Signal Processing for High School Students: Learning from a Reach-out Experience

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Abstract – As part of a pre-engineering summer camp, high school students were exposed to advanced college-level subjects in digital signal processing. The experience showed that despite the measured decline in enrollment of new students into science, technology, engineering, and mathematics disciplines, approaches to bring more information to them before they make their carrier decisions can influence their attitude towards a specific field. This paper describes the strategies used to structure the workshop, the delivery mechanisms, and the assessment methods used to quantify their success, rounded by a discussion of important lessons learned by us, as educators, through this experience.

Index Terms – K-12 initiatives, reach-out experience, signal processing in high school.

INTRODUCTION

In recent years, multiple concerns have been raised by an apparent decline in the number of students nationwide, choosing to pursue careers and advanced degrees in science, technology, engineering, and mathematics (STEM) disciplines. One major reason for these concerns is the risk of loosing continuity in the knowledge chain necessary to properly solve the challenges faced by coming generations.

Among the factors contributing to this problem is the limited amount of information reaching students in the early stages of their education about technological issues and their role in our lives. It results common to find college students who do not associate, for example, cellular phones with electronics or with signals and communications, or iPods with embedded systems. Examples like these hint that many students make decisions about their careers without seeing the relevance of STEM subjects in fields such as medicine, national security, economy, and even entertainment.

Numerous approaches have been reported to introduce pre-college students to technological subjects. One of such mechanisms is in place in the Electrical and Computer Engineering (ECE) Department of the UPRM through a pre-engineering summer camp for high school students [3]. In this program, groups of twelve-graders from schools all over the island are taken to a four-week camp where they are brought in contact with different subjects within the areas of ECE. As part of this program, with the sponsorship of a renowned industry partner, last summer we initiated the offering of a series of workshops in digital signal processing (DSP).

Two groups of students were given a daylong introductory course in DSP including hands-on laboratory activities. An assessment of their inclination, knowledge on the area, and awareness of its importance were made prior and after the workshop in attempt to quantify their impact. In this paper, we discuss the strategies used to structure the workshops, the delivery mechanisms, and the assessment methods used to quantify their success. We analyze successful and not so successful approaches unveiled through our experience when delivering college-level subjects to high school kids and their effectiveness in creating awareness about the importance of STEM disciplines and motivating them to see these as choices for their lifelong careers.

The rest of this document has been organized as follows. The next section provides background on the pre-engineering program at the UPRM and the target audience of these workshops. Next, we discuss how the workshop was structured and delivered based on the background of the target audience. The last two sections discuss the assessment methods used to quantify the workshop impact and its measurements and the lessons we learned from the experience.

WORKSHOP SETTING AND TARGET AUDIENCE

The Pre-engineering Summer Camp is a program created and run by the University of Puerto Rico at Mayaguez (UPRM). The UPRM has the largest Hispanic engineering school in the U.S., and it counts with about 765 faculty members and almost 14,000 students. It ranks 14th in the nation for undergraduate engineering enrollment, 23rd for awarded engineering degrees and 10th for engineering degrees awarded to women [1].
The Pre-College Engineering Program (PCEP) is a residential workshop designed to introduce talented high school students to the engineering professions [3],[4]. The program aims at motivating talented youth to choose and pursue studies in engineering, enhancing their ability to make sound career decisions. Every summer, 30 male and 30 female Puerto Rican high-school students have the opportunity to spend two weeks at the UPRM campus. To facilitate interaction and manageability, two separate co-ed sessions are held each year. Funding for the program is mostly provided by corporate institutions.

Program activities include an overview of all engineering disciplines offered at UPRM. The sessions also include: laboratory tours, field trips to manufacturing plants and construction projects, engineering workshops, design and creativity competitions, contact with professional engineers, and exchange with engineering students. During the program the students are expected to gain (1) experience about engineering as a possible career; (2) familiarity with the academic preparation necessary for careers in engineering through involvement in hands-on workshops; and (3) exposure to the college environment and to the resources available. In the process, participants explore their interest and vocation to become engineers, and clarify which specific engineering disciplines they prefer and why. A total of 810 students have attended the program since its creation [2], from which 94% of the participants have ended-up pursuing careers in engineering.

The PCEP program brings to the field of engineering gifted students with underprivileged social backgrounds. Each year, the program receives approximately 350 applications from all high schools in Puerto Rico. Students that will complete their eleventh grade by June are eligible for admission to the program of the year. Since about 99.9% of the population of Puerto Rico is native and consequently of Hispanic origin, efforts to target a minority population are unnecessary. Over 50% of the participants come from low-income households with less than $10,000 per year.

This program employs and involves a number of Engineering undergraduate and graduate students, who largely contribute to the success of it. The full-time PCEP includes 8 engineering students. They act as mentors, participating with the high school students in all program activities. Approximately 50 other engineering students are involved in seminars, panels, and lab presentations that enrich the PCEP experience. Therefore, through this program engineering students have the opportunity to communicate what they are learning, and to reflect on their studies as a whole.

During the two weeks of summer camp, students have the opportunity to attend diverse activities and workshops on an elective basis. Last year we decided to introduce a workshop on Digital Signal Processing as one of such activities. The participation in this workshop was on a voluntary basis. A number of other activities were also organized for the students during those days, from which they were asked to choose those that called their attention most based on a ten-minute presentation offered during the PCEP opening. From a group of 60 students distributed in two sessions, 26.7% of them selected the DSP workshop.

**Structure and Delivery Mechanism**

The DSP workshop was structured with the following learning objectives in mind:

- Students should comprehend and recognize basic concepts of Digital Signal Processing.
- Students should be able to identify and manipulate in a proper way a DSP board in order to get a proper output when performing experiments.
- Students should respond to signal processing related phenomena and infer an appropriate solution to a posted problem by identifying the parameter(s) to change.

The design of the workshop took into account several criteria such as the age range of the audience, the scholarly level, and the proximity with DSP-based devices in their daily lives. The structure was divided into five sections that included: Motivation, Theoretical Formulation of Digital Signal Processing (DSP), Technical demonstrations, a Practical Session with the DSP board, and an Evaluation.

1. **Motivation.** This part of the workshop was given a special treatment to try to catch the student attention from the beginning. To this end, the workshop began with an informational video provided by Texas Instruments Inc. describing typical DSP-based gadgets and applications for personal and home use. The video resulted very appropriate for this stage of the workshop, creating curiosity in the students on the know-how and giving them a vision of the use of DSPs in applications they never though depended on signal processing.

2. **Theoretical Formulation.** This section was oriented to explain the audience several fundamental concepts of Digital Signal Processing. Concepts such as the definition of continuous and discrete signals, sampling and reconstruction of signals, quantization, analog-to-digital (A/D) conversion, and filtering among others were discussed in this part. Most of the concepts were transmitted using a graphical content to maintain the students’ attention.

3. **Technical Demonstrations.** This section was oriented to provide the students with their first contact with a DSP board. We utilized the TMS320C6711 board of Texas Instruments Inc (Figure 1), which provided all the peripherals around the DSP to perform the demos and experiments. The students learned to identify all essential components in the board such as the DSP processor, the memory modules, and the input/output and communication ports. Attaching speakers to the audio port allowed a demonstration with the DSP, consisting in recording the voices of some of the participants and then reproducing it at different sampling rates. This technical demonstration reinforced the concepts discussed in the theoretic formulation section, such as the sampling frequency using a voice signal, its storage in a digital way and finally its reconstruction in order to play it back.

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4. Practical Session. This activity gave the students a hands-on experience with a DSP application. They were asked to complete an exercise composed of two experiments developed in the Code Composer Studio (CCS) IDE. Figure 2 shows a screenshot of one of the exercises developed by the students in the practical session using CCS.

The first exercise consisted in generating a continuous sinusoidal waveform from a provided digital data set. In the second exercise, they were asked to filter a noisy song using different cut-off frequencies of an FIR filter (600 Hz, 1500 Hz and 3000 Hz). In this second experiment, the students were able to perceive the change in the filtered song by playing it through the speakers. This session provided the students with a programming environment experience (CCS, IDE) where they learned how to build, compile, debug, and load a program onto a DSP unit.

5. Evaluation. In the final workshop section, students participated in a game that put under test their just learned DSP skills. The game consisted in deciphering a voice message garbled by intentional changes to its sampling frequency. In the competition, the students had to tune and execute a program in MATLAB that made changes to the message sampling frequency in order to decipher it. The first in deciphering the whole message would be the winner.

The whole workshop structure was organized following the three-domain structure described by Bloom’s taxonomy [5]. Bloom’s Taxonomy has been recognized to provide an excellent structure for planning, designing, assessing, and evaluating training and learning effectiveness through a structure that uses levels of deepening into the discipline being taught. The three domains established by Bloom are: the cognitive, the affective, and the psychomotor [6].

As far as the cognitive domain, the objective was that the students understood and applied the concepts of signal processing given in the theoretical section.

In the affective domain, it was pretended that the students arrived to the level of receiving phenomena. In this level, a central objective was to get the students pay attention to an example in the DSP board and then practice it in the section of experiments.

In the psychomotor domain, the students were taken to the level of manipulation of the DSPs. This level included their active participation in the repetition of the experiments. A deeper level in the psychomotor domain was achieved at the end of the workshop when the students applied the learned skills to modify a program to solve the problem posted in the game.

ASSessment Methods and Data Analysis

Despite the short length of the workshop, it contained an assessment plan that included formative and summative techniques [7]. As part of the formative techniques, an entry questionnaire was administered to the students to assess their background, career inclination, and expectative from the workshop. This first questionnaire revealed that our target audience did not have any previous knowledge about digital signal processing. It also showed that most of them (75%) were not aware of any personal or household device that used a DSP chip. This answer was despite most of them having cellular phones and MP3 players, and several others also brought in digital cameras. Regarding career inclination, none of them was even aware of the possibility of pursuing a career in Signal Processing and only 29% had interest in areas that could lead to such a field. When asked about their expectation from the workshop, we noticed that the informative presentation given during the PCEP opening generated a lot of interest about the field of DSP. Sixty-nine percent of the participants indicated they expected to gain knowledge on signal processing while the rest expected to have better criteria at the time of choosing their career.

Two major summative assessment techniques were applied. The first was related to the game at the end of the workshop, where the knowledge required to solve the problem handed required application of most of the concepts taught to them during the entire workshop. All the participants were able to perform all the steps needed to decipher the hidden
message, including the inferences required to obtain the correct sampling frequency.

A second summative measure was an exit questionnaire administered after the game competition was over. The main purpose of this last metric was to quantify the level of success of the workshop in reaching its main objectives of creating awareness in signal processing and seeing how much interest in the area created the knowledge of its existence and use.

Surprisingly, 54% of the students were able to provide a description of signal processing, 75% were able to identify multiple electronic devices that employed signal processing, and 70% identified signal processing as an area of study that attracted them. Moreover, the results indicated that the students enjoyed most the practical part of the workshop, particularly the game, and 73% of them considered the workshop fulfilled their expectations.

LESSONS LEARNED AND RECOMMENDATIONS

The exercise of exposing high school students to college-level subjects such as digital signal processing resulted in an interesting experience after all. During the planning of the workshop, one major concern we had was whether a sufficient number of students would be attracted to it. To our surprise, over one quarter of the camp participants signed for the workshop. We consider this a significant number since there were five other activities from which they could have chosen that same day. So, given the proper motivational invitation, students, even without previous knowledge on a field can be attracted into it.

The entry questionnaire confirmed a common situation among general public: there is no awareness of any link between engineering subjects of study and everyday life, despite the general acknowledgement of the impact of technology in modern society. Equally important is to learn how misleading can be to assume that students in a pre-engineering camp would have at least an insight of such connection. One of the assumptions we made when designing the workshop invitation was to discard this hypothesis. This assumption proved to be successful in attracting participants to the workshop. This is a lesson learned which, we think, can be extended to the efforts in attracting students to the engineering career in general. Specifically, we suggest that informational and recruiting efforts should link the subjects of study with everyday life and achievements, and not only the overall and apparently abstract field of engineering.

The conduction of the exercise highlighted the preference of the students to acquire knowledge by means of practical exercises and experiments. The pedagogical value of such a procedure is commonly accepted, and therefore it was part of the planning from the very beginning. However, we also decided to include theoretical principles, something that many educators try to avoid in the beginning when designing experiences of this kind.

More specifically, instead of adopting the attitude of first doing and then “informing” of the theoretical tools needed to acquire a better understanding, we included theoretical tools from the beginning, and linked them to the physical effects. For example, deciphering the message in the final section of the workshop was directly related to appropriate coefficients in filter equations, and were not just a matter of chance. Entering in contact with the technology and theory behind it really calls their attention to the point of becoming an enjoyable exercise and learning tool. In addition, Mathematics and Physics, two “difficult” and usually avoided subjects, become alive in the process too.

![Figure 2. Code Composer Studio DSK Tool](image-url)
The success in working with high school students with this philosophy may bring up some interesting items to consider in the design of continuing education workshops for teachers.

Perhaps the most important and motivational finding was that by exposing students to a completely alien technological subject with an appropriate point of view, changed their potential career decisions from an “I don’t know it even exists” to be an attractive field of study.

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REFERENCES


