Integrating Free-Open Source Tools as Teaching Resources for an Electronic Engineering Undergraduate Program

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ABSTRACT

Since the last decade of the twenty century the influence of computers, the Internet, and Information and Communication Technologies (ICTs), has progressively increased on teaching-learning activities for engineering programs in our country. Parallelly to the multiplicity of traditional propietary software and hardware resources used in universities, an alternative trend, based on free-open source resources for software and hardware, has gained importance for academic community members. Free-Open source tools and resources have many features that make them very attractive for people related to engineering because of aspects like costs, upgrade-license management flexibility, collaboration, source code accessibility, among others. Today we can access a plethora of free-open source hardware and software (F-OSS/HW) resources related to electronic engineering, ranging from Ohm's law to specialized topics on robotics, control and automation. Through the incorporation of free-open source tools to courses belonging to an Electronic Engineering undergraduate program, from basic level semesters to advanced ones, major improvements related to teaching and learning experiences could be achieved. This article presents some outlines to develop strategies for the improvement of teaching-learning efficiency in electronic engineering by adopting free-open resources as a driving force for the enhancement of educational and research performance on both teachers and students.

Keywords: Electronic Engineering, Information and Communication Technologies, Free-Open source tools, Teaching strategies, Project-based approach

1. INTRODUCTION

Teachers have today the opportunity of integrating free-open source software and hardware (F-OSS/HW) resources to courses belonging to engineering undergraduate programs since the early stages of student's higher education (UNESCO, 2004). Some favorable items for the teachers result from the fact that the influence of ICTs is greater for younger generations than for the older ones. Young people assume the use of technological means with naturality and a proactive attitude which differs from that of older people; teachers and academic board. Teacher must adopt new approaches in order to improve the efficiency of the teaching-learning processes like those carried out during stages of undergraduate education in engineering. In Colombia, traditionally the propietary resources for both hardware and software, cover most of the applications used by students, teachers and Institutions, but in order to comply the legal issues regarding licensed software the avalaibility of resources become narrower and upgrades are scarce. Aditionally to the limits before mentioned, exist economic and infrastructure constraints. The adoption of alternative or complementary software and hardware tools turns into a way for facing the problems above mentioned and could result in the broadening of the knowledge horizons for the academic community involded (Kume et al., 2009). Because of the feature of being open, software and hardware resources invite people to perform improvements on them. When people become engaged with the development or refinement of the resources themselves, usually contribute to widen their impact, efficience, usability or other performance related issues, volunteer's or communitarians research interests usually grow and their learning turns into a comprehensive approach instead of a partial one being limited to classroom activities.

In the electronic engineering field, F/OSS-HW provide to people with resources for simulating, designing, debugging, programming, web browsing and networking among others. For students there is the possibility to make their homeworks, assignments or laboratory activities and practicals by using F/OSS-HW resources which information is easily accessible via Internet. In addition, the improvements achieved in the networking infraestructure of our country greatly favor the adoption of teaching strategies supported in web resources (Meneses et al., 2010). Network traffic has a higher quality than years before and necessary data rates are available to perform different activities related to searching, downloading or accesing information which makes easier the adoption of innovative strategies based on ICTs.

2. Integrating F/OSS-HW Resources to Higher Education

2.1 Resources for Almost Every Topic

At the University of San Buenaventura – Medellín (USBMed), students make their way through the Electronic Engineer program starting with courses belonging to basic science fields like mathematics and phisycs. Parallely students can take courses of the liberal arts ranging from academic disciplines such as languages, literature, history and philosphy. Free-Open Software tools are best suited to become integrated to courses of the first semesters of the undergraduate program on Electronic Engineering because software applications cover general to specific topics. Software resources can be easily found for cover common needs like text editing, mind mapping, chart drawing, preparison of slide presentations, etc. At the math or physics level, the number of general or specific programs has greatly increased over the last years. Resources can be found for almost any platform and the on-line resources have gained popularity, from the typical embedded simulations in university pages or personal webpages to course related materials in video broadcast tools and social network-type applications. Learning managing systems (LMS) also belongs to the set of educational tools that can be incorporated to teaching activities in the early semesters, in fact LMS can be integrated to the whole academic cycle (Table 1).

Table 1: Some resources fitted to undergraduate Electronic Engineering program teaching/learning needs

Free-Open Source Software-Hardware Resources	Courses, Subjects or Curriculum Fields Supported
Scilab, Octave, GNUPlot, LabPlot, TeXmacs, Freemat, Maxima, Sage	Basic Science: Math and Physics Courses
Kicad, Xoscope, Qcs, Gpsim, WinOscillo, Arduino, Pingüino, Flex board, Erika Enterpise+RT Druid, Great Cow BASIC, LDmicro, RTAI-Lab COMEDI, PiKdev, Piklab, USB-DUX, Liberlab, PHOENIX	CAD for electronics, Electronic Circuits, Microcontrollers, Development Boards for Embedded Systems, Data Acquisition
Moodle, ATutor, Dokeos, Sakai CLE, Sakai OAE, Claroline, DoceboLMS e-learning platform, Synergeia, Wims, Xampp, Apache, Linux OS	Theoretically this can support all the courses
Oppen Office, Mozilla Firefox	This can support the three major course fields: Basic Science, Professional Apllication and Socio-Humanistics studies

At present time, Information and Communication Technologies are integrated to the whole curriculum of Electronics Engineering at the USBMed, this shows that ICTs represent a common resource for teachers and students but their function differ depending from the user's role. The teachers have experienced the ICTs' boom after being educated in a traditional way, most recently in a mixed way, in which Internet and newer technologies partially complemented traditional teaching mostly supported on blackboard and teacher discourse. Younger people and new generations of students have grown with ICTs being a more familiar component of their daily life.

Older people had to get accustomed to ICTs, contrary to that, for younger people pervasive ICTs presence it is a natural fact. The attitude towards technology means could be quite different, younger people integrates rapidly technological tools showing a highly dynamic approach in a proactive way. On the contrary, older people might keep some distance to technology and maybe do not consider so important to participate actively in technological scenarios. This kind of gap between academic counterparts must be minimized in order to improve the efficiency of the teaching-learning process (Demetriadis et al, 2007). By improving the dynamics of teaching strategies regarding to the use of ICTs and Hardware and software resources, the motivation of students can be highly increased. Teachers can change their pedagogical methodologies for newer ones and must widen their academic tool set for designing course activities. A favorable condition can result for educators having lack of ability or poor knowledge on new pedagogical trends, theories, strategies and tools, because they can improve their professional competences while integrating new tools to their daily activities at the Universities.

2.2 Free-Open Hardware Resources

Traditionally we have heard extensively about free and open source software tools or resources, but there is an extra category of interesting resources that could take the form of hardware or circuit boards that are very useful to Electronic Engineering students. As an example we can mention FOSS-supported boards that allows the development of applications with microcontrollers on topics like embedded system design (Lohöfener, 2004), simulation and debugging, data acquistion and signal processing. These boards are very useful and offer to people involved an useful tool, not constrained to propietary elements tied to software programs licences or Integrated Development Environments (Table 2). For the Electronic Engineering program the work with this type of free-open source hardware is best suited to the professional application courses, but this does not mean they can not get included in other courses belonging to basic science branches like physics, calculus or electromagnetic theory for mentioning some of them. It is important to state that in cases like the above mentioned, the open source or free hardware concept is tied to the parallel development of software, firmware and interfaces of the type of Integrated Development Environments or IDEs. A common feature of OS-FHW is the public visibility of the design, circuits, platform schematics, prototype drawings, code and other related items (Bucher et al., 2010).

Table 2: Some Free-Open Hardware Resources for Electronics

Free-Open Source Hardware Resource	Courses, Subjects or Curriculum Fields Supported
Arduino, Pingüino, Flex board, Erika Enterpise+RT Druid, RTAI-Lab COMEDI, PiKdev, Piklab, USB-DUX, Liberlab, PHOENIX	Microcontrollers and Embedded Systems, Data Acquisition, Automatic Control, Electronic Instrumentation, Telemetry

2.3 Free/Open Source Software Also Turning into “Libre”

Free-open source software (FOSS) is well known in almost every place of the world. Today we can found software programs belonging to highly specific engineering topics. As time passes this software tools have become more stable and include more and enhanced functions that overcome traditional limitations of first developments. This features avoid that FOSS can be rapidly relegated for their propietary counterparts because of advantages regarding to toolboxes and functions. FOSS collaborative efforts have provided their results to community and more comprehensive software applications are available to users and supporters. Most of the free and open source software suppliers have been located traditionally in Europe and in developed countries like the United States, but because of new local efforts, political decisions and support of some governments, the number of resources having interface languages different than english has increased (Damiani et al., 2009). Programs developped fully or partially in Spanish, French and in other languages like Portuguese are available currently turning projects into really collaborative ones. Government policies like the adopted in countries like Spain to support the development of tools and strategies to improve teaching/learning, have been transferred succesfully to universities which in turn have highly benefited spanish-language speaking countries like ours because teachers and researchers have gain further knowledge and experience about using open-source free/libre resources at the academic level. Open source-Libre software starts turning into a reality from initiatives born in academic spheres, organisations, individuals or governments. Developing countries can get even higher benefits than first world countries because of their limitations at the per-capita income or budget limitations of institutions and government agencies. Inhabitants of developing countries can take advantage of this kind of 21st technological resources-democracy, because Internet worldwide availability get information closer to them. Nowadays, people can access information through the web without needing to spend much money or take a trip to remote places. Normally people can acces the new progresses as soon as they get published, in this way the knowledge avalaibility can overcome geographical and language barriers.

3. A possible Strategy for the Integration of F/OSS-HW to Undergraduate Courses Teaching

3.1 Gradual Adoption through Integral Plans

The integration of F/OSS-HW resources to normal teaching activities in engineering undergraduate programs must be started as part of an integral plan, intended to improve the quality of the teaching-learning process. The instruments must not go beyond of the objective itself and people committed with the labor of improvement must understand that the most important are the benefits for students and teachers. Pedagogical approaches like Problem Based Learning, Blended Learning and collaborative work can complementary support course activities and planning (Fernandez et al., 2010). Classroom projects and academic activities which involve the teachings and concepts of different courses must have the advise of tutors, teachers and students so they can give, when performed, an extra potential to the effectiveness of the teaching-learning process. Planning the academic strategies in this way will optimize of the use of knowledge and material resources in an integral and unified way, pointing to the achievement of professional and intellectual competences more than to individual course goals and grades. Teachers must observe students having poor competences for issues like planning, working in a collaborative way or following a project centered approach to plan effectively activities that will remediate this. Workgroup is not strength of our cultural features however, for worse; usually we do not try to overcome this limitation. Teachers also adopt individualist behaviors, they establish isolated points of activity not considering their mate's work or even not knowing the complete curriculum of the programs they work in. This must be corrected in order to get progresses.

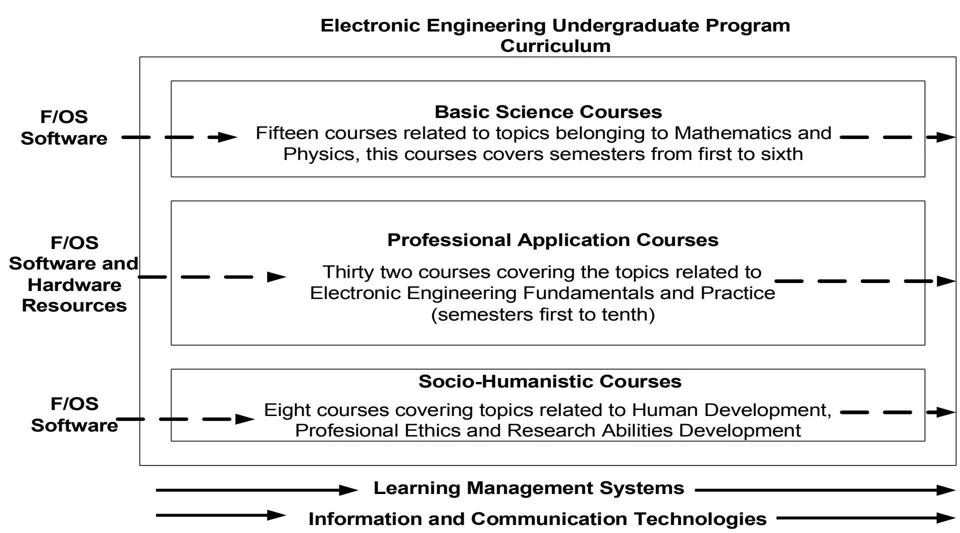

Figure 1: General Overview of the Electronic Engineering Undergraduate Program Curriculum (USBMed) and Possible Scheme of Integration of ICTs and F/OSS-Hw Resources to Teaching Activities

3.2 Institutional Support and Favorable Attitude Towards Change

An innovation or new educational strategy is best supported if executive staff of universities or government agencies provides the extra training that the adoption of these new academic tools involves (Terbuc, 2006). Many people decide to stay away from things that could represent additional effort or extra compromise with traditional course and class planning and supervision. A government support obviously increases the speed of adoption of F/OSS-HW by people in general not only by students. In Colombia the supremacy at the public level and private belongs to proprietary software and hardware. A few advances have been made but these remains as isolated efforts. Politicians and government guidelines remain far of adopting alternative approach to these technological means. For this reason it is possible that the most pertinent approach to be the gradual one, in which mixed tools, proprietary and F/OSS are to be used. The adoption or suggestion of alternative tools to support educational processes must remain optional and must become valued as people perceive them as a comprehensive option, which represents more challenges than the mere learning of a new instructions set. As students, teachers and researchers understand in a more comprehensive way the pros and cons of F/OSS-HW resources, they could adopt strategies or choose the front better fitted to their particular interests.

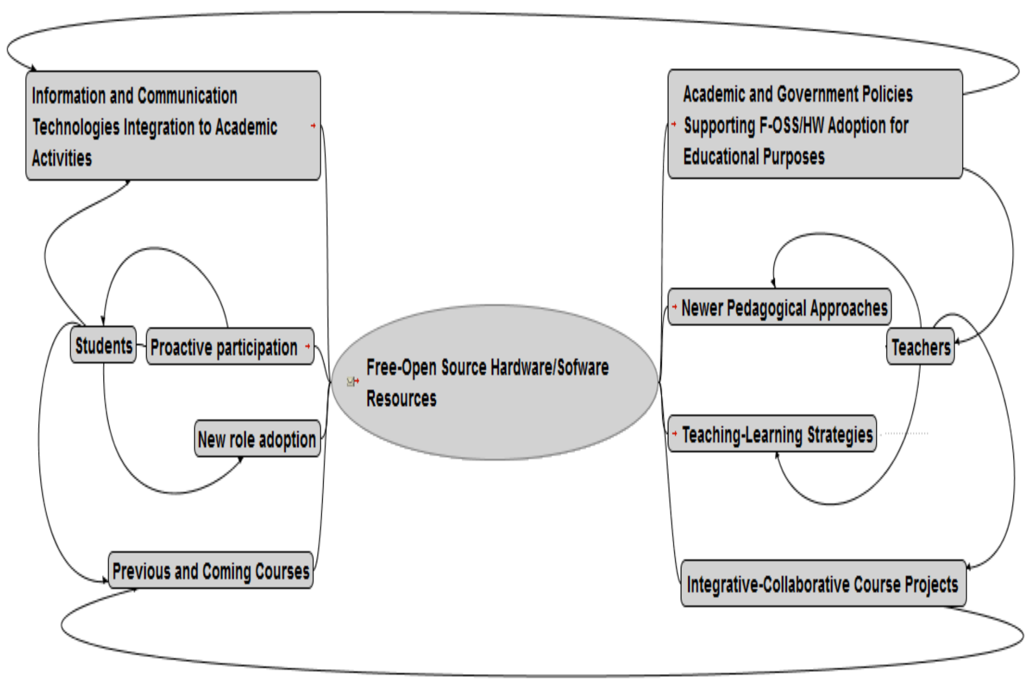

Figure 2: Items related to the adoption of strategies for incorporating F-OSS/HW resources to teaching activities in Electronic Engineering

3.3 Free-Open Source does not Mean Moneyless

An important issue that is well known for people having previous knowledge on free-open resources but which deserves our attention is that F-OSS-HW does not mean moneyless. Money is an important part of F/OSS-HW tools and projects and can have diverse forms, through donations, investment in companies or through specialized development or support. The open or free conception, apart from being an inherent philanthropic feature of the tools or solutions, gives to people interested the option to follow an alternative way to make business or found enterprises that are intended to provide utilities. Entrepreneurs also take part of open source-free world (Coris, 2003). The free condition of tools is also relative in the sense this can be not absolute or everlasting, in many cases the free term refers mainly to the process of getting the software or upgrading it, but when people need specialized support or decide to improve codes, prototypes, platforms or other tools, they must need some budget to perform their activities. Free turns into freedom because the user can follow his own way when performing tasks related to the tools he acquire. Many people decide they must be highly committed with collaborative efforts and communities either giving economic support or improving the tools, but others can decide they only want to use tools but are not interested into assume major compromise with the free-open project or tool.

4. An Example: Integrating Foss-Hw Tools to Courses Involving Embedded Systems Design and Application

4.1 A Project Based Approach

Many teachers usually develop Classroom or Course Projects as part of an integral strategy to favor student's learning by expanding their approach to the educational process. Methodologies like project based learning, if properly used, could contribute to the continuity between courses belonging to different semesters and can take advantage from the fact that students can get encouraged to involve themselves with the work because they perceive they really are building their future professional skills and the knowledge they acquire is not disperse but is part of major topics very important for them (Meneses et al, 2010). If a common or connecting thread is identified, even if this is not explicitly stated, both teachers and students will perceive they are participating in a complete collaborative project which requires the efforts to be not individual but grup-made (Azeta, 2008). Teachers must have knowledge on the courses the students have previously attended before arrive at the current level of education to optimize the experience effectiveness.

A course project in Electronic Engineering integrates activities like the learning and use of programs on the software side and the construction and testing of the circuits on the hardware side. The evaluation can be diversified through the use of on-line resources available for free like web site hosting that can be use to describe project information and results. Learning management systems like Moodle can be integrated also to manage grades and online activities; even technical features of most demanding activities like virtual laboratories can be integrated to Moodle (García et al, 2009).

4.2 The Big Picture

We will draw a general chart illustrating the constituting blocks of a course project involving the design and implementation of an embedded system similar to those commonly used in electronic instrumentation, automatic control or digital signal processing courses. Different stages of project development like circuit schematic design, embedded device programming and debugging, system modeling validation (Ma et al., 2008), project report generation, web browsing and public presentation of project can be made by using FOSS-HW currently available and highly known worldwide.

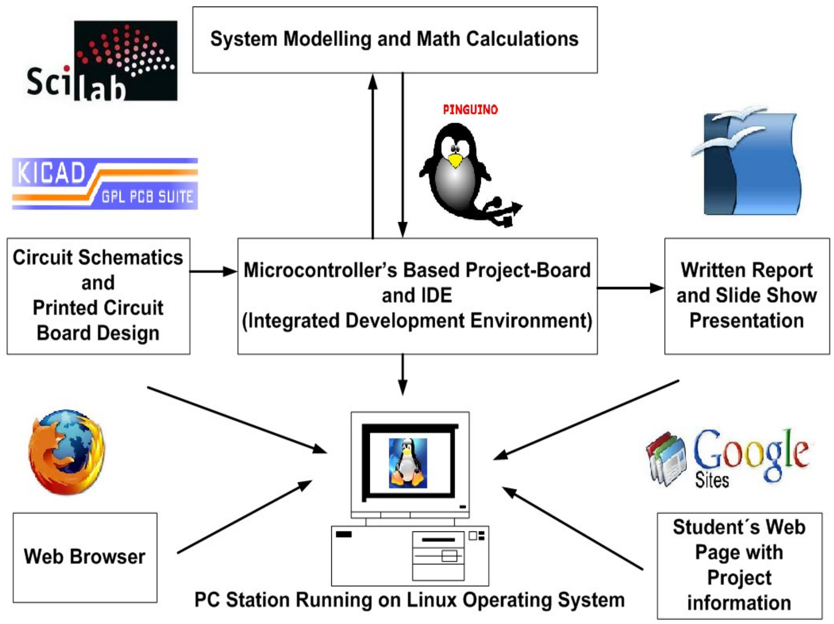

Figure 3: Incorporating F-OSS/HW resources to teaching in Electronic Engineering trough the development of a course project

Checklist of the course project activities involves:

- **Project outline presentation:** Covered topics, Exigency level, Scope, Teams composition, Budget Estimation (Bill of materials), Evaluation Scheduling and Tutoring. A problem based approach can be used to present the possible project topics.

- **Base project documentation construction**: The web resources available from diverse sources can be accessed through the use of a web browser like Mozilla Firefox and complementary tools like Thunderbird for mail services management. Students can download datasheets, whitepapers, technical reports, articles, papers, and thesis, watch videos, visit and participate in blogs, forums, etc., in order to get the documents related to their projects.

- **Circuit Design:** The circuit schematic is designed and corrected using Kicad.

- **Project Evaluation**: Periodic examinations on project's progress.

- **Embedded System Development:** Microcontroller programming and Debugging using Pinguino IDE and Board. Pinguino Board use a bootloader so there is no need to use extra hardware for transferring the code to microcontroller.

- **System Modeling**: Scilab, its command window and Scicos (now called Xcos) is used for system modeling and performing math computations (Peng et al., 2006). Scilab scripts runs also on extensively used engineering software programs.

- **Written Reports Preparation**: Open office has multiple tools for text edition and slide presentations among others. In addition files can be also open under proprietary software.

- **Team project's website building:** the students involve themselves in the construction of a free-hosted web site to share the information of their projects, their most significant findings, experiences and conclusions. Students can embed images, videos, text and links to other websites they consider important regarding to their projects. Through the web site, other students and teachers can know the work of their mates and can get information for future projects. Website is also a resource to continue projects through different courses and to give concepts relating to project evaluation.

- **Work in an alternative operating system:** Though all the F-OS resources proposed for the course project runs on Windows operating system, exists the opportunity for students to work with Linux distributions for widening their knowledge about operating system performance features and main differences.

- **Adoption of complementary tools:** Students and teachers can install other resources like virtual machines, remote desktop applications, etc., to enhance their possibilities while working in the projects.

PBL centered approach propose the institution of a tutor function instead of teacher traditional support (Ordosgoitia et al., 2009). If a change of pedagogic approach is to be used, a careful planning must be done to avoid poor results in student's performance or misconception of course learning goals. The proposed strategy does not put aside traditional class time having presence of teachers and students at the classroom or laboratory in order to keep track of team's advances and difficulties. Extra care must be observed to avoid students acquire loss of interest in participating actively in projects. Responsibilities must be clear to avoid one person make all the work and for this reason individual work is allowed. The number of students for project team is limited and the maximum limit depends on projects complexity.

5. Conclusions and Future Work

Emerging trends in technology influence all the aspects of people´s life, including education. New strategies to use alternative technological resources like FOSS-HW for educational purposes could represent a valuable tool for teachers because they can constitute an instrument to widen their professional skills. Additionally, free-open source software/hardware is a promising research field for students and teachers. Through their use they can overcome limitations regarding to license purchasing and product's upgrade. Research activities on F-OSS/HW could contribute to cross boundaries imposed by people's insufficient economic capability which is derived from low incomes in developing countries like ours.

High dependencies on propietary software programs or hardware for electronic engineering, do not favor the dynamics of courses neither of the undergraduate program because user's posibilities can be seriously limited. A common problem in our country is that students and teachers cannot acceed higher qualitiy resources because these are not included into the software license acquired, and represent an additionnal cost that Educational Institutions can not afford. In countries like Colombia, the investment in technological upgrades is not easily supported by university or government offices in charge, because of budget constraints.

In our country the most common educational model for undergraduate engineering programs is mostly centered in class attendance and on-campus activities. Virtual education and pedagogical strategies like blended learning, despite of many remarkable efforts made by national universities, have not reached their true potential because most of the benefits that can be derived from existing technologies, communication infrastructure, ongoing and coming developments, still remain unused. A big amount of work is still needed to reach significant improvements in higher education relating to e-resources integration.

Many of the F-OSS/HW tools proposed here to be adopted for teaching in electronic engineering courses have formats that can be exported or that can be interfaced to many proprietary resources. The integration of students to this kind of projects does not suppose to put aside proprietary resources, instead of that a gradual integration is proposed, having enough flexibility to avoid constraining attitudes towards students that would be contrary to the original intention of this alternative proposal. All the people committed with the project must be conscious that benefits must overcome course boundaries, and would represent a lasting gain because they are closely related to student's professional skills and to very important topics like computers, internet and ICTs.

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