

Developing electronic devices for the disabled as an active learning experience in Electrical Engineering

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ABSTRACT

This paper presents an optional course for Electrical Engineering students of all levels that focuses on the development of electronic devices for the disabled. The objective of the course is to give students a practical hands-on experience in basic electronics as well as to create an open-source library of designs that can be easily replicated and provide affordable devices for people with disabilities. Results show a high motivation for the students, that embrace the active learning experience as an opportunity to learn practical electronics skills and contribute to the welfare of a vulnerable population, reflecting on the social role of technology.

Keywords - disabilities, electronic devices, active learning

Session Type: Poster session

Introduction

It is generally accepted that project-based learning is a highly effective approach to teaching engineering (Mills & Treagust, 2003) (Savery & Duffy, 1995). More recently the introduction of design thinking concepts in the engineering curriculum was proposed (Dym et al., 2005).

On the other hand, service learning is acknowledged as a positive approach for teaching problem solving skills and improving students' motivation, while at the same time engaging the community and developing citizenship among the students (Bringle & Hatcher, 1996).

The course presented here is inspired by these trends and follows similar motivations and methodology as the ones described by Bykbaev et al. (2011) for senior Engineering students and Godino-Llorente et al. (2012) for EE Masters' students.

The main idea behind this course is to provide a highly motivating experience for engineering students with the combination of a project-based approach to learning basic electronics, with a meaningful project that can have positive impact in real life.

According to official sources from 2004 (INE, 2004), 7.6% of Uruguayan population has at least one disability, totalling 210,000 persons and affecting 21% of homes. The disabilities are distributed as motor difficulties (31%), vision impairment (25%),

audition impairment (14%), mental disabilities related to learning (12%), mental disabilities related to socialization (7%), and others.

One particular characteristic of electronic devices for the disabled is that a wide range of useful devices is of low technological complexity, however the market dynamics are such that commercially available products are expensive and out of reach for most of the population. In a small country as ours, many devices are not even available locally and have to be imported by individuals or institutions, increasing the total cost. In this context, the challenge to develop solutions that can be replicated locally and distributed at a low cost to people with disabilities provides a strong motivation for students. Besides learning to create and build basic electronics projects, the students have the opportunity to have a positive impact in a vulnerable population.

Methodology

The course consists of three distinct phases. The first one is composed by two lectures about disability given by specialists in the subject, with the goal of providing a context for the course. The topics are: characterization of disabled people in Uruguay, institutional context, technology applied to disabilities, the concept of digital ramps. Many examples of existing commercial devices are presented, evaluating their strong and weak points, and showing their practical use in disabled people's day-to-day life.

Next, the students are presented with three lab sessions about practical electronics. These hands-on sessions introduce basic abilities like identification of electronic components, use of basic instruments, Arduino programming (Arduino, 2013), creating printed circuit boards (PCB) and soldering techniques.

After these two phases, the students have introductory notions in the two main topics involved in this course. They will continue to develop their knowledge about electronics and the technological needs of disabled people in an autonomous way, within their final projects.

The students are divided in groups of three and each group works in a project with the help of the teachers. Teams can choose between projects based on specifications drawn by NGO experts or to join an educational project in schools for disabled people.

In the first case, students have to develop projects that meet specifications supplied by experts from the health area, without any direct contact with the final users. Each group is given enough room in the technical definition to develop their creativity, with time and money constraints. In general, students use electronic components available in the country.

The role of the teachers is to help students with their technical doubts, teaching them extra tools if needed, such as software for designing electronic layouts. The students organize their work by themselves, working at the University or at their own homes.

The projects are characterized for being of relatively low technical complexity so they can be approached successfully by students without previous experience. However, this does not mean that the resulting products are of little use, since these devices are generally out of reach of the general population due to the nonexistence of a local market for them and a high cost of import. The students are asked to write a step-by-step guide for constructing the devices, that is published in the course website (Taller de Electrónica Libre, 2013) and becomes available to anyone who wants to replicate them.

On the other hand, students who choose the second path are incorporated to a multidisciplinary team (Flor de Ceibo, 2013) that works promoting Information and Communication Technologies within the framework of Ceibal Plan, that is a One Laptop per Child implementation in Uruguay (Plan Ceibal, 2013). They make visits to the primary schools for disabled people, where they meet children with cerebral palsy needing technological ramps. Their interaction with the teachers and the multidisciplinary team (composed of several students from the University and led by a teacher from Psychology) helps them to understand the raw reality that they find in the schools. In order to do that, they take part of some meeting of the whole team and of some activities with the disabled children (DanceAbility, 2013).

These students develop low-cost switches made with everyday materials and adapted for specific children, given they have different levels of motor control in different body parts (hands, feet, head). They also offer workshops for teachers and relatives of disabled children on how to build the devices, teaching them basic concepts of circuits and electronics.

At the end of the course, students make a public presentation of their projects, not only showing their results but also the process that they undertook. This is an opportunity to exercise oral communication abilities, in many cases being the first time students face this challenge at the university level. The presentation is open to the general public, with special invitations to the different organizations that worked in collaboration during the semester.

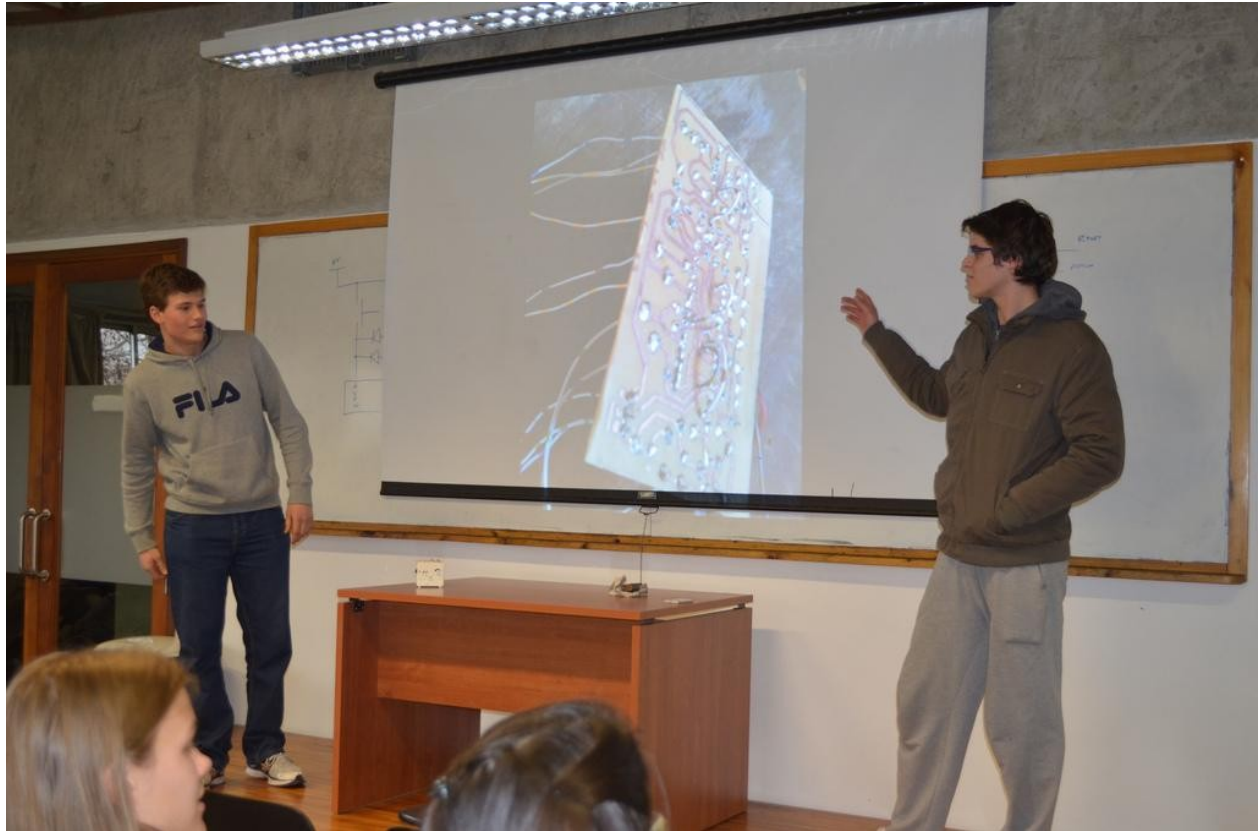


Figure 1. Students presenting their projects at the end of the course

Results

Some of the devices developed by the students are:

- low-cost switches: after analyzing different alternatives, the students arrived at a novel design implemented with cheap and easily available materials like plastic sheets, screws, washers, weather strips, recycled headphone cables, etc. (Fig. 2).

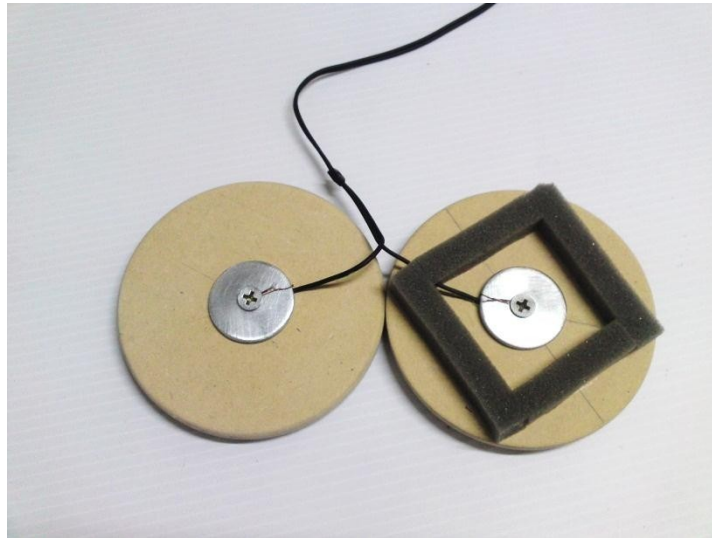


Figure 2. Low-cost switch construction.

- mouse adaptations for external switches: this classic adaptation introduces a jack mounted on the mouse chassis that is connected in parallel with the left-click switch.
- keyboard adaptations for emulating the mouse movement: this adaptation required opening and reverse-engineering an existing computer keyboard, routing the connections corresponding to the arrow and enter keys to large buttons built on top of a cabinet; with an adequate configuration in the Operating System, the arrow keys can be used to move the mouse pointer in the screen, while the enter key acts as the left-click switch.
- picture-based communicators with scanning: this design implements a sequential activation of LEDs with stop and reset buttons that can be activated with external switches.
- blackboard-based communicator with wireless controls: this project uses a scanning method similar to the previous one, but the activation signals are taken from four wireless devices and the area for placing pictures is larger, so it can be used at a larger distance by many students at once.

- voice-based communicators: two different designs for communicators were implemented using commercial voice-recording chips, one for a single message, and the other for multiple messages; the communicators can be activated by mounted as well as external switches.
- toy adaptations for external switches: several toys with simple electronic functions were adapted for activation with external switches, in every case a special analysis of the internal circuit was performed and wires connecting to a jack were introduced in the convenient place; some of the toys adapted are remote-controlled cars and stuffed toys with sound, lights and/or movable parts.
- induction loops for hearing aids: this project consists of building and testing induction loop amplifiers, based on schematics provided by the teachers.

There were two workshops implemented: one with teachers and the other with relatives of children with disabilities (Fig. 3). These hands-on workshops were focused on the building of switches and toy adaptations. The students prepared and directed the workshops, being able to communicate with non-technical persons the basic elements and methods for building the devices. Many switches were built and several toy adaptations were successfully implemented during the workshops, empowering the attendants to replicate the work in the future to cover for their needs.



Figure 3. Primary school teachers assembling low-tech devices for disabled children from their school.

Case study

Children with cerebral palsy may experience several communication impairments, due to difficulties in their motor control as well as in their cognitive development. In particular, they cannot produce speech appropriately due to motor disorders and their language development can be delayed (Pennington, 2008). Some studies report that between 16% and 24% of children with cerebral palsy cannot communicate verbally, needing some kind of augmentative and alternative communication (AAC) system (Clark, 2012), in order to communicate their decisions in another way.

One widely used AAC system is called switch access scanning and consists in a board with several messages (for example: "I want to play", "I want to go to the bathroom", "I love you", etc) displayed graphically and sometimes accompanied by short words in big size (some children have sight difficulties too). The most basic low-tech device is simply a board with several printed cards with messages, that are pointed sequentially by another person who wants to know what the child is trying to communicate, until the child makes some kind of signal (movement or sound). However, this kind of device requires that the adult has to be in front of the child exactly when the child takes a decision, probably for a long time, because it may be difficult to get them concentrated.

On the other hand, there are software implementations of the switch access scanning system, based even in the Sugar environment installed in the XO laptops of the Ceibal Plan. Though the software does not need adult supervision, few children use it intensively, given that they can almost no manage the small dimensions of the XO laptop. Standard PC or laptops can be used, but the first ones are very cumbersome and the second ones can be easily broken by sudden involuntary movements.

Therefore, in the context of the course, some students developed prototypes of electronic versions of this AAC technique, combining the advantages of both low-tech and software implementations. One project was a picture-based communicators with scanning, based on a simple circuit composed by a counter, a timer and digital gates, that sequentially turn on LEDs placed on a plastic box, each one associated to a card with a message (see Fig. 4, left). The child can stop the sequence using a custom-made push-button connected to the box. The last LED selected remains on until an adult comes to see the message left by the child. The time interval between LEDs can be adjusted by an adult, given that some children with cognitive difficulties may need more time than others to decide whether to select or not the current option.

Another project, the blackboard-based communicator, was based on the same principle, but for a different context: a classroom. Primary school teachers make use of the scanning system for the whole class, with a low-tech board next to the standard chalk blackboard. A team of students built a full-size version of it (design shown in Fig. 4, right), using similar technology to that of the previous project, with the addition of wireless doorbell devices to make remote controls for the children.

When one child sees the option that he wants to communicate, she pushes a button connected to her remote control, stopping the scanning sequence. There is also another set of LEDs that identify the remote control used to stop the scan. Then, the teacher can know at the same time who pushed which option, and work with that. The teacher has the possibility of restarting the device to allow the other children to say what they want, or to work with a different question.

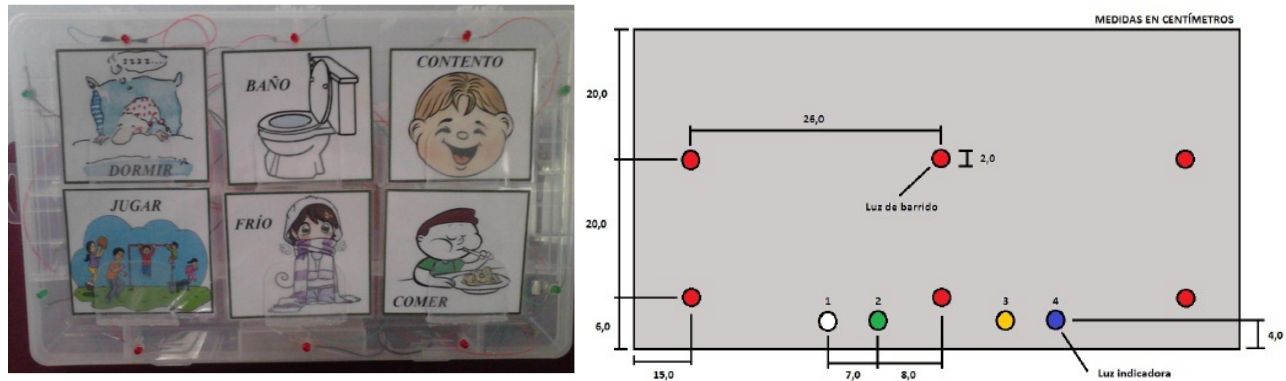


Figure 4. Individual switch access scanning device (left) with message cards and its corresponding LEDs. The device shown on the right is for use in the classroom: 6 red LEDs (indicated by circles) correspond to different options, whereas the 4 LEDs with different colours are assigned to the remote controls used by the children (via push-buttons).

Conclusions

The results show that students have a high motivation both for having the opportunity to work in a practical project and for contributing to the welfare of a vulnerable population. This was evidenced by students' performance and commitment during the whole semester, in some cases going beyond the end of the semester.

The simplicity of the electronic designs and the generation of documentation with blueprints and instructions available freely online, enables any person with basic knowledge in electronics to replicate these devices, increasing the impact of the students' work.

This course was able to fill the gap between the academic teaching of technical subjects and the social role of technology. Not only did the course introduce students to practical electronics, problem-solving and team-working skills, but also by engaging the community, the course promoted the personal development of the students.

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