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Implementation of Service-Learning Projects in Engineering Colleges*

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In recent years, engineering colleges have started to integrate service-learning projects into many of their required courses. In the literature, there are many important definitions for service-learning pedagogy, including reciprocity, reflection, coaching and community projects. This paper presents a service-learning pedagogy implementation program for educating engineering undergraduates to solve real-world problems. Three project models for mechanical engineering, ranging from a single semester to a full calendar year, form the basis for the analyses presented. Finding appropriate community partners and projects are critical for a successful experience for all involved parties. From the results of this analysis, it is possible to conclude that, through these projects; students acquired and applied the competencies in the defined curriculum.

Keywords: service-learning; assistive technology; community engagement; design

1. Introduction

In recent years, engineering colleges have integrated service learning into many of their required courses.

There are several different definitions for service learning in the existing literature. B. Jacoby [1] defines service learning as the integration of academics with community service in credit courses, with the key elements such as reciprocity, the voice of reflection, coaching and community projects. To J. Duffy et al. [2], service learning is a 'practical' approach to learning in which students achieve academic goals in a credited course for meeting the real needs of the community. Service learning is defined by R. Bringle et al. [3] as a credit-based, course-supported educational experience in which students participate in an organised service activity that meets defined educational outcomes and addresses the needs of the community, while requiring students to reflect on the service activity to gain a greater understanding of course content. Several service projects in engineering courses do not meet the full definition of service-learning projects [4].

Several research projects have proposed training programs based on service-learning pedagogy. A. R. Bielefeldt et al. [4] proposed five model projects that have been tested in universities in the United States. J. Duffy et al. [2] proposed 35 different courses based on service learning that can be implemented in engineering courses. B. R. Hulman et al. [5] discussed the design of a bioengineering course within a project based on service-learning pedagogy, demonstrating that a combination of challenging engineering design projects and long-term service to the community proves to be extremely successful. E. Coyle et al. [6] employed service-learning programs in which students earned academic credit for their participation in working groups. These working groups resolved technical problems proposed by not-for-profit organizations. E. Tsang et al. [7] implemented a service-learning program in an initial course of mechanical engineering. During the three years of their study, service-learning pedagogy proved to be an important tool in teaching and practice of engineering that enhanced teamwork and human relations. Recently, W. Oakes et al. [8] presented a methodology that included training models based on service-learning pedagogy. In these models, instructors must devote both time and attention for developing relationships with partners prior to the beginning of the course and when following up to help ensure optimal outcomes for the partners.

This paper presents the service learning pedagogy implementation in educating engineering undergraduates, at Colegio Salesianos Atocha (CSA) and Universidad Carlos III de Madrid (UC3M), to reach the actual societal challenges. Three different projects form the basis for the analyses presented. These projects are summarized in Table 1.

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Table 1. Summary of project models incorporating service learning

			Electrical machines				
Project name	**Automatic collet chuck**	**Wheelchair**	**Grinder**	**Milling machine**	**Stapling machine**	**Drilling machine**	**Jigsaw**
Department	Mechanical	Mechanical	Mechanical	Mechanical	Mechanical	Mechanical	Mechanical
Location	UC3M	UC3M	CSA	CSA	CSA	CSA	CSA
Duration	1 year	1 year	1 semester	1 semester	1 semester	1 semester	1 semester
Majors of participating students	BME	BME	HNC	HNC	HNC	HNC	HNC
Required or optional for students in the major	Optional	Optional	Required	Required	Required	Required	Required
Number of students enrolled per project	3	3	4	4	4	4	4
Number of faculty	4	4	4	4	4	4	4
SL clients / community partners, tutors	1	3	2	2	2	2	2
Special support equipment	Yes	Yes	No	Yes	No	Yes	No
Frequency of client interactions	Twice a month face to face meetings	Three times a month face to face meetings	Once a month face to face meetings	Once a month face to face meetings	Once a month face to face meetings	Once a month face to face meetings	Once a month face to face meetings
Lifecycle	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sustainability	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ecodesign	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SL client	Small companies	Community rehab programs	Small companies	Small companies	Small companies	Small companies	Small companies
Credits	6	6	3	3	3	3	3

Finding appropriate community partners and applicable projects are critical for a successful experience for all involved parties. Students form teams of three or four and select the project on which they want to work.

From the results, it is possible to conclude that students acquired and applied the competencies in the defined curriculum; but it was also discovered that the projects resulted in an additional workload for the college staff. The easiest way to improve the efficiency in service-learning pedagogy is by providing training to the university offices that will facilitate the interactions with service-learning clients.

2. Teaching-learning methodology

2.1 Finding project partners and sequence of students' activities

Finding appropriate community partners and projects are the cornerstones for successful service-learning experiences. This process requires the identification of companies, non-profit organizations, municipalities and others interested in offering projects that can be reliably performed by freshmen and finished on time. The community partner should be available to meet the instructor, provide information and ideas prior to starting the course and be available for questions during the project; but this does not necessarily mean that they have to invest a lot of their time. However, at the time of defining students' projects, it is helpful if partner representatives can meet the students directly in order to clarify doubts.

At CSA and UC3M, projects have been identified through contacts with two small companies and a non-profit organization with limited financial resources. One of the partner companies repairs consumer machines and was interested in developing an online course for disabled workers and creating an online brochure. The other small company was interested in developing a collet chuck for turning machines. The non-profit organization was interested in developing a low-cost wheelchair and had engineers on staff, allowing students to continue the projects after their coursework was complete.

Professors, instructors and clients began by identifying the tasks to be performed by students and defined the timelines in which the tasks would be completed. Later, students developed the technical proposals which defined their scopes of the work and included their statement of qualifications among other things. After that, students made poster presentations to the partner companies, conducted feasibility studies and provided alternative assessments and/or created a prototype (see Fig. 1).

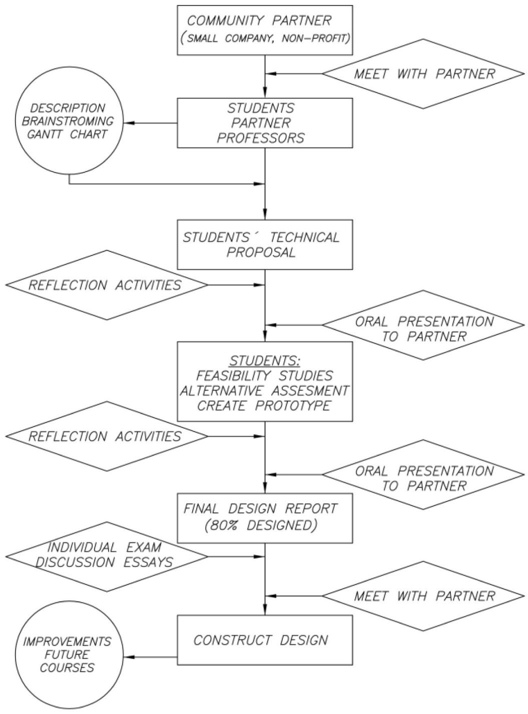

Fig. 1. Sequence of students' activities.

2.2 Forming teams for the service-learning projects

Teams comprising three to four students appear optimal. Students' preferences were the primary criteria used to form teams. Service-learning projects were among the top three choices of the students.

2.3 Students' reflections

Reflective practice is a required component of rigorous service-learning experiences [4]. The purpose of reflection is to promote learning about the larger social issues behind the needs to which their service is responding. This learning includes a deeper understanding of historical, sociological, economic and political contexts of the needs or issues being addressed [1]. Proposed service-learning projects include multiple student reflection elements, as summarised in Table 2. The quantitative and qualitative components of the data were analysed separately and the data derived from the focus groups were classified as strong, moderate or weak. Students' assessments of a given criterion were classified as strong if members of at least four of the seven focus groups believed there was a positive benefit of their participation in service learning in this course [5].

2.4 Course elements

When service-learning pedagogy is implemented, instructors and professors should take into account a few important elements. Students should develop their design in one semester or in one year. Students should finish any project they started so that the project can be a rewarding experience. Additionally, students should pay close attention to the sustainability of the project and to its environment and lifecycle. These course elements must be taken into account in order to successfully achieve the required

Table 2. Summary of students' reflections of service-learning in meeting ABET learning objectives

Criterion	Quantitative HND-CSA	Quantitative BME-UC3M	Qualitative HND-CSA	Qualitative BME-UC3M
An ability to apply knowledge of mathematics, science and engineering	Moderate	Strong	Moderate	Moderate
An ability to design and conduct experiments, as well as to analyse and interpret data	Strong	Strong	Strong	Strong
An ability to design a system, component, or process to meet desired needs	Strong	Strong	Strong	Strong
An ability to function in multidisciplinary teams	Moderate	Strong	Strong	Strong
An ability to identify, formulate and solve engineering problems	Strong	Strong	Strong	Strong
An understanding of professional and ethical responsibility	Strong	Strong	Strong	Strong
An ability to communicate effectively	Strong	Strong	Strong	Strong
The broad education necessary to understand the impact of engineering solutions in a global and societal context	Strong	Strong	Strong	Strong
A recognition of the need for an ability to engage in lifelong learning	Strong	Strong	Strong	Strong
A knowledge of contemporary issues	Moderate	Strong	Strong	Strong
An ability to use the techniques, skills and modern engineering tools necessary for engineering practice	Strong	Strong	Strong	Strong
An ability to make measurements on and interpret data from systems	Strong	Strong	Strong	Strong

Table 3. Group assessments

Project	Location	Technical proposal	Solution	Design	Prototypes implementation,	Oral presentation	Partner's assessment
Drill	CSA	5%	25%	20%	30%	10%	10%
Milling	CSA	5%	25%	20%	30%	10%	10%
Stapler	CSA	5%	25%	20%	30%	10%	10%
Sander	CSA	5%	25%	20%	30%	10%	10%
Jigsaw	CSA	5%	25%	20%	30%	10%	10%

professional skills that would have to be implemented at the conclusion of their studies.

3. Student learning outcomes

In order to assess each student's achievement of the learning goals, we use two associated percentages (individual and group).

The group percentage was assigned during the oral presentations once a month, as shown in Table 3.

The individual component consisted of two assessments, one for competences achieved by means of the project and another for skills and abilities to solve or manage similar projects. We performed an initial assessment at CSA. In this assessment, a student disassembled the machine, and was then encouraged to reassemble it. The maximum allowed time was 10 minutes. At the end of the course, the same assessment was carried out. The results of both assessments (initial and final) are summarised in Table 4.

As shown in Table 4, in the early phase, the majority of the students were not able to reassemble the machines within 10 minutes. At the end of the course, however, students were able to reassemble the machine with shorter task times.

Table 4. Individual assessments

Project	Location	Student	Reassembled machine time (initial)	Reassembled machine time (final)
Drill	CSA	1	12' 32" *	3' 15"
		2	11' 43" *	3' 00"
		3	12' 52" *	4' 25"
		4	10' 46" *	5' 41"
Milling	CSA	5	abandoned	5' 35"
		6	07' 43" *	5' 57"
		7	10' 36" *	4' 45"
		8	12' 09" *	6' 32"
Stapler	CSA	9	11' 41" *	3' 43"
		10	09' 10" *	4' 20"
		11	13' 00" *	4' 39"
		12	12' 17" *	4' 05"
Sander	CSA	13	10' 24" *	5' 26"
		14	11' 02" *	5' 57"
		15	12' 47" *	5' 48"
		16	09' 36" *	7' 06"
Jigsaw	CSA	17	12' 15" *	5' 21"
		18	12' 20" *	abandoned
		19	abandoned	5' 01"
		20	12' 41" *	6' 14"

4. Benefits of the service-learning projects

As shown in Figs 2 through 5, during the 2009–2010 academic year, as students worked on the same machine, there were improvements in both skills and training. It was felt, however, that some students applied themselves only minimally to the effort and simply copied the work of their peers. During the 2010–2011 academic year, when professors and instructors distributed different machines to the students, they noticed a substantial improvement in students' outcomes. Deeper analyses of the teaching/learning process, however, showed that students learned a lot about the machines themselves, but they were not able to use the machines to sort, classify and manage products.

During the 2011–2012 academic year, service-learning pedagogy was implemented and included the following features:

- Projects or machines from the same community partner, so that students could work on similar projects.
- Projects provided students with items that needed improvement at the company or in society.
- Learning should not be limited only to a single project but to several similar projects.

The service-learning pedagogy implemented during the 2011–2012 calendar year supplied the following improvements with respect to previous academic years:

- Higher involvement of students.
- More student interaction with industry and real-world projects (better professional integration).
- Emphasis was placed on practical work. Professors were therefore able to introduce subject theory with the application of service-learning projects (see Fig. 6).
- Achievement of adequate improvements in development and evaluation of competences resulting in, improved students' subject assessments (see Figs 2 through 5).

On the other hand, service-learning pedagogy requires an additional workload for the college staff, especially for professors and instructors. The

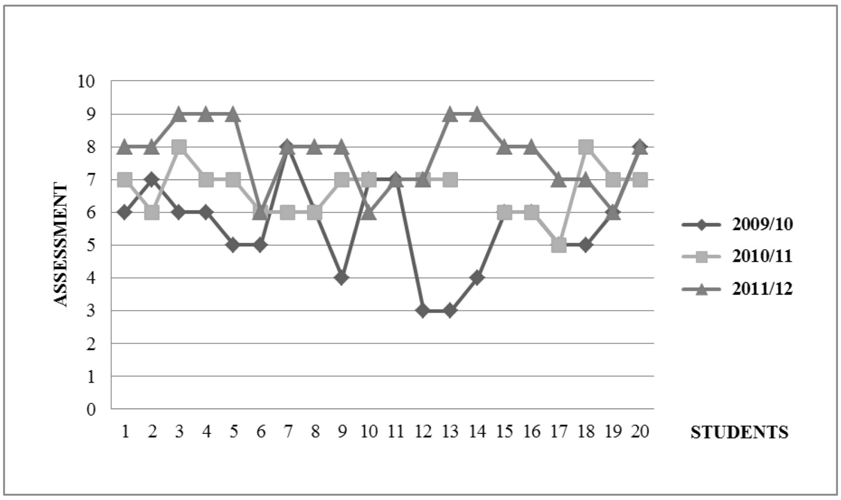

Fig. 2. Machine assembly-disassembly assessments.

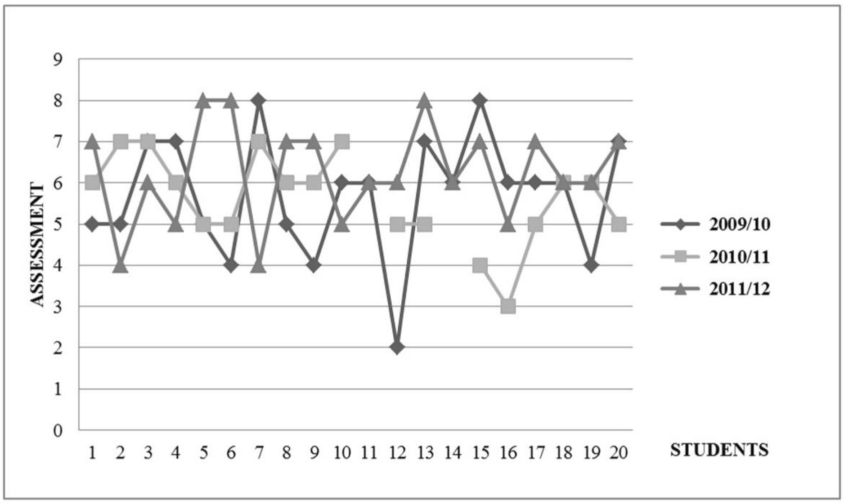

Fig. 3. Graphic representation assessments.

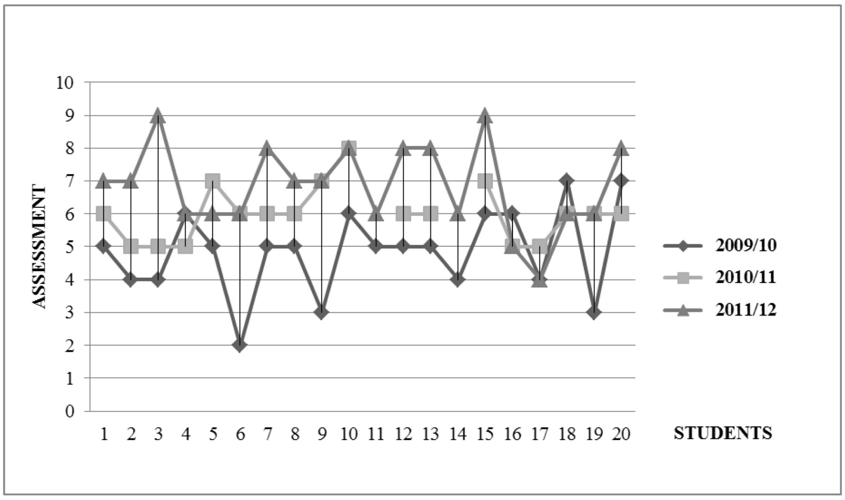

Fig. 4. Machine elements assessments.

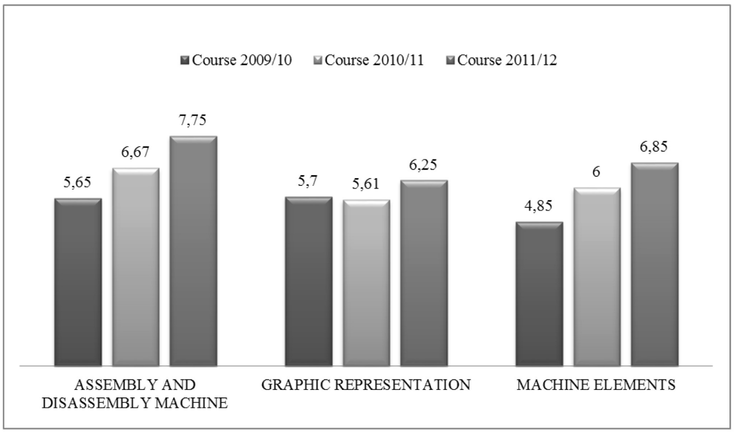

Fig. 5. Assessment evolution.

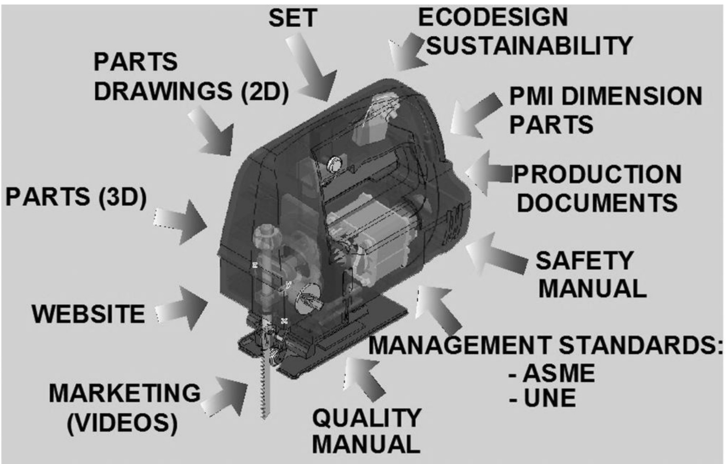

Fig. 6. Subjects theory by means of service-learning projects.

easiest way to improve efficiency in service-learning pedagogy is by means of learning offices that are able to facilitate interactions with service-learning clients.

5. Conclusions

During the 2011–2012 calendar year, we implemented service-learning pedagogy in two engineering colleges: CSA and UC3M. The pedagogical effort was not to focus on the results obtained from a single test exam but from a doing/learning methodology. Additionally, an active role was transferred to the students who were allowed to put into practice the professional skills that would have to be implemented at the conclusion of their studies. Students' teamwork skills improved and the students showed improved academic results. Professors and instructors could implement and demonstrate the validity of their theoretical models while considering ergonomic and environmental factors, assembly resources, workplace design and safety issues. They were able to create worker training procedures and guides and to demonstrate the possibility of a new product assembly that offers both time and cost reductions.

6. Future research

In order to achieve an adequate development and evaluation of competencies, this proposal can be applied and studied in a program that includes subjects divided among various educational levels or that considers different curricula objectives.

Additional studies can include ways to improve the efficiency of service-learning pedagogy and reduce the workload for professors and instructors by implementing learning offices.

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