New Project Approaches in Advanced Microelectronics: The Students' Perspective

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Abstract

This paper describes how microelectronics can be regarded as a compelling work topic among students when experienced within their own built work environment. Undergraduate students from several degree years have formed a group in which have been developing microelectronics related projects in an autonomous way. In this initiative, the topics are freely chosen by the students, mainly addressing the design of integrated circuits. For that reason, the projects entail scientific concepts with very high-degree of complexity. Nonetheless, with an outstanding enthusiasm and well-organized as a team, the students manage to surpass the lack of great knowledge in technical details. Throughout basic understanding of essential concepts, this autonomous group of students demonstrates how an extracurricular activity within an academic environment can effectively enhance productivity and motivation for working on scientific areas that are often considered interesting, yet difficult in practice. The present paper describes the key activities of the group, its organization, and the chosen strategies for the definition of a high-complexity project within distinct heterogeneous levels of knowledge and expertise among students.

Keywords: project approaches; microelectronics learning; student-led projects; microelectronics students' group.

1 Introduction

Engineering programs often undertake certain curricula that involve great technical detail and thus require a lot of students' effort to achieve reasonable learning requirements. Microelectronics is one of such courses but with the particularity of being regarded as theme of great popularity in terms of modern industry and commercial interests. However, today's technology evolves rapidly and as a consequence also the complexity of electronic related topics increases. New industrial applications and fast emerging technologies offer a wide range of quick renewable issues, both technical and theoretical. Such issues are extremely dense, most of times requiring deep understanding of interdisciplinary concepts. It is therefore hard to find such wide-ranging topics in any electrical engineering study plan, at least within an acceptable level of detail. On the other hand, a well planned course cannot forget the motivational component throughout all the teaching and learning processes. Motivation and understanding are sometimes difficult to accomplish as a simultaneous process and in order to include motivation for the main topics the understanding goals require elaborated planning and very clear definitions. According to (Perkins & Blythe, 1994), the basic definition of understanding is not just being able to solve a bunch of routine problems from a textbook, but also being able to apply the topic to real life situations. This is obviously of extreme importance in any engineering course. Hence, a project approach can be an excellent exercise to induce the professional environment needed for the motivation of students. In fact, students often demonstrate noticeable lack of interest when they do not see an immediate usefulness of certain topics or professional needs to understand them. As projects are common tasks in microelectronics engineering, a project based process can be quite efficient in developing knowledge in this field.

Distinct approaches have been addressed for the motivation of microelectronics students in engineering courses, e.g. (Hashim, Jamal, Phang, Nurzaihan, Halim, & Razak, 2006; Reis & Indrusiak, 1998). A remarkable example is reported in (Hashim, Jamal, Phang, Nurzaihan, Halim, & Razak, 2006) where a clean room was built in a Malaysian University. This initiative aims to expose the students to the "real-life" of clean room environment, protocols, safety requirements and good laboratory practices in clean rooms. Another way to emulate the industry-like environment is to introduce tools that are commonly used by semiconductor industry in the course when teaching the design of integrated-circuits, or chips as popularly known. This can successfully increase the interest of students in these specific subjects. Although such commercial tools are not much user-friendly, students know by hand that the hard knowledge can actually benefit them as future professionals. Moreover, computer aided-design (CAD) tools are becoming more and more important in teaching of microelectronics (Reis & Indrusiak, 1998). Nonetheless, this hands-on approach cannot and should not be a substitute for the most theoretical aspects. Both are indispensable in the teaching and learning aspects of a very in-deep subject like microelectronics.

Project (or problem) based learning (PBL) is well-known by its capability to improve quality of the learning process through real problem solving and can be straightforward exploited in microelectronics learning. Conversely, people-oriented management theories also have interesting features that are highly compatible with PBL. People processes from total quality management (TQM) and PBL are compared in (Hadgraft, 1995) focusing approaches on how to improve the productivity in University departments. Some noticeable issues are highlighted in the referred work, such as how unfavorable can be considering undergraduate students as external to departments. In general this is traditional and, for instance, in the case of our present institution, each year our department is missing more than two hundreds of young minds in research and community activities. On the other hand, any quality program in industry contexts involves worker empowerment, giving the responsibility to the workers to improve their productivity in their workplaces. TQM can be applied to PBL, and in the specific case of University departments, a new culture can arise based on trust and respect for student contribution (Walsh, 2007; Hadgraft, 1995).

This paper is about an autonomous group working within great professional resemblance although within an academic environment. Students demonstrate they can manage themselves, especially in creating self-motivation. The present paper describes, from the point of view of most experienced students, a new experience on how undergraduate students can enhance noticeably the interest in microelectronics, improving the theoretical and technical knowledge through their projects. As further described in this paper, within specific work environments microelectronics can be found not only an attractive research activity by undergraduate students but also quite self rewarding. The paper reports the activities and organization of the group in which have been developing complex projects such as the design of integrated-circuits.

The paper is organized as follows. First the motivation for group establishment is presented following by the description of group organization and activities. A brief overview of work methodologies and the established work environment are also included together with the approach adopted for the ongoing team project.

2 The microelectronics students' group

The idea of starting a small set of engineering projects initially motivated a group of seven undergraduate students of the Integrated Masters degree in Electrical and Computer Engineering from the Faculty of Engineering of University of Porto (FEUP). The projects mainly address microelectronics, particularly focusing integrated-circuits design. Several reasons led to the preference of this key topic. First of all, fundamental electronics at FEUP as long-term courses have traditionally sustained the attraction of students in these fields with good quality and extensive lectures material, e.g. (Ferreira, Oliveira, & Tavares, 2004). Secondly, microelectronics at FEUP had recently received increased interest by new Ph.D. students working in wireless communications circuits. Moreover, a wide set of professional software tools dedicated to integrated circuit design has been continuously made available by the Department of Electrical and Computer Engineering (DEEC) at FEUP through the Europractice academic program (Europractice, 2009). Most of European research institutes renew every year the Europractice agreement from which low-cost integrated-circuit manufacturing and a variety of software tools are provided. Some of these software tools are difficult to work with, yet are widely used in semiconductor industries and starting a small professional environment resemblance also motivated these students. Thus, the students recognized that they had it all to initiate a small set of projects. The initiative aimed to develop specific microelectronics topics that were proposed and originally assisted by a PhD student with fundamental research knowledge in this theme. The group was then named *Microelectronics Students' Group* (MSG, 2009).

Generally, it takes some time for a group to bring out the capabilities to a point where it can be effective. During the initial period the undergraduate students had not any background regarding integrated circuit technology. Nevertheless, the students promptly demonstrated sustained interest and revealed pertaining autonomy. The first project tasks required considerable time devoted to its development, which the students had to accomplish in their free time and usually that meant late in the evening. Along just a couple months of work, the students accomplished circuit designs that usually demand considerable effort. Two Professors readily recognized the importance of such initiative and strongly encouraged its continuity. The Professors formally presented the group as a project of DEEC/FEUP having themselves as supervisors and managed to provide facilities and equipment for the students develop their projects. The following sections report on how the students' group structured their activities, work flows, and methodologies in order to establish their own productive work environment.

2.1 Group organization and activities

The supervisors support the idea of the group consisting on an autonomous unit. Although the supervisors have no direct participation in group activities, they provide management whenever required and still confer responsibility to the members to freely promote new activities. Following such formal establishment of the students' group within the department, the early members realized that a much more suitable structure was needed to extend their activities as a group foreseeing the inclusion of new student members. At first, the students started in a more or less conscious way to establish a preliminary course of actions. A technical concern that has been considered unavoidable was an infrastructure for managing the technical information, both in terms of data and hardware management. This is so because the development process of their projects relies almost entirely on it. In the microelectronics field this implies a computer network properly configured and well-structured for the use of computer-aided design software (CAD) in an efficient way. In the semiconductor business, companies have teams exclusively dedicated to this issue, i.e. the information technology section (IT). However, this is not an immediate task, even for an IT professional it requires significant effort and interdisciplinary concepts that are hardly found in young electronics engineers. Nonetheless, the group has nominated some students in charge for this task and, in fact, they accomplished the design of their own computer network environment, almost resembling a professional system used in semiconductor industry. These students are responsible for continuously improving this framework and for providing support to other users when needed. In the case of any non-autonomous students' group, such infrastructure would not be held by students. However, this is a technical implication that is inherent to the principle of this group autonomy.

In a certain way, technical concerns started to sketch out the group structure. For instance, due to the infrastructure requirements, students had to nominate individuals for certain "job titles" and respective tasks, each one with its specificity such as: CAD managers for different software vendors, a System Administrator for the computer network, and a Webmaster. Having ensured the platform functionality, knowledge is the subsequent key issue for making use of the tools. Technical guidance is in fact crucial for the group activities. Therefore, Ph.D. students can large contribute to it. They must provide essential assistance by initially giving undergraduate students enough theoretical and technical backgrounds to launch their works. Monitoring the quality of their work along time is important as well, since it can have strong impact in the way students gradually expand their knowledge. It is also indispensable in any kind of extracurricular work that students are kept in an environment featured by high motivation and creativity. Actually, along one year of group activities, motivation has demonstrated that sometimes is just enough to be conducive to excellent results.

Projects are always an excellent approach to promote team work among the students of the University and to enhance their scientific activities. In the area of microelectronics it is mandatory that the projects should be funded, otherwise integrated-circuits cannot be produced and so the "visibility" of the work would be inexistent. The present group proposed a team project to the University of Porto by the *LIDERA* program (LIDERA, 2009). This program consists on funded projects that must be led by students and can be also proposed by themselves. The project proposal of this group had surprising acceptance exalting in rank by the highest number of candidates among all the other projects. The group incorporated new members in their recent self-established team organization. Currently, the group includes more than twenty students, from the first to the last year of the Integrated Master programme in Electrical and Computer Engineering. Figure 1 shows how the students are distributed along degree years. Three major groups of undergraduate students can be distinguished in number: *1)* the last year, which encloses most of the students, *2)* the from the second to the fourth degree year; and *3)* first year and Ph.D. students that together form a subgroup that is even less in number than the previous ones. This student diversity has great impact on how the projects are planned. We will describe later some of the adopted strategies addressing this issue.

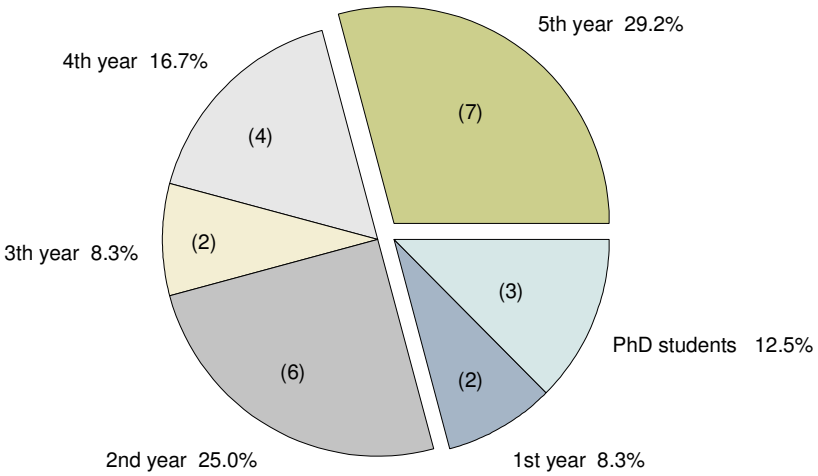

Figure 1: Students' diversity in the group in terms of degree years

New members often inspire new ideas and in this case new activities. The group became aware of the need to motivate students for this engineering area, starting with younger students from high-school. Therefore, a set of workshops have been organized taking place at FEUP along all the year. These workshops involve two high-school institutions having specific technical courses wherein the students have already learned some basic concepts about electronics and telecommunications. Most of these young students have in mind choosing FEUP as their graduation school in a near future. Thus, these workshops help them to have a snapshot about modern technologies such as microelectronics. As so, these workshops are also exceptional opportunities to learn from the academic experience of students nearly the same ages.

The extensive practice acquired along the students' activities allowed them to collect a great deal of technical information regarding the use of software tools, optimized practical procedures, and solving turnarounds found in common problems. They even felt the need to develop new tools to easier some routine tasks, which are particularly suitable for beginners. All this built up knowledge led them to write didactic material, which the students share in the internet (MSG, 2009). The developed material is considered to be extremely useful in lectures of four courses at FEUP, e.g. detailed information about tools usage in design of integrated-circuit. Also, whenever new members arrive, the students run short introductory courses based on these resources for the new participants. It is important to mention that this helps the group to establish positive self-sustained dynamics, that is, by creating the culture of being responsible for continuously transmitting the essential knowledge acquired in the group along time.

2.2 Project methodologies

The group is very heterogeneous in terms of degree years, which can be reflected in fundamental knowledge for this kind of activity. Nonetheless, the proposed projects have a multidimensional structure and everybody fits in. In microelectronics three important domains are mainly distinguished: digital, analog and radio-frequency (RF). Typically, the list of domains as ordered is also associated to the increasing complexity of related topics. The project tasks are then planned in a way the students are allocated in a domain that can fit their levels of knowledge and training. Figure 2 shows a representation of how students are allocated to the different domains based on the task planning just mentioned. As can be seen, the resulting effort for each student is almost similar. Although the students have distinct tasks, they need to interact with other students in order to define the operation of the circuits when connected between them. This kind of interfaces between workers is natural in microelectronics and it is the basis of several technical discussions, which constantly motivate the understanding of new concepts. Moreover, it brings on "negotiation" of technical specifications between students to make the implementation of the circuits feasible. Therefore, this work environment mimics somehow a professional environment that the students might experience in future.

When working with junior circuit designers, different learning stages can be noticed. During the initial stages, the students often become mired in minor technical details in their tasks, such as transistor sizing and recurring circuit simulations. Interaction with most experienced students helps younger students to consider structural changes in their circuits. In general, this leads to greater performance improvements, both in the circuits and in the motivation of the students. Gradually, with experience, the students learn how to identify the main design trade-offs. Leadership of such a wide group requires lots of effort and dedication. In the meantime, one of the Ph.D. students is responsible for the group guidance, but more Ph.D. students are required also for project planning and continuous management. Since their knowledge is wider in technical scope, the system architecture must be specified by them. The drawing of interfaces between students' tasks is however natural. Nonetheless, the interaction between adjacent works needs Ph.D. students to help providing better technical decisions to undergraduate students. At the moment, the most experienced undergraduate students are contributing to this very important task.

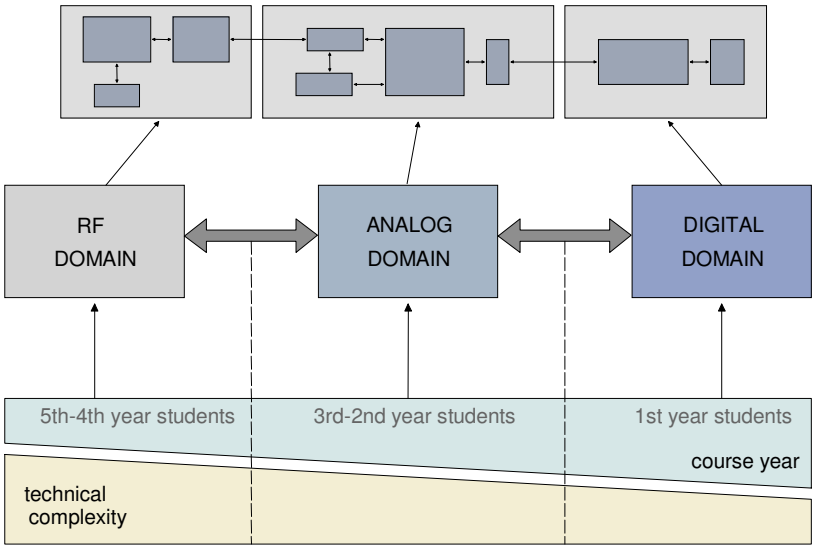

Figure 2: Allocation of students into the areas of study per group degree year

Whenever possible, the group performs public presentations of developed works, which is not limited to just the other students of the faculty. During the last "Meeting of Young Researchers of the University of Porto" (IJUP) the students' group has presented eight oral presentations of the works just developed, which is at least representative of the quality of the work developed. Moreover, when visiting the faculty, people from the semiconductors industry and researchers from related fields are commonly invited to know the group activities. The shared insights, both with academics and professionals from industry, are always welcome and in general visitors have very positive comments about the activities performed in this students' group.

3 Conclusion

This paper describes the student's perspective on microelectronics design as research and development activities. This is an initiative in which undergraduate students from different degree years, throughout their own built work environment, have constituted a group for designing integrated circuits. Even though the different levels of experience of microelectronics design among the students of the group, focusing more on the concepts than the extensive technical details the students manage to deal with scientific concepts of high degree of complexity. Working in an autonomous way and defining their proper organization, the group established professional similarities both in their work environment and results. This experience shows that an extracurricular activity can effectively enhance the productivity and motivation for scientific areas that are often appealing, however considered extremely difficult in practice.

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