The Needs of Innovation in Mechanical Engineering Education: The Position of the Politecnico of Milano

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ABSTRACT

The Department of Mechanics (DM) of the Politecnico di Milano (PdM) and the Fondazione Politecnico (FPM) have taken actively part in different initiatives related to teaching and learning quality. First step was one extensive survey of alumni in Mechanical Engineering (ME) on regional basis (Lombardy region) for defining the levels of mastery in different topics attained during the studies, compared to the levels required by the enterprises on the workplace. Regarding knowledge even a surplus of mastery furnished by university was felt by the alumni, but regarding competences and skills also gaps were found. Later the participation to the EC funded project ECCE has allowed to compare the Italian situation not only to European universities but also to the expectations of industrial stakeholders and engineering associations. Recognizing the need of changes, some members of the Pedagogic Faculty of Catholic University in Milano university have been recruited for giving courses for young professors for increasing their teaching qualities. Finally in the basic course of Applied Mechanics in the second year of the bachelor curriculum an innovating method has been introduced with the aid and support of a team of the Pedagogic Faculty. The aim of the introduced innovation was to develop some of the missing skills, and more in detail team work capability, active learning, critical thinking, project management, and presentation skills.

Keywords:

INTRODUCTION

The engineering work place has undergone significant changes in the last decades. A growing number of engineers operate in environments that require intensive cross disciplinary activity, where economic, social and ethic concepts have also to be taken into consideration. Many engineers work in service-oriented businesses rather than in the more traditional product-oriented businesses. Language skills as well as presentation skills are required. And they depend obviously also on networking and computing tools that have appeared on the scene less than twenty years ago. Therefore a re-examination of the preparation that mechanical engineers receive in order accomplish these new requirements seems necessary. At European level also the accomplishment to the so-called Dublin descriptors is required. Many countries have adopted an accreditation system that reflects the needs of the European Higher Education Area, where already accreditation systems and formats in Engineering studies have been developed (as the EUR-ACE system). In the last years many efforts have been dedicated at PdM in order to analyze the actual European situation, to strengthen the links with the labour market, to introduce some innovating changes in the curricula, and finally to adopt the EUR-ACE accreditation system. In 2012 finally among others the course of ME at the PdM got the accreditation with a good score.

PRELIMINARY INVESTIGATION

Since year 2008 the ME course of PdM in cooperation with FPM has improved his links with industrial companies and institutions, in order to check the needs of the labor market, to evaluate the employability of the mechanical engineering alumni and finally to define a kind of ranking of competences. The first input was a survey performed with the regional institution Assolombarda that represents the enterprises of the Lombardy, one of the biggest industrial regions of Europe. The result of the survey indicated a trend in required competences, which were not covered nor trained in traditional curricula. Knowledge of foreign languages, team work abilities, project management abilities and critical thinking were some of the required skills that in traditional curricula were not trained at all. Regarding knowledge and specific skills even a surplus in university preparation with respect to the required level was found. Figure 1 shows with more detail some of the different aspects of the competences which were insufficiently covered by the university studies, as result of the Assolombarda survey.

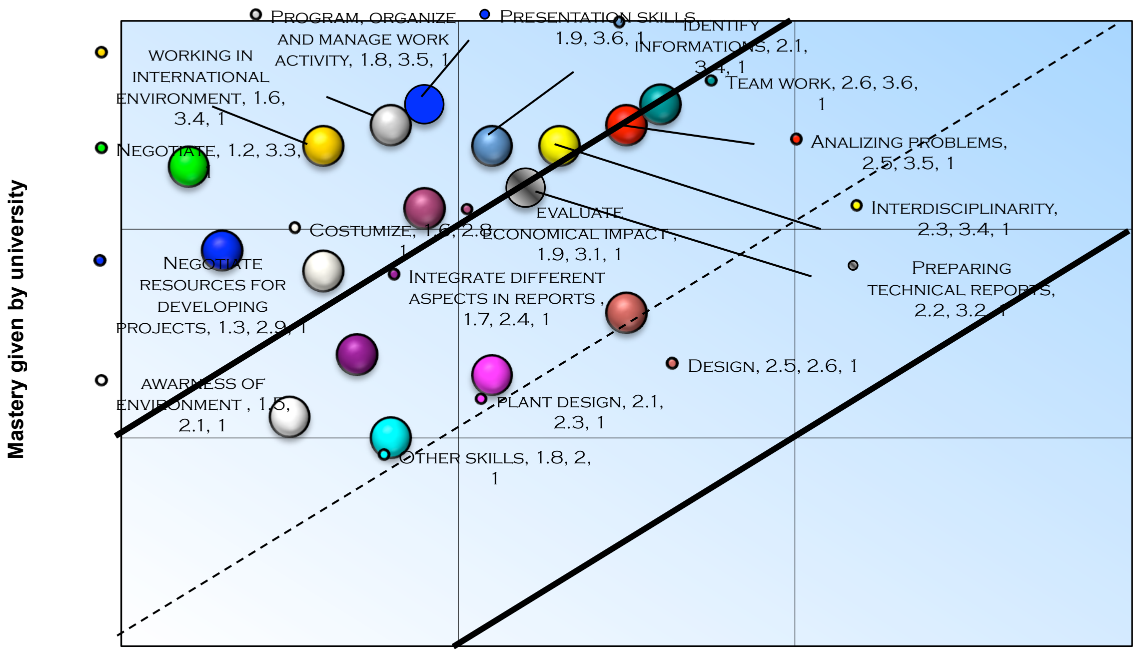

Figure 1 Levels of mastery required by job versus level of mastery furnished by university, as felt by alumni from PdM.

This was the first input for extending the research on European basis, and for starting a process for introducing some innovation in the traditional Mechanical Engineering curricula. From informal contacts with some leading European universities that offer mechanical engineering curricula, it resulted that some university had already introduced innovating teaching methods for covering the gap between the expectations of the market and the competences furnished by the university, utilizing the opportunity of the changes required by the Bologna process. In general all the contacted universities were aware of the changes in the engineering labour market and of the necessity of analyzing the situation. Also the position of industrial stakeholders, recruiting enterprises and of engineering associations is obviously required for getting a clear picture of the situation of Mechanical engineering education.

POSITIONING AMONG EUROPEAN UNIVERSITIES AND STAKEHOLDERS

In the frame of this process, the Fondazione Politecnico di Milano (has proposed and has leaded a Project, funded by the European Commission, on establishing an “Engineering Observatory on Competences Based Curricula for Job Enhancement” (acronym ECCE), in which the Mechanical Engineering Course (MEC) of the Politecnico was one of the academic partners. Other partners have been academics (university of Stuttgart Germany, university of Birmingham UK and university of Budapest Hungary) and professional organizations (like SEFI Société Européenne pour la Formation des Ingenieurs (France), CEFI Comité d’études sur les formations d’ingenieurs (Europe), Associaciò Catalana d’Enginyers de Telecomuniciò in Spain, DEKRA Akademie, biggest training enterprise in Germany).

The aim of the project was first to define with the aid of professional engineering organisations the expected learning outcomes (LOs) for engineering curricula (mechanical, civil and information technologies) which are suitable for actual engineering professional life. According to the Bologna process the studies in Italy and in many European countries are divided in two levels (bachelor and master), as shown in Fig. 2. The third level (PhD) has not been considered in the project.

The project has been developed using the level descriptors defined by the European Qualification Framework (see [1]). The Learning Outcomes (LOs) have been defined using categories of EUR-ACE Framework Standards (see website [2] for more information) for the accreditation of Engineering Programs, and additional specific details for different professional engineering courses (mechanical, civil, telecommunication and information technologies). The main objectives, preliminary and final results of the project can be found in the website [3] of the project. Detailed results of the project have been published also in [4]. For mechanical engineering education specific descriptors listed in Table I have been chosen.

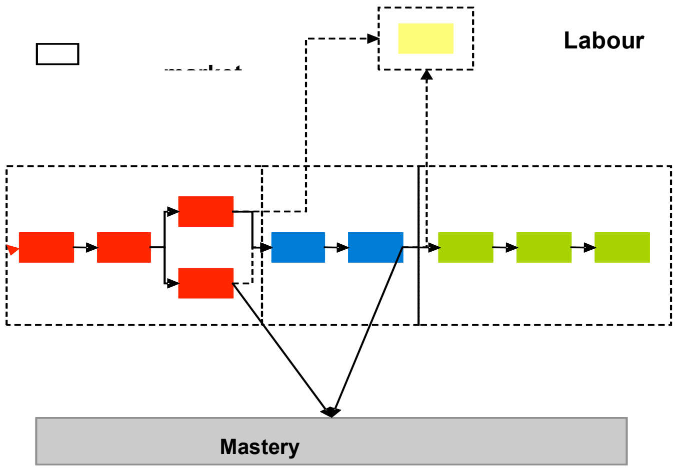

Figure 2 –Actual organization of engineering studies in Italy

Table I Descriptors for Engineering education adopted in the ECCE project.

Knowledge	Know and understand the fundamentals of mathematics, physics, and engineering sciences
Engineering analysis	Ability to use simple models for mechanical systems (machines or components) for analyzing its behavior, its performance, the arising stresses and strength of components
Engineering design	Ability to develop projects and design mechanical systems able to accomplish given requirements of motion, of performance, of strength and lifetime
Investigations	Ability to investigate by means of bibliographic research, experimental tests and suitable modeling
Engineering practice	Ability to integrate knowledge of different engineering fields

Surveys addressed to alumni have been launched in different countries or regions, aimed at defining for different categories of learning outcomes the levels of mastery (in a scale from 1 to 4): a) Obtained at the end of studies, b) Required in actual working position, c) Desired (by the alumni) at the end of studies. As an example the results for the category of Soft Skills and Management taken from survey addressed in France to all engineers are shown in fig. 3: a clear gap exists between levels reached at the end of studies and required or desired levels according to the opinion of alumni.

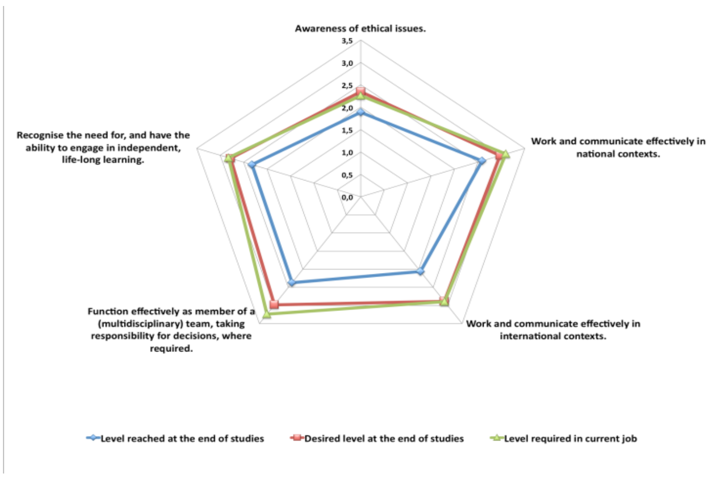

Figure 3 Levels of mastery in some soft skills as felt by alumni in France

The alumni were asked to define for each one of the 5 categories, and within each category for each descriptor, the level of mastery required in the actual job, the level reached at the end of the studies and the level alumni would have desired at the end of studies, scaled between 1 (no or limited understanding) and 4 (fully conversant).

The categories which show the maximum gaps between acquired levels and required levels are mainly Soft Skills, Management and Sustainability, but also Engineering Design, Investigation and Engineering Practice.

Regarding skills and competences the trends identified in the regional survey were definitely confirmed at European level, by all alumni surveys launched in Germany, UK, Italy and Hungary.

Surveys addressed to enterprises have also been launched, for defining similarly the levels of mastery in the selected learning outcomes: a) Required by the labour market, b) Found actually in the hired engineers

Similar results have been found in interviews with industrial stakeholders, and in surveys sent to enterprises. As an example the highest gaps between level reached and level required for Italian enterprises related to Mechanical Engineering Education resulted for the category of Management and Sustainability in i) ability to evaluate economic implications of different engineering solutions ii) ability to apply project management techniques iii) ability to apply risk assessment techniques, and for the category of Soft Skills in i) work and communicate effectively in international contexts.

It is interesting to point out that the EC (with the aid of professional agency Gallup) has made in 2010 a rather extensive survey involving 27 european countries , called “Employers’ perception of graduate employability” in which 7063 enterprises have been interviewed, asking among others: a) the importance of various skills and abilities for graduates (mainly in business, economics and engineering) b) opinions about skills and capabilities that graduates should have in the future (next 5-10 years). The results are shown respectively in Fig. 5 and 6. Complete results can be found in [5].

It can be seen that teamworking skills and communication skills, besides of course the sector specific skills, are felt as very important for professional life.

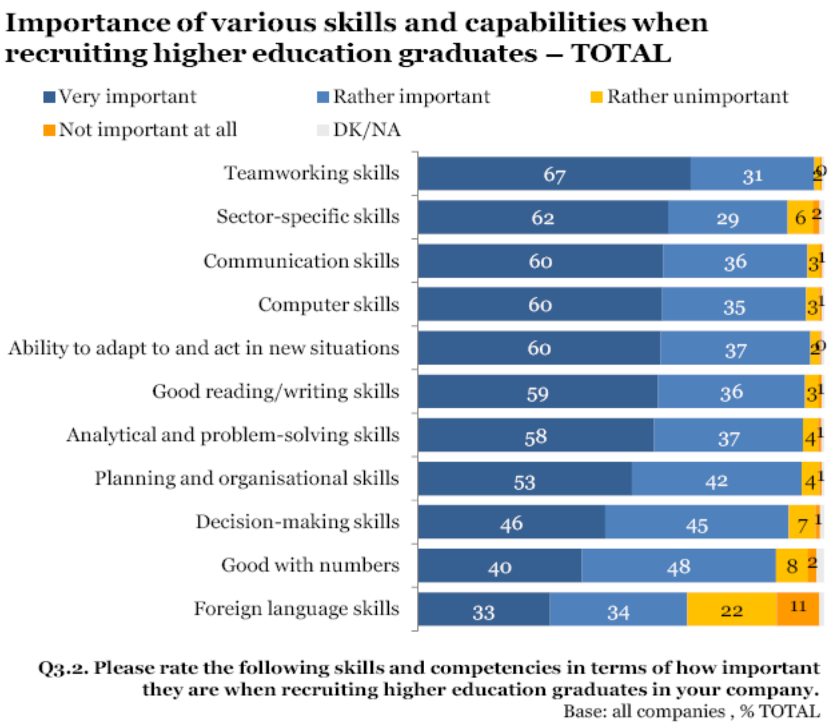

Figure 5 Importance of skills and capabilities according enterprises (from [5])

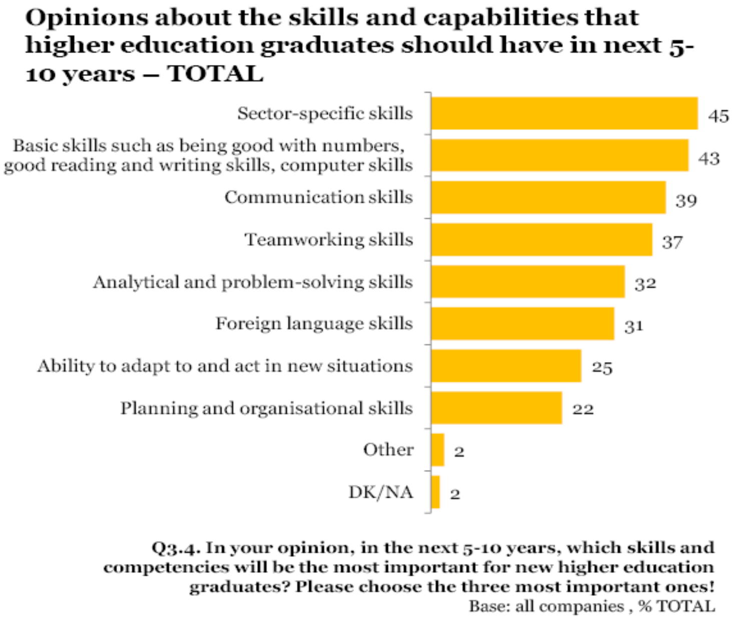

Figure 6 Skills required for the next decade according enterprises (from [5])

Taking account of all these results it was decided in the faculty of ME to start with some initiative to try to fill up some of the gaps mainly for training teamworking, communication skills, project management, and awareness of economic issues. Not all topics can be covered during university studies, but a feeling of professional life can be given to the graduates. Recognizing the need of changes the Industrial engineering faculty (to which the ME course belongs) decided to ask for support some members of the pedagogic faculty in Milano (CREMIT) for giving courses for young professors for increasing their knowledge about teaching methods and quality. All faculty members have been informed about the need to introduce some changes in the teaching approach for allowing training also in soft skills and project management. Finally it was decided to launch an experiment in the basic course of Applied Mechanics in the second year of the bachelor curriculum in Mechanical Engineering.

Experiments of innovating teaching methodologies

Despite difficulties in finding resources, the necessary space and time for introducing innovations, an experiment of introducing in the basic course of Applied Mechanics, at the second year of the bachelor degree, some improvement has been made, without changing the structure of the course, by changing simply the modalities of the development of the practical exercises where the theory must be applied.. Teamworking has been introduced, active learning has been fostered and guided, team work, project management, communication skills and critical thinking have been trained by means of the development of a project, its peer review and its final presentation. In such a way something resembling a working environment was simulated. Teams of 10 people were formed, a tutor has been assigned, initial, intermediate and final team meetings were programmed and milestones were set for the progression of the work. Team meetings and meetings with the tutor were supervised by the staff of CREMIT, in order to observe the interrelationship dynamics. The flow sheet of the experiment is shown in Fig.7.

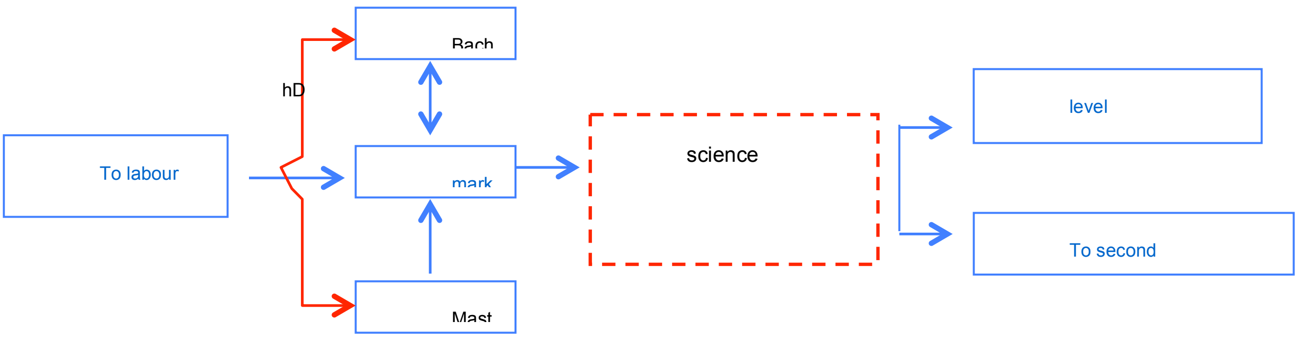

Figure 7 Organization of the experiment

The same topic (in the considered case it was “Energy Saving in Railway Transportation System”) was assigned, considering different scenarios of application. Regional, tram and metro network were assigned to the groups of 10 students, so that different technical solution could be obtained. The project was proposed in a form of a technical feasibility study. A general frame was given, with related support material, but the groups were free to integrate the information from other sources. The students had to search from different data sources the necessary information for completing the project, integrating technical basic knowledge from electrical engineering, mechanical engineering as well as from economic and management engineering. A key aspect was to limit the extra knowledge necessary for the development of the project, in order to enhance the added value related to the cooperation. Each group was assigned a technical supervisor (tutor), and could meet in a meeting room, at a predefined time table to discuss the status of the project and arising difficulties. Group members had to elect a team leader (coordinator) responsible for the work progress, and to assign specific tasks to each component of the group (such as search of support material, calculation, programmer, calculation reviewer, presentation and report preparation). Main part of the work was housework where the group members had to organize themselves working both in presence and/or interconnected by means of internet with different modalities. At the end of the activity the project had to be presented and discussed in a plenary session of all students, professors and supervisors. An exhaustive final report was required as well as a power point presentation showing main results with animation of the selected solution. Presentation skills were so trained. A vote increment ranging from zero to 15% was available according to the overall evaluation formed by the team internal peer review and the external evaluation of the project development (by professors, tutors and students of the other groups). This way also critical thinking and responsibility were trained. The project has been carried out on voluntary basis (ca. 20% of the total number of the students attending the 3 parallel courses of Applied Mechanics agreed to participate and 10 teams of 10 people each were formed). The experiment has finally been evaluated by all participants (students, supervisors and professors) by means of a questionnaire. During the first implementation of the experiment, the organization of team work, of the internal communication and the peer review and the final evaluation were supervised by professionals from pedagogic faculty CREMIT. A certificate signed by CREMIT responsible, the head of the mechanical engineering course and the course teacher, describing the project in terms of the following Dublin indexes: *applying knowledge and understanding*, *making judgements* and *communication skills* was delivered for all who gained a positive evaluation at the end.

CONCLUSIONS

The experience of a team working project for the second year of bachelor's course was carried out and positively evaluated by all parties, despite the involvement of a lot of extra work for students, supervisors, professors. Feed back from labor market is not yet available. A key aspect was to limit the extra knowledge necessary for the development of the project, in order put the emphasis more on the added value related to the cooperation and team working than on additional technical knowledge. Next step will be the systematic application of the experimented modalities to some teaching courses, in which a project can be developed. The experience gained on the first application and the feed-back from participants will be useful for the subsequent edition, aiming at finding a suitable compromise among different aspects like amount of required work and quality of the final work, number of participants and management of information flux (data, report, presentations) through e-platforms at disposal, organization of the necessary technical data, procedure, models and self learning capability. The final aim is to achieve a sustainable framework enabling to manage all the students of the second years' course of applied mechanics. For a proper simulation of a working environment it is considered mandatory to keep the structure of cooperative team working, and work progress organization in terms of milestones and peer reviewed final presentation.

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