

Bridging Physics to Electronics Engineering – an Outreach Effort targeted at Tertiary Institution

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Abstract

Physics is one of the key subjects in the science curriculum in high schools. A good understanding of many concepts in physics is essential to comprehend the materials covered for students pursuing an electronics engineering program in the university. Unfortunately, a trend observed in today's high schools is a clear diminution of student interest in physics, leading to dwindling physics class sizes compared to a decade ago. The lack of interest and passion for physics at the high school level ultimately leads to smaller intakes at the university level for electronics engineering courses, and/or lower qualification cut-offs for students entering the programs. This lack of interest in electronics subjects is apparent in other science, engineering degrees with lower intakes in their electronics related modules. This results in a significant reduction in good students graduating from engineering programs. This paper will first share survey results that reveal possible reasons behind the decreasing number of students entering engineering programs. Two concerted efforts launched from the Department of Electrical & Computer Engineering at the National University of Singapore (NUS) to halt the declining interest in high schools will then be presented.

Keywords: Electronics engineering education, physics

1. Introduction

The modern world without electronics engineers is unimaginable, and it is not an overstatement to claim that these engineers helped to shape that world. The contributions from these engineers have been very broad-based and are evident in all aspects of daily life. As we move into the future, the continued demand for engineers will be correlated with the world's need for technology, and statistics have clearly shown that the world today is experiencing an accelerating need for technology in diverse areas. In both the local and global contexts, the continued demand for electronics engineers is clear and certain. The uncertainty lies mainly with the supply line of good engineers to meet these demands.

Despite these favorable data and forecasts, Singapore is not immune from the worldwide phenomenon of diminishing interest in engineering. The number of students opting for an engineering education has been decreasing, with many young students now opting for other programs in the universities. In the universities and higher institutes of learning, explicit and extensive efforts in outreach have been initiated to arrest this trend and to reinvigorate enthusiasm for this field among prospective students. Some

institutions hold the view that out-of-date programs may be putting off students and have designed new and more enticing engineering programs. Some institutions incorporate links with industry in their programs to show students the industrial relevance of their education. Other institutions are inculcating new teaching methods to train and educate prospective engineers. Complementing these initiatives are outreach efforts, which aim to inject practical aspects of theoretical engineering lessons at the beginning stages of tertiary education.

At the Department of Electrical and Computer Engineering (ECE) of the National University of Singapore, a comprehensive series of outreach efforts has been aimed at addressing this issue from a very early stage, by improving the education of students in high schools. This paper presents attempts to create a bridge between physics and electrical and computer engineering, in ways that will interest students, and broaden their perspective on what they learn in class. The motivation for these efforts stem from survey results that were collated over the course of 20 career talks in high schools from 2006-2008. The reasons behind the declining interest in electronics engineering as revealed by the survey results will first be discussed. Next, two special programs that have

been initiated will be elaborated in full. Both share the common objective of connecting the students' understanding of physics in the schools to real engineering achievements and applications. The first program is focused on the setup of thematic electronics "learning corners" in the schools. A "learning corner" is a dedicated area of a classroom offering practical activities that introduce students to electronics. The second program is focused on the collaboration with the schools to enhance the *Higher 3 (H3)* physics program through a vacation internship program at the university. (H3 subjects are meant to allow exceptionally strong high students to pursue a subject or area in which they have the interest and aptitude. The results of the H3 subjects can be used for entry applications to tertiary institutions). The internship is specially designed with respect to the physics syllabus to broaden the students' studies with practical hands-on sessions.

2. Survey of Prospective Students

From 2006 to 2008, more than 20 career talks and road-shows were delivered at various local high schools showcasing the Electrical and Computer Engineering (ECE) program offered at NUS. Surveys were conducted at most of these activities, to provide the outreach team with feedback on the rationale behind the students' subsequent selection of the various programs at the universities. This was undertaken with the hope that the team would then be able to respond with appropriate outreach programs. The sample size over the two years totaled over 2000 students. However, it should be noted that the survey participants were students who were currently enrolled in high-school physics programs and were thus eligible to apply for admission to an ECE program in a tertiary institution. These students represented only a fraction of the overall student cohort. Incidentally, in most of these schools, the physics classes were the smallest among the science classes, a vastly different scenario from that a decade ago.

Fig. 1 shows the proportion of students surveyed who intended to enroll in an ECE program. Only about 37% of this group of eligible students expressed clear interest in ECE. Again, it is necessary to clarify that the pool of students surveyed were those who were enrolled in physics programs. The rest of the students in the same cohort were not eligible, and thus if those were viewed as also falling into the category of "Not Planning for ECE", the actual percentage of students with an interest in ECE would be much smaller.

The next step is to understand the broad reasons why students were not keen on ECE, or not sure if it would be an option in their selection of university programs. The great majority (57%) of the students who were not keen to pursue a degree in ECE had no

interest in ECE, nor other fields in engineering. From the reasons cited by these students, many were interested in more "trendy" courses in the media limelight at the moment, such as finance or business administration. It is highly possible that this group might have reached that conclusion with only a very cursory understanding of what ECE entails. High school physics students at this stage would have only covered some basic electronics in their physics classes, so their impressions of ECE were possibly shaped inappropriately by their limited exposure.



Fig. 1: Declared interest in ECE.



Fig. 2: Main reasons for not having ECE as a choice in mind.

A notable proportion (11%) of these students cited physics as a deterrent towards pursuing an engineering or ECE degree. This suggests that improvements in the teaching of physics might possibly change some of the mindset of these students. Table 1 shows some of the reasons given by the students for not selecting ECE as one of their choices.

Table 1: Some frequently cited reasons for not selecting ECE as one of their choices of university programs.

I was never interested in engineering
I do not like electronics.
Though very interesting, it seems like a sunset industry
I still don't know anything about electronics engineering
I'm not good in physics
I don't like physics
Physics is difficult

I don't think I will do well in engineering as I am poor in physics

Physics is not as fun as the other subjects

Physics is tough

From the survey results, it was clear that outreach efforts must be geared towards enhancing the level of interest in physics. The study of this important subject must be made more interesting and motivating by bringing new perspectives of the subject to the school. Two special programs were thus setup for this purpose, they will be detailed in Sections 3 and 4.

3. ECE Learning Corners in the Schools

The first program was aimed at establishing ECE Learning Corners at strategic high schools. With such a localized corner within the school itself, students were able to engage in the various activities set up there without having to leave school. They were also free to explore the activities whenever their individual schedules permitted. Much of engineering education is built on concepts and theories taught in physics lessons in the high schools. These concepts and theories form the main foundation of many of the interesting and ground-breaking developments in engineering-related topics. The ECE Learning Corners provide links to connect the physics concepts that the students learnt in class to electronics-related engineering topics. In Singapore, schools are classified into clusters according to their geographical locations, and schools within the same cluster often share their resources. With cost and time constraints, it was not viable to establish ECE Corners in every school. Thus, the outreach team identified a prominent school in each cluster in which they established the ECE Corners. Efforts were first spent convincing schools to set aside space for the corners by showing them the activities that the outreach team envisioned, and the complementary benefits that the activities would bring to the school curriculum.

In the ECE Corners, several different types of activities were conducted:

3.1 Short-term activities

Short-term hands-on activities centered on ECE themes were designed for students who were eligible to apply to the ECE program. The duration for these activities ranged from two hours to half a day, and could be scheduled anytime in the year, including the school vacations. The outreach team endeavored to design something suitable for everyone. Each activity was designed to be concise and focused on one interesting area in ECE so that it could be delivered to a large number of keen students. Figs. 3 to 5 show some thematic setups that encouraged participant exploration in some of the ECE Corners that were established. Another popular project which motivates students is the use of RFID for different applications.

For example, in the thermal setup of Fig. 3, students were first introduced to the history and importance of control theory. They then experienced the difficulties of manually controlling the temperature in a chamber using a handheld controller. Next, they were introduced to virtual instrumentation and had to design a simple automatic controller to control the temperature in the chamber to a desired set-point. These setups were rotated on a periodic basis among the Corners at the various schools and new setups were also introduced periodically. The outreach team conducted workshops in the Corners with students as well as with teachers to help them to use the resources more effectively.



Fig. 3: ECE Corner at a junior college, consisting of a temperature control system demonstrating a control and automation theme.



Fig. 4: ECE Corner with an interactive digital media theme.



Fig. 5: ECE Corner with an energy harvesting theme.

3.2 Longer-term projects

Longer-term projects (3 to 9 months) were carried out by students mentored by ECE faculty members.

Equipment was loaned or donated to the Corners so that students could work on them during their breaks between lessons, on days free from lessons, or over the weekends. The research topics were usually related to the faculty members' research. The faculty members would meet students at the ECE Corners for regular discussions. This arrangement offered a more conducive and productive environment for the students as opposed to having the students come to the university to work on their projects.

3.3 ECE in-house vacation programs

Week long ECE Vacation Programs were organized to allow students to have a sample of what is ECE. Students formed teams of about 4-5 in a group and worked on building remotely-controlled vehicles or other interesting electronic gadgets like audio amplifiers or wireless audio-video (AV) transmitters. The students also spend about 1-2 days sampling the various types of research work performed in the ECE Department laboratories. Students were split into small groups that rotated between the five research groups in ECE for 1-2 days, during which they experienced for themselves the focused activities in each of these research groups. At the end of the program, the students proposed (if they wished) longer term projects in the area of their choice as mentioned in section 3.2.

4. Physics Supplement in ECE, NUS

In Singapore, H3 Physics is offered to high school students who performed well in Higher 2 (H2 – equivalent 'A' level subject) Physics classes. Essentially, these are the top science students whom the outreach team would particularly like to recruit into the ECE program. However, the current number of students enrolled in H3 Physics is generally lower compared to the other science subjects such as Chemistry and Biology, with more dropping out along the way. This situation motivated the outreach team to analyze how they could work together with the schools in a more formal manner to increase the interest and enthusiasm of students in H3 Physics.

The syllabus of the H3 Physics course includes the following topics: Relativity, Quantum Theory of Light, Matter Waves, Quantum Mechanics, Solid State Physics and Photonics. One of the major difficulties in conducting these subjects is that the school usually lack expertise to mount experiments to compliment the theory learnt making the learning abstract from student point of view. The schools offering H3 Physics agree that a practical dimension to the syllabus would be highly useful, but that is difficult to implement within the schools, as the equipment needed is highly specialized and expensive, and teachers are not well positioned to

adopt and use such equipment in meaningful practical sessions.

Thus, an outreach program was developed to offer a H3 Physics-Supplement to the students of H3 Physics. Students were invited to spend a week in university laboratories during their vacation to undergo specially designed hands-on sessions to consolidate the theories that they learnt in class, and also to learn about application areas. This helped to enhance awareness of the need for H3 Physics and motivate more good science students to take up the subject.

The hands-on sessions fell under two themes, each relating to a specific industry or application area: a) Modern Physics and Automation and b) Modern Physics and Optoelectronics. Students carried out sessions under these themes after the relevant topics had been addressed in their classrooms. In the university laboratories, students were split into groups of at most 10 students to maximize interaction with the instructors. They were given some initial briefings to connect what they had already learnt to the experiments they were about to conduct. At the end of the sessions, they were required to submit a report detailing their observations and a summary of what they had learnt. Each of the reports was graded and a consolidated assessment was performed based on all the reports.

5. Students and Teachers Feedbacks

At the end of the outreach activities described in the preceding sections, surveys were conducted to gauge their effectiveness, measured against the outreach objectives set forth. The outreach team undertook such a directed and localized feedback approach rather than falling back on the actual student intake number as a gauge of the effectiveness of the outreach effort, since the latter is linked to many other factors beyond the control of the outreach program. Stagnant or decreasing student numbers would not necessarily mean the activities were not effective; without the outreach efforts, the situation could well have been much worse.

In addition, in some activities, feedback from the teachers was valued more highly than feedback from the students themselves. Students may realize the benefits of certain parts of the activities only some time after the survey had been conducted, whereas teachers were better able to appreciate and give more timely feedback in these instances. For example, in the H3 physics supplement program, feedback from the physics teachers was constantly sought as the supplementary materials were designed and refined. In addition, teachers were invited to the actual workshops as observers and thereafter provided feedback for the next round of workshops.

As an example, survey results are provided here for the *Immersion Program* at the department described in Section 3. The surveys were designed in the form of questionnaires and interviews. About 230 survey forms were collected from the students and teachers from the various high schools that have participated in this activity since 2007.

The level of satisfaction of the participants after attending the activities is shown in Fig. 6. More than 80% of the participants expressed positive feedback. Only 2% of the 230 participants were not satisfied with the activities organized for them. Fig. 7 displays the reasons the participants gave for participating in this outreach activity. About 44% of the participants wanted to gather more information about the contents of engineering courses and the tertiary education at NUS. Proper design and implementation of the outreach activities should be able to have a positive effect on this subset of participants. About 7% of the participants were attracted to the fun nature of the activities. To engage them, the organizers injected fun elements into the activities. These reasons cited by the participants provided some insights into ways to engage young minds while designing outreach activities. The participants' comments and suggestions regarding the outreach activities are summarized in Fig. 8. These constructive comments aid in fine-tuning the outreach activities for subsequent batches of students. Fig. 9 illustrates the main factors that affected the selection of tertiary degree programs for the participants. A majority of the participants provided rational answers for choosing their ideal degree program in the near future. The outreach team will have to provide an updated assessment of the job market in order for the participants to make informed decisions regarding their choices for their tertiary degree programs.

6. Conclusions

In this paper, outreach efforts to stimulate and increase student interest in studying physics at the high school level, with the goal of recruiting better and more students into electronics engineering programs at tertiary institutions, were discussed. The results of surveys conducted on high school students that revealed a lack of exposure to and knowledge about electronics engineering were presented. In addition, the dire need to stimulate student interest in Physics, which is often a pre-requisite for electronics engineering programs, was highlighted and discussed. Two outreach programs were designed and launched to enhance student interest at a young age via structured and specially-formulated supplementary hands-on activities and sessions conducted either at the university, or within learning corners located right in the high schools.

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Fig. 6: Level of satisfaction of the participants.



Fig. 7: Reasons for participating in the immersion program



Fig. 8: Comments from participants after attending the immersion program



Fig. 9: Main factors that affect the choices of the participants in the immersion program in their selection of tertiary degree programs.