertainty. The teachers had a significant experience about teaching students with three or four years of university education, see [13]. There was no previous experience of our team on teaching freshmen with the significant differences in maturity, background and motivation. There was no previous experience in the program with a teaching methodology aimed to build

devices and prototypes without a very solid background on Physics, Math and modeling skills.
Despite of these uncertainties, the offer was not intended to be a pilot program for a reduced target: Tallerine was offered, although not mandatory, to the complete generation of EE freshmen students: about 150.
The main tool to cope with the uncertainty was the close monitoring of the learning process and the pre-design of the projects in a modular way. Projects were conceived in such a way that they can be enlarged or simplified in accordance to the students response.
Each student chose his/her first and second preferred project. Vacancies were solved taking the students preferences into account and trying to balance the five projects each with about 30 students.
The course began with a first magistral class (the unique, by the way) to welcome the students, explain the methodology, the schedule and the basic rules. Its main objective was to be sure that they understand the basic fact that Tallerine is a course *to do things* and *not to listen.* The message was explicit and completely in line with the previous publicity. During the first class a survey was done in order to collect some data and measure the initial enthusiasm with the proposal. On the 7th week of the semester the survey asking directly for the student enthusiasm with the course was repeated. The results, broken down by project, are shown in Fig. 4.

Fig. 4 shows that the project Solar was very effective in keeping (and increasing) the student motivation the first part of the semester. Projects Otello and Android show that several students lose part of their initial enthusiasm. In particular, in these weeks and projects the students made their first experiences with programming, compiling and debugging, some defiant tasks that yield their results later. It was very important to get timely these data and share it with the teachers team.

The perception of the students about the course is very positive. The results of a polley done at the final of the semester was first published in reference [2] and it had little variations on the complete period 2013-2017.

The projects were presented in a public event at the final of the semester. There were demonstration of musical instruments, photovoltaic battery chargers, games and application on Android devices, Otelo competitions, implementation of Simon games in a quite festive event.

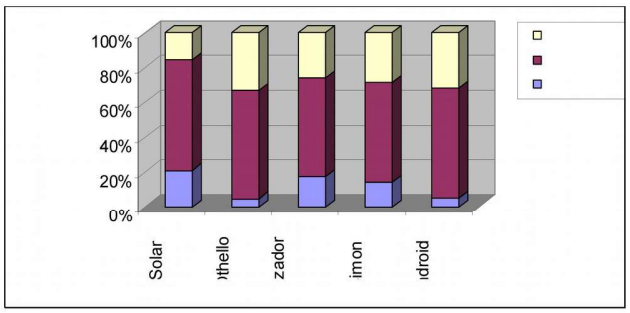

Figure 4: Intermediate survey, by project. Left to right: Solar, Othello, Sintetizador, Simon and Android. Skyblue: students who feel more enthusiastic than initially; violet: students with the same enthusiasm; white: students with less enthusiasm.

The videos elaborated by the students have shown to be an excellent tool for socializing, describing the main ideas and the project. Is also a very valuable way to freely express the students opinion and mood about the course.

The videos [7-9] are particularly descriptive of the course methodology, as seen by the students. The reader can look all the videos on Youtube [11]. They are spoken in Spanish, but most of the message is not verbal.

In 2015 Unidad de Enseñanza de la Facultad de Ingenieria (Education Department of the Engineering School) evaluated the 2013-2014 experience of Tallerine. A description of the results follows. A broader study reaching year 2017 is currently in progress.

First, it was evaluated the student performance on the other first semester courses (Calculus with one variable (16 credits), Geometry and Linear Algebra (9 credits) and a first introductory course of Physics (10 credits)) for several students populations: Computer Sciences students, Mechanical Engineering students, Electrical Engineering students having done or not Tallerine. The performance is computed by adding the credits won by each student. The study ranges 4 years from 2011 to 2014. Tallerine was offered since 2013.

Table I list the students performance of 2013+2014 generations of EE students having donde Tallerine, taking as control groups the students of Computer Science, Mechanical and EE not doing Tallerine. For each program the total number of students, N, the median and the average of the credits won are listed. Notice that the median provides little information since the possible values are {0,9,10,16} and the respective additions. A zero median in Table I tells us that half the students has won zero credits for the corresponding program.

Second, the focus is put exclusively on the EE students in the period 2011-2014. The performance of the students having done Tallerine is compared with the EE students without Tallerine.

Table II lists the results of the same analysis taking the EE students generations 2011 and 2012 as control group. It is clear from both tables the correlation between the performance on these math and physics courses and the fact of having done Tallerine.

The impact of Tallerine on the evasion was also measured. The number of students with no activity the year following the first semester was obtained for several engineering programs. The results for EE were disclosed in Table III regarding the inclusion or not of Tallerine in the first semester.

TABLE I. CREDITS WON BY 2013+2014 STUDENTS FOR COMPUTER, MECHANICAL AND ELECTRICAL ENGINEERING

Program	Computer Science	Mechanical Eng.	EE w/o Tallerine	EE with Tallerine
N	1047	225	110	166
median	0	0	0	9
average	5.9	10.6	5.8	12.9

TABLE II. CREDITS WON BY EE STUDENTS .

Program	EE 2011-12	EE 2013-14	EE w/o Tallerine 2013-14	EE w Tallerine 2013-14
N	204	276	110	166
median	0	0	0	9
average	8.6	10.0	5.8	12.9

Table III shows that EE is the program with less inactivity of the three programs considered and that all the Tallerine students remain active the year after the course.

In order to avoid a possible bias due to differences between different programs, four generations of EE students were compared, see Table IV.

No student that realized Tallerine in 2013 or 2014 abandoned the program the year after the first semester.

Results in Table IV question us *Is Tallerine providing something useful, valuable, to students*? Or, merely, *the active students do the course and the inactive ones not*?

In order to answer this questions, the 10% of the 2013-14 EE students was interviewed by phone. The aspects mentioned by the students were the following:

- Tallerine allowed them to integrate study teams that went beyond Tallerine and improve their study strategies for other courses.
- Tallerine helped them to gain insight about their vocation, being this EE or not.
- Tallerine was a concrete meeting with the professional activity.
- The students highly valuates that the course is offered in the first semester and ask other programs to include a similar activity.

The Facultad de Ingeniería has done a deep discussion about the teaching strategies to face the difficulties at the beginning of the different engineering programs. The results of Tallerine, along other active learning courses in Physics [14], provided a valuable experience that paved the way of a change of teaching strategies prioritizing this kind of activities in first semesters. Currently, Computer Science and Chemical Engineering are designing freshmen curses with similarities with Tallerine.

TABLE III. INACTIVE STUDENTS THE YEAR AFTER THE FIRST SEMESTER, 2013-2014.

Program	Mech. Eng. 2013-14	Comp. Science 2013-14	EE 2013-14	EE w/o Tallerine 2013-14	EE w. Tallerine 2013-14
N	225	1047	276	110	166
Inactives	34	130	26	26	0
%	15.1	12.4	9.4	23.6	0

TABLE IV. INACTIVE EE STUDENTS THE YEAR AFTER THE FIRST SEMESTER, 2011-2014.

	EE 2011-12	EE 2013-14	EE w/o Tallerine 2013-14	EE w. Tallerine 2013-14
N	336	276	110	166
Inactives	32	26	26	0
%	9.5	9.4	23.6	0

IV. CONCLUSIONS

This document is a brief description of the experience with Tallerine, a hands-on freshmen course for motivating and introducing students to the EE program. The course has shown to be very successful to integrate the students between them and to improve their study strategies for the Electrical Engineering program.

Some key aspects of the teaching methodology were identified as the main tools for the results obtained: teachers motivation and rapport, quick feedback, suitable communication, close monitoring and the employment of suitable surveys for measure students motivation and team performance. The documentation of the projects via the elaboration of short, public, videos was a true finding very helpful, in addition, for course and program communication.

The academic performance of the students on the first courses of the program has improved and the inactivity indices in first semesters has drastically diminished. No Tallerine student was found to be inactive the year after the course. Student inteviews by phone pointed several valuable outcomes of Tallerine regarding social integration, program insight and study teams.

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