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The Social and Environmental Impact of Engineering Solutions: from the Lab to the Real World*

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Professional skills such as 'an understanding of professional and ethical responsibility' and 'the broad education necessary for understanding the impact of engineering solutions on a global, economic, environment and societal context' have proved difficult to teach. Moreover, it is difficult to develop these skills at the comprehension and application levels of the Bloom taxonomy. In the Barcelona School of Informatics we teach these skills at application level by using Service Learning. In this paper, we describe a lab activity in which students repair old fashioned or broken PCs, and install free software in order to use this equipment in solidarity projects. This kind of activity has several effects: first of all, it is a way to recycle and reuse some of the many PCs that our university discards and which otherwise would be thrown away. Secondly, students obtain real insight into the above-mentioned skills, which are quite difficult to teach. Students work on real problems that meet full realistic constraints, and learn the social and environmental impact of technology in a very good way: increasing the useful life of electronic equipment, reducing e-waste and influencing the quality of life of the most deprived sections of society.

Keywords: professional skills; service learning; sustainability; solidarity

1. INTRODUCTION

IN ADDITION to the classical technical skills, the new trends in engineering education include the so-called professional skills. ABET's EC 2000 criteria contain a set of professional skills that include process and awareness skills [1]. Process skills include communication, teamwork, and understanding ethics and professionalism, while awareness skills include engineering within a global, economic, environmental and societal context, lifelong learning, and knowledge of contemporary issues. These skills are usually hard to teach and some of them are difficult to include in subjects such as Mathematics or Computer Architecture.

In our school, the Barcelona School of Informatics (http://www.fib.upc.edu) at the Technical University of Catalonia, a broad range of subjects have included skills such as communication, teamwork and lifelong learning as part of their objectives. The knowledge of contemporary issues have always been taught in senior year subjects, but it is quite hard to teach 'an understanding of professional and ethical responsibility' and 'the broad education necessary for understanding the impact of engineering solutions in a global, economic, environmental, and societal context'.

These two skills are closely related with the concept of sustainable development. One of the widely accepted definitions of sustainability is the one from the Brundland commission [2]: the ability to satisfy today's needs without compromising the ability of future generations to satisfy their own needs, which is a matter of intergenerational justice. This definition includes two fundamental concepts:

- The idea of 'needs', which includes social responsibility (technology can play a significant role in a distribution of wealth to prevent polarization, and in the transfer of services and information)
- The idea of the 'limits' of the environment to satisfy present and future needs.

As engineers, we are used to applying our knowledge and experience to solving problems rather than to defining needs. One could argue that the fundamental tasks for engineers have not changed: finding new solutions to technical problems or social demands and optimizing existing solutions. While in essence this is still true, the scope and the nature of systems that engineers are dealing with have changed. The effects of engineers' developments and solutions on the environment, the economy and society must be studied before being implemented.

Sustainability therefore requires a systemic view

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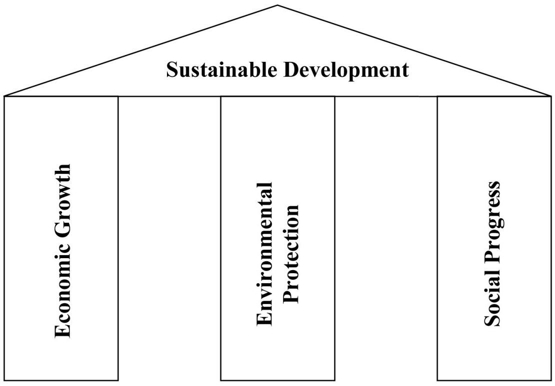


Fig. 1. The three pillars of sustainable development.

[3], in which every decision made by looking at only one part of the problem can negatively affect the solution as a whole. There are three pillars of sustainable development [4]: the economic, the social and the environmental (see Fig. 1). Only when all three pillars are taken into consideration can a sustainable solution be found.

Although the three pillars of sustainable development can be included as a new lesson or project in some subjects, these approaches do not necessarily mean that students get involved in the problems, with the result that while they 'know about' them they do not 'understand' them. In other words, they do not achieve the required level in Bloom's taxonomy.

Bloom's taxonomy [5] distinguishes six levels of competence in the definition of educational objectives: knowledge, comprehension, application, analysis, synthesis and evaluation. In this work we present activities one can do to help students to achieve the first three levels of competence in these skills. So, what can we expect from our students at every one of these levels?

- Level 1 (knowledge): students should be able to identify the economic, social and environmental costs of Information Technologies, and be able to define why technology can transform the way we live.
- Level 2 (comprehension): students should be able to foresee how their current and future work will influence the economy, society and the environment, and apply this to their daily work.
- Level 3 (application): students should be able to tackle real problems related with these skills, different from the ones studied, and apply the acquired knowledge to find solutions, taking into account economic, social and environmental constraints.

One can consider two approaches to working these skills into the studies: firstly, by including new subjects specially designed for teaching these skills in the degree, and secondly by integrating sustainability in other (existing) subjects.

Subjects specially designed for teaching these skills are used to study the social, economic and environmental impact (and effects) of information technologies, their history, laws affecting their practice, professional ethics, professional deontology, etc. The goal then is for students to acquire some knowledge— skills such as critical and reflexive thinking—and some methodologies aimed at tackling the complexity of sustainability. These subjects are used to cover the first level (knowledge) of the Bloom taxonomy.

A better solution is to integrate sustainability into existing subjects. In fact, all subjects should include ideas on sustainability, because one subject in which students are taught to use computer resources in a responsible way and another subject that does not insist on an efficient design of these resources is a contradiction. It is essential to introduce an analysis of the economic, social and environmental impact of the proposed solutions into every subject. Sustainability is thereby integrated into daily engineering work, and level 2 (comprehension) can be achieved.

Level 3 (application) can be achieved in some subjects if lab work is oriented towards real environments, collaborating with organizations sensitive to ideas such as the environment or social awareness. By its very nature, this solution cannot be applied to all subjects, although it is known that not all subjects in a degree must include all the skills, or develop them at the same level.

Level 3 can also be attained during undergraduate or graduate projects. In this case, the final memory should include a study of the economic, social and environmental impact of the project. Furthermore, the project can be done in collaboration with the third sector (also known as the non-profit or voluntary sector). Information technologies can contribute to sustainable development in local community projects as well as in international projects: computer systems to control resources (water, food, medicines . . .); encouraging the use of free software to facilitate the empowerment of minority cultures; installing computer labs in schools and community service centres, or building the information support for NGOs are all projects enabling students to become conscious of social inequalities, the digital divide and environmental problems.

To conclude, therefore, level 3 can be attained by using Service Learning [6]. Service Learning is a method of teaching and learning that combines academic classroom curriculum with meaningful service throughout the community. As a teaching methodology, it falls within the philosophy of experiential education. More specifically, it integrates meaningful community service with instruction and reflection to enrich the learning experience, teach civic responsibility, encourage lifelong civic engagement and strengthen communities for the common good.

In this paper, we describe a lab activity enabling students to acquire the above-mentioned skills by using Service Learning. The activity consists of a lab shared by two subjects with an impact on the real world: preparing old PCs to be used in solidarity projects. Through this activity, students are involved in a project that could influence the quality of life of people outside the university. Some students have the opportunity to develop a specific project for the people that will use these PCs later on, as well as hearing from them what difference their work could make on their quality of life. Furthermore, refurbishing old PCs in a lab provides a direct experience in product life-cycle and reduction of e-waste (electrical or electronic equipment which is waste, including all components, sub-assemblies and consumables, which are part of the product at the time of discarding [7]) due to the fact that unrecoverable parts are sent to recyclers. The activity is aimed at reinvigorating the civic mission of higher education and instilling in students a sense of social responsibility and civic awareness through the development of teaching and learning opportunities

First, from the educational point of view, opportunities for integrating and relating theory to practice are created; academic theory is experienced in a real world context, and new education techniques are promoted. The University finds a teaching environment in the community, and the academic and professional capacity of students are increased. Furthermore, since the European Higher Education Area (EHEA) first drew attention to the learning process from the student perspective, evolving from 'teaching' to 'learning how to learn', the practical aspect in education has increased in importance.

Secondly, the community benefits from the service; issues vital to social, civic and political society are explored, and the civic and personal capacity of students are enriched. Finally, the University receives feedback from the community; real world problems learned from active participation in the community can influence the university to adapt its program so that it can teach what is required by society.

As regards Human-scale engineering, it is clear that by its very nature engineering is bound up with society and human behaviour, and involves responsibilities that should be borne in mind by every school of engineers. With our initiative, the University can move closer to society, while at the same time society improves its opinion of the university.

2. BACKGROUND

Sustainability has been identified as a critical aspect that should be included in engineering and design courses [8], and an important part of the future education of engineers [9]. Teaching sustainability requires ways of thinking to be reviewed as well as ways of teaching. Intellectual development, critical thinking and a systemic approach are all required in order to progress from 'ignorant certainty to intelligent confusion' [10]. A study carried out in 2007 [11] reports that most of the examined universities 'bolted-on' various components of sustainability or studied-centred learning in their existing programs. New teaching strategies must be built to tackle engineering requirements in the 21st century.

As graduate education in North America and Europe still consists largely of attending courses, in some schools the principles regarding sustainability are taught within a single course. There are very interesting approaches, some including multi-disciplinary groups [12] or active learning strategies, such as role-play-simulation, debates and scenario building [13]. Some of these approaches complement the theoretical course; for instance, at the University of Bremen [14] they complement lectures and seminars with field trips, invited speakers and interdisciplinary student projects in co-operation with other divisions and partners from industry. In Berkeley [15], they encourage socially-conscious design projects, using Project-Based Learning methods.

Our initiative uses the principles of service learning, which is 'a form of experimental education in which students engage in activities that address human and community needs together with structured opportunities intentionally designed to promote student learning and development' [16]. Service learning has been widely studied in relation to engineering [17], and applied in some programs such as those at Purdue University [18].

Real-world problems presented through service learning help students to engage in active learning and problem solving, which can develop sustainability knowledge, create new perspectives and provide them with exposure to authentic techniques in the practice of engineering. Biggs [19] emphasizes that 'learning takes place through the active behaviour of the student: it is what he does that he learns, not what the teacher does'. For this reason the proposed activity is directly associated with real world needs and constraints. Vanasupa et al [20] report that 'understanding the broader context' and 'a moral and ethical development' are two of the factors that most influence learning. Our results demonstrate that obtaining concrete and real results to help society and the environment provides our students with great motivation and deep learning of awareness skills.

Finally, Colby and Sullivan [21] give 5 recommendations to improve ethics teaching: 1) defining ethics and professional responsibility broadly; 2) integrating with other learning goals; 3) using active pedagogies; 4) engaging faculty; and 5) increasing institutional intentionality. We will show that these recommendations fit into our initiative.

3. METHODOLOGY: USING LABS TO TEACH SUSTAINABILITY AND SOCIAL RESPONSABILITY

We have defined an activity that enables students to acquire awareness skills at level 3 of

Bloom's taxonomy. This activity, known as the 'reuse workshop', consists of a lab shared by two subjects with an impact on the real world: preparing old PCs to be used in solidarity projects.

This kind of activity has several lateral effects. First of all, it is a way to recycle and reuse some of the many PCs that our university discards every year (since most of our computers are renewed every three years) and which otherwise would be thrown away. Secondly, but no less important, students obtain real insight into three ABET skills: 'a knowledge of contemporary issues' (another professional skill); the previously mentioned 'an understanding of professional and ethical responsibility', and lastly 'the broad education necessary for understanding the impact of engineering solutions in a global, economic, environmental, and societal context', a skill difficult to teach, but which here meets full 'realistic constraints'.

The two subjects shared in the lab for carrying out the reuse workshop are: 'PC Architecture (PCA)' and 'Free Software (FS)'. The main PCA goal is to provide the students with knowledge about the past, present and future of Personal Computers and their components [22]. However, some other objectives are also defined in this subject: improvement in critical thinking; the ability to manage information; decision-making, and gathering and integrating information. The course is based on master lectures, and students are required to develop and present a project during the course, which can be related to technical issues or to ethics and solidarity (i.e. 'Interfaces and devices for disabled persons' or 'The One Laptop per Child Project'). The FS course main goal is to present Linux and Free Software as a further possibility as opposed to traditional and closed software, as well as the influence of these two approaches to hardware manufacturing and PC life-cycle [23]. FS students also present a project, and it is common to create round-tables to discuss contemporary issues and students' future professional and ethical responsibilities. Both subjects have only one group per semester, and only 24 people can join each subject per semester (since every student defends his or her project in class, time restrictions prevent us from accepting a higher number of students).

PCA and FS are both addressed in the lab activity, which consists of repairing and fixing broken and old-fashioned PCs (PCA students) and installing free software (FS students) adapted to the final users' requirements. The final users are solidarity projects (for instance, schools in developing countries). To carry out this lab, we need the collaboration of the University, the School and a group of volunteers.

The lab activity lasts for six hours and is divided into three sessions (over three days). Every session lasts two hours. It is usual for the planned work to exceed two hours. In these cases, a substantial percentage of students continue the laboratory voluntarily until the planned work is completed.

On the first day, PCA students analyze the computers and separate those that still work from those that are broken. Working PCs are analyzed (CPU model, kind and amount of RAM memory, hard disk characteristics, etc), labeled and catalogued. To carry out this analysis we use specific tools gathered or created by former volunteers.

On the second day, the FS students install the necessary software in the working PCs according to the needs of the end user. At the same time, PCA students take charge of broken PCs, repair them whenever possible, or remove all the parts that still work (for repairing other computers) and separate the broken parts, which will be sent to government organizations specialized in recycling.

On the third day, students of both subjects share the lab, interacting in the repairs and the installation of software.

Prior to the lab activity, the students are informed about the final destination of these computers, so they can adapt the computer to recipients' needs. They also know that the generated e-waste will be sent to the appropriate destination to be recycled.

At the end of the third day, local NGOs or people in charge of the projects receiving the repaired computers come to the lab to pick up them. Students can then interact with these organizations. For some students, this is their first contact with these kinds of organizations. They establish links with local and international organizations, which are sometimes the beginning of a long-term collaboration.

Students work in highly constrained conditions, and they discover that rejected equipment can still be useful. The students are also aware of the social and environmental responsibility of using resources properly. Moreover, students know these computers will end up in the hands of people that have few opportunities to repair them, which encourages students to perform serious and responsible work. Finally, students' personal satisfaction from this lab is high, because they know that people who really need help will benefit from their efforts.

In the reuse workshop, there are also talks about sustainability, social commitment, and environmental ideas. All activities except for the shared lab are open to the community. For instance, some of the PCA or FS projects related to ethics and sustainability are presented in the workshop to the whole University community. This workshop takes place twice a year (spring and fall courses). The 12th edition of the workshop will be held in the fall of 2009.

There are two essential factors for the workshop that we as teachers cannot control: volunteers and institutional support.

Without volunteers, almost nothing can be done. Academic staff is required to integrate these ideas into their subjects and to advice on projects. Students are required to implement these projects. Administration staff is required to help maintain the system. Moreover, institutional support is required: the University and the School should facilitate and motivate these initiatives.

A growing movement in solidarity exists in our University, which enjoys strong support from the institutional framework. An internal institution, named the *Cooperation to Development Centre* (CCD is the acronym in our language, http://www.upc.es/ccd/), coordinates this movement. This centre has as its aim the centralization of all solidarity initiatives of the University, as well as offering legal, logistic and financial support to these initiatives. Another institution in our University, named the *Centre for Sustainability* (https://www.upc.edu/centresostenibilitat/), encourages the reduction, reuse and recycling of several materials, in particular electronic equipment. This centre is responsible for gathering together all the computers we are going to repair and fix in the reuse workshop. Furthermore, the Barcelona School of Informatics provides storage space for the computers as well as lab facilities.

However, the most important resource is people. The Barcelona School of Informatics gives support to an internal non-governmental organization named *Technology for Everyone* (TxT is the acronym in our language, http://txt.upc.edu). This organization consists of students, academic and administration staff, and participates in several solidarity projects around the world. Some volunteers manage the organization of the reuse workshop, so students involved in the lab can devote all their efforts to repairing and fixing computers, and to installing adapted software. It is thanks to the volunteers and to support from institutions that the reuse workshop works successfully.

4. RESULTS

It is always difficult to measure the real impact of an initiative like the one presented here. Firstly, because it affects a wide range of aspects that are sometimes difficult to measure, and secondly because there is no control group that can be used to compare the obtained results. However, we have tried to obtain different sets of indicators that reflect the outcomes obtained by this initiative.

The first set of indicators is easy to measure and gives an accurate idea of the work carried out. The reuse workshop started in 2003 and is held twice a year. Up to November 2008, more than 1200 computers were repaired, installed and handed over to 102 solidarity projects. We expanded from 6 projects involving 20 computers in 2002–2003 to 15 projects and 118 computers during the 2007–2008 course (figures from 2008–2009 are not yet available). Some of the equipment repaired in the reuse workshop is destined to improve the services and programs of third sector organizations. They can use these computers in their organization, or for carrying out initiatives of social interest such as organizing computer classes in social institutions (adult schools, old people's homes or orphanages). Most of the repaired computers have been donated to schools and social organizations in our country, Spain. However, people from 17 foreign countries have also received about 450 computers in international cooperation projects (Angola, Algeria, Bolivia, Burkina Faso, Colombia, Cuba, Ecuador, Equatorial Guinea, Gambia, Guatemala, Haiti, Morocco, Mozambique, Paraguay, Peru, Senegal, and Togo).

Although these figures can be considered a successful result on their own, the most important point is the growing number of students who wish to collaborate in preparing computer networks, teaching courses or analyzing the needs (just doing engineering work) in these countries during their school holidays. More detailed information on these points can be found on the TxT web page and in the CCD annual report (see previous section). Without this initiative, all these equipment would have ended up as e-waste: none of these computers would have been reused, and very few recycled. Of course, not all the equipment can be reused either, because it is broken or obsolete. As we stated before, broken computers are stripped into parts and the profitable components are used as spare parts for other equipment, while the University transports the remaining parts to a suitable recycling plant. However, equipment considered obsolete at the University can be useful in a less demanding environment, especially if less demanding software has been installed in them. These renewed computers are capable of meeting all the needs of the final recipients.

Nevertheless, it should be pointed out that there is a lot of room for improvement. Our University has around 30,000 students, an academic staff around 2,500 people, and an administration staff of about 1,500 people, as well as more than 10,000 PCs, which are renewed every three years. In view of this, the reuse workshop is clearly insufficient if the objective is to reuse all the equipment. Similar programs of reuse and recycling should be applied systematically in all UPC Schools to achieve all the potential benefits of this kind of program.

While a large part of the reuse workshop is devoted to repairing PCs, part of the time is also given to debates and/or presentations whose content is related with social topics. Some are prepared by our students, and the impact of this work is also quite difficult to measure. Our experience shows that the knowledge acquired in the reuse workshop provides our students with great motivation, since it leads to concrete results in the real world. Students not only get more involved in the subjects, but they also want to develop their brand-new discovered ability further in order to change the current state of things. Students enrolled in PCA often enrol in FS the following term (and sometimes vice-versa), while some do their Bachelor or Master thesis in solidarity projects, mostly using PCs similar to those they have helped to prepare. Some details are given below:

- Since PCA and FS started sharing the lab in 2004, 174 students have attended PCA, and 102 students have attended FS. Of these, 27 students have attended both subjects (15.5% of the PCA students, and 26.6% of the FS students).
- More than 30 students have done or are doing their Bachelor or Master Thesis on solidarity projects, implanting the results they achieve in the countries with whom the project was carried out. Some examples of the work carried out are: the software controling the irrigation system in the Chancay-Huaral valley (Peru) or the software used in the child vaccination program in Western Sahara refugee champs (Algeria).
- We have detected an increasing interest by students in doing their Bachelor or Master Thesis in projects with a strong social and/or environmental component. Five years ago it was very difficult to find students who wanted to work in these kinds of projects, and very few professors who devoted any time to advising them. In five years, the number of professors supervising thesis of this type has doubled, and there is a growing movement of students asking to do this kind of thesis.
- Some students from our school have started PhD studies in our University 'Sustainability PhD program'. Practically all of them are related with the reuse workshop.
- Some students have continued collaborating with the NGO TxT after finishing their studies (only a few at the moment, but we are just at the beginning).

Finally, in order to find out students' opinions about the work being performed in PCA and FS, we surveyed students from both courses. The results of these surveys are analyzed in the next section.

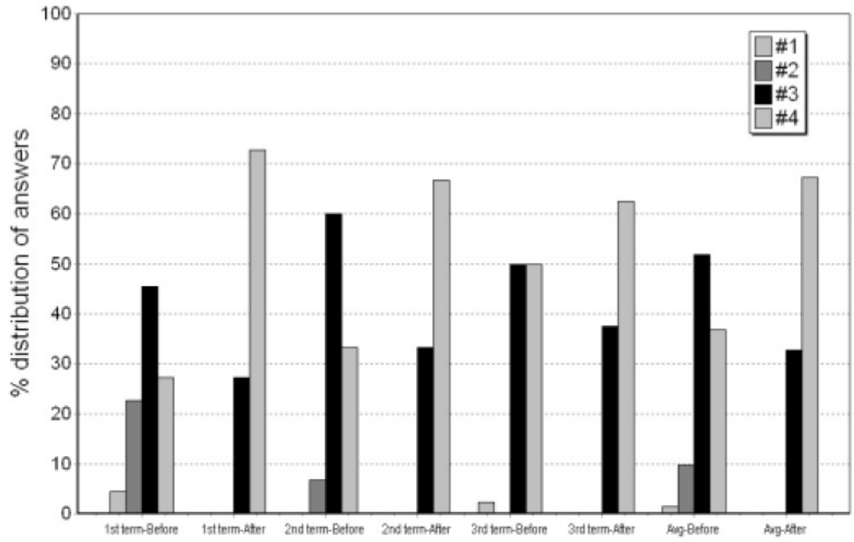
5. ANALYSIS OF RESULTS

There are significant differences between the PCA and FS surveys, due to the fact that we asked many different questions about every subject. Furthermore, FS students were surveyed at the beginning and at the end of the course (some questions unrelated with the lab required this), while PCA students were surveyed only once (at the end of the term). Nonetheless, the surveys include the lab questions. The questions and answers can be found in Table 1. We show only the answers from the last three terms (when it was decided to include all these questions in the survey). All students from PCA and FS answered the survey. In the figures, the three terms are spring 2008 (1st term), fall 2008 (2nd term) and spring 2009 (3rd term).

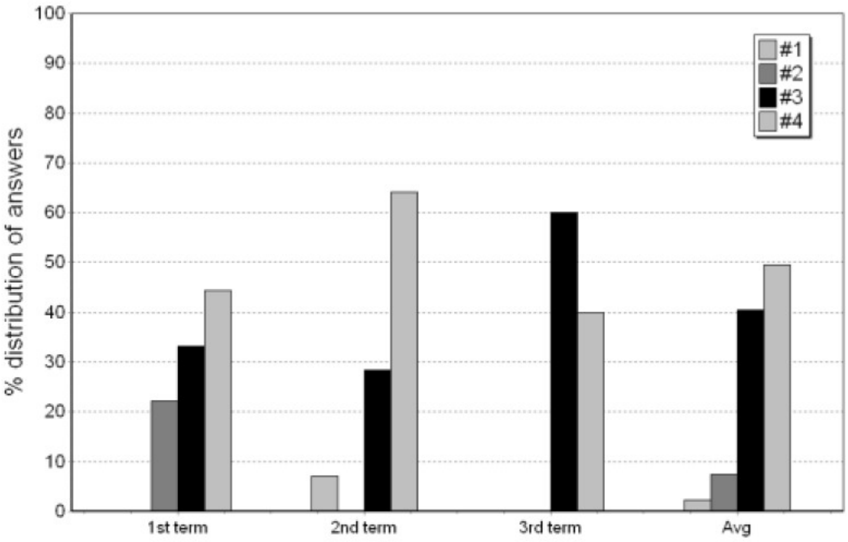
The first question is 'In this subject there are always several projects related to the social function of the engineer. What do you think now about having these kinds of projects in the subject?' Figure 2a show the results for FS (where the answers before and after the projects were presented—and their evolution—can be seen), while Fig. 2b shows the results for PCA. In the case of FS, answer #4—'There should be least one

Table 1. Questions (and answers) of the students' surveys

	Question	Possible Answers
1	In this subject there are always several projects related to the social function of the engineer (such as human rights, environment or devices for handicapped people). What do you think now about having these kinds of projects in the subject?	#1) I am against it. All the projects should be technical. #2) It is an important topic, but it should be developed by the professor. #3) I like these kinds of projects but they are not essential for an engineer. #4) There should be least one project of this kind every term.
2	In the reuse workshop, all refurbished PCs are assigned to a project, and you know who will be the final recipient. Does this way of working motivate you?	#1) No, it does not motivate me at all. #2) I am interested in installing/repairing PCs and in learning, I don't care about the destination of them afterwards. #3) Knowing that I am helping other people is an additional motivation for me. #4) My main motivation is that I am helping another people, not repairing/installing PCs.
3	Mark on a scale from 1 (not important) to 10 (highly important), what importance you assign to the social function of the engineer (environment, human rights, etc . . .)	Note: In this question PCA students are requested to give their opinion before and after attending the subject and so both subject results are comparable.
4	Do you think that the social function of the engineer should be addressed in more subjects? (Remember that this subject is not the only one that addresses this topic)	#1) No, this topic is well covered as it is now. #2) A little more, with more subjects addressing these topics. #3) These topics should be extensively included in more subjects. #4) There should even be subjects exclusively dedicated to these topics.



(a)



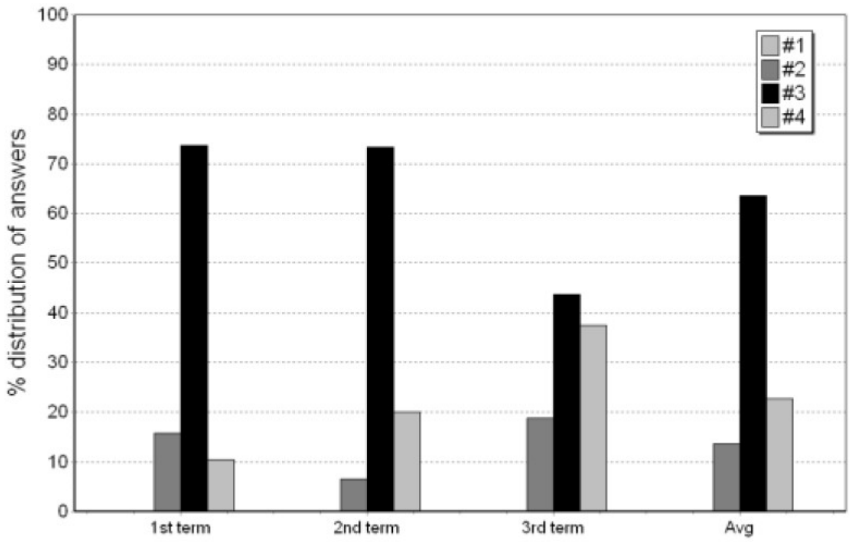
(b)

Fig. 2. Results for FS (2a) and PCA (2b) for question 1.

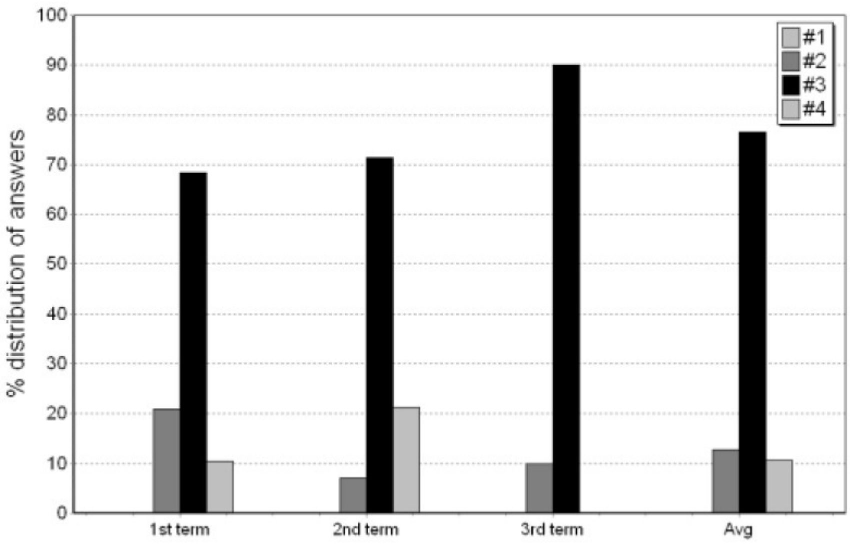
project of this kind every term'—was the most chosen. However, the most outstanding point is the spectacular difference in the answers between the beginning and the end of the term, which shows the change in mentality of our students. In the case of PCA, answer 4 was chosen by a minimum of 40% of students (49% on average), which is a good result.

The second question, 'In the reuse workshop all refurbished PCs are assigned to a project, and you know who will be the final recipient. Does this way of working motivate you?' is answered by FS students only once, at the end of the term (after the lab, there is little point in asking it before). In this case, results are similar for both subjects, which shows that helping people motivates students, but that their main interest is in the technical aspect rather than the social aspect of the subject (Figs. 3a –FS– and 3b –PCA–).

The third question is: 'Mark on a scale from 1 to 10, what importance you assign to the social function of the engineer'. In this case, we ask PCA (Fig. 4b) students what importance they assign before enrolling in the subject and now (but in only one survey); while in FS (Fig. 4a) we ask them twice. There is a marked growth in PCA, but less in FS. In order to improve analysis of what influence the subjects have on changing our students' opinions, we have performed a paired t-test between the results obtained before and after the subject. The significance obtained in the average for FS is a=0.004, while for PCA the significance rises to $a=7x10^{-11}$. We believe that this is due to the fact that some FS students have enrolled in



(a)



(b)

Fig. 3. Results for FS (3a) and PCA (3b) for question 2.

PCA before, so there is a higher mean entry value. As a conclusion, we would like to point out that both subjects significantly affect our students' opinions, and that the final mean is greater than 7.

Finally, Figs. 5a and 5b show the answers given by FS and PCA students (respectively) to Question 4, 'Do you think that the social function of the engineer should be addressed in more subjects? (Remember that this subject is not the only one that addresses this topic)'. In the case of PCA students, the most chosen Answer is 3: 'These topics should be extensively included in more subjects', while the FS students evolve from Answer 1 ('This topic is well covered as it is now') to Answer 2 ('A little more, with more subjects addressing these topics'). However, the important point is the evolution of the students' attitude, and the fact that they think that the social function of the engineer should be learned during the degree.

Thus, according to the results of the reuse workshop in students' attitudes and opinions, we believe that our students really change their point of view as regards the social and environmental impact of the engineering work, thereby achieving a deep knowledge of some skills that are typically difficult to teach.

6. SUMMARY AND CONCLUSIONS

Learning the skills: 'an understanding of professional and ethical responsibility' and 'the broad education necessary for understanding the impact of engineering solutions in a global, economic, environment and societal context', requires a change in the way of thinking with the aim of incorporating our mental model (our vision) into

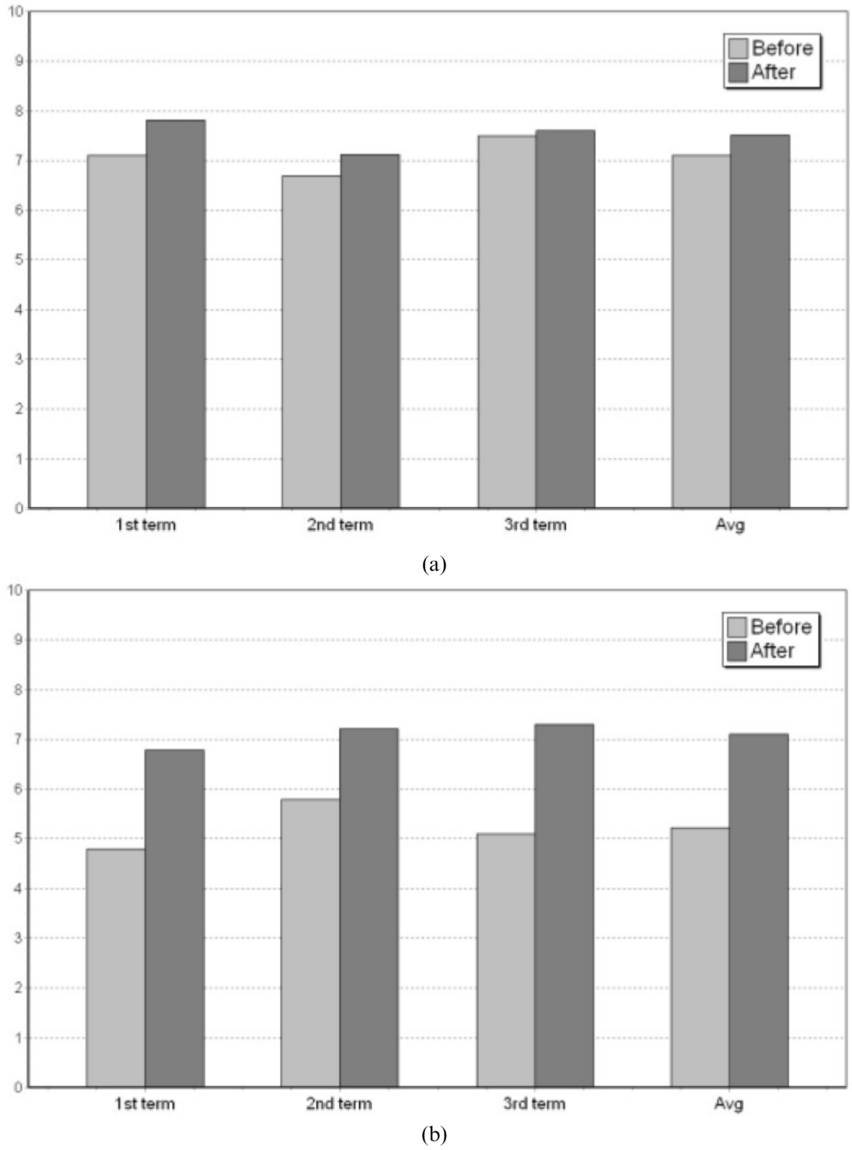


Fig. 4. Results for FS (4a) and PCA (4b) for question 3.

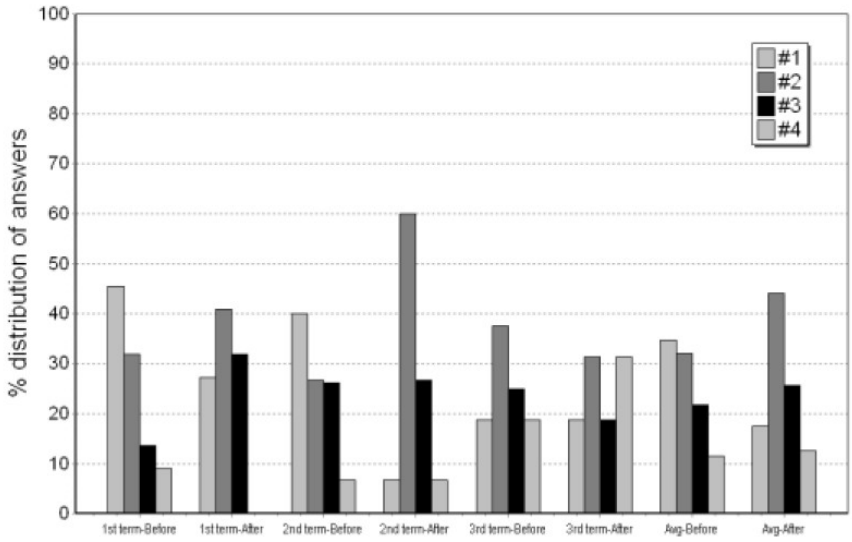
an environmentally and socially conscious conceptual framework.

There is no model for achieving these skills, and for that reason a familiarization with different approaches is recommendable, as well as their application in the context of the university with the aim of generating new learning forms. Through reflection on these experiences, students are able to draw their own conclusions and develop their own consistent and evolutionary conceptual framework, which will involve them to a continuous learning process related with the previously mentioned skills.

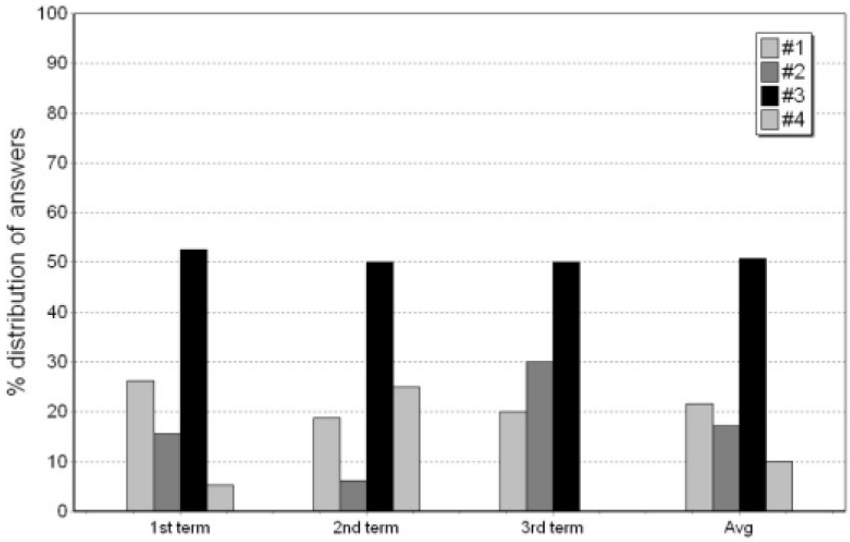
These skills can be reached at different levels. In this paper we present an initiative for attaining some skills at level 3 (application) of Bloom's taxonomy by the use of service learning. The involvement of institutions is required to achieve this goal: the institutions involved should provide an appropriate framework, publicize the projects carried out, encourage voluntary workers and recognize their work, as well as providing human resources for logistical tasks and financial support for the cooperation projects.

While the teaching goal is the acquisition of the two skills: 'an understanding of professional and ethical responsibility' and 'the broad education necessary for understanding the impact of engineering solutions in a global, economic, environment and societal context', we should not confuse the means with the ends. The final goal is to change the way of thinking of University members in order to create an environmental and social awareness that can have a real impact on society.

Improving education in sustainability has a positive impact on changing attitudes and the way one thinks. It also increases interaction with and responsibility towards society, thus providing the beginning of a positive feedback loop. This loop will start with the degree studies and last all through life. Former students, now professionals,



(a)



(b)

Fig. 5. Results for FS (5a) and PCA (5b) for question 4.

will carry out projects in which they will apply the sustainability concepts acquired when studying for their degree. It will result in better projects, which in turn will influence future engineers and academics, thereby closing the loop.

Conducting a real lab such as the one proposed here, in which students come into contact with real problems (such as e-waste, refurbishing of computers and the needs of deprived sections of society) and work under real constrains, provides a real insight into the above-mentioned skills. This work shows that the best motivation for our students is the realization that the reuse workshop will lead to concrete results in the real world. This knowledge provides students with a deep understanding of the underlying implications of technology, especially those related with society and the environment.

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