SURVEY FOR PROGRAM EVALUATION OF AEROSPACE ENGINEERING AT POLITECNICO DI MILANO

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ABSTRACT

The paper presents the results of a survey performed at the Department of Aerospace Engineering of the Politecnico di Milano among alumni, also with leadership positions in industries and with faculty positions in universities. The survey is performed to evaluate the program so to assess the student skills, and to determine the appropriate levels of student proficiency according to the CDIO Syllabus. The results have been also used inside the Erasmus Mundus project "DOCET / EQF-CDIO Correspondence model for the recognition and enhancement of engineering degrees" (December 2008 – May 2010), that has built a correspondence model between CDIO syllabus and the new European Qualifications Framework (EQF).

KEYWORDS

Survey, Program evaluation, Learning outcomes, Curriculum design, CDIO, European Qualifications Framework (EQF).

INTRODUCTION

The paper presents the results of a survey performed at the Department of Aerospace Engineering of the Politecnico di Milano (Italy). The survey asks questions on the desired levels proficiency, on the program evaluation plan, and on program strengths and weaknesses. It is constructed so to be clear and concise, and consists of two parts.

The first part includes the questions reported on the example "Establishing the Desired Levels of Proficiency for Graduating MIT Engineers at the CDIO Syllabus Second Level" of the CDIO Syllabus [1-2]. The questionnaire asks the respondent to rate the received and the expected level of proficiency of a graduating engineer on a five point activity based scale, developed for this use at MIT. The second part consists of some specific questions related to the programs of the courses at the Politecnico di Milano. In this case, both quantitative and qualitative responses are solicited.

The survey includes alumni of various ages, also with leadership positions in industries and with faculty positions in universities. About 200 answers of the survey have been collected. The quantitative responses are used to guide the determination of the expected levels of students proficiency and to evaluate the existing programs. In particular, the average values give an indicator of the expected level of proficiency.

The survey data together with the qualitative comments will be used to define the new programs course that have to be implemented in the next years in the Italian Universities, according to the so called "270 system" given by the Italian Ministry of University.

The results of the survey are also compared with those ones obtained by similar surveys performed in the past at MIT, Department of Aero and Astro, and at Queen's University Belfast, School of Mechanical and Manufacturing Engineering, so to compare the proficiency expectations in countries with different cultures and different University systems.

The results has been also used inside the Erasmus Mundus project "DOCET / EQF-CDIO Correspondence model for the recognition and enhancement of engineering degrees" (December 2008 – May 2010) [3], that has built a correspondence model between CDIO syllabus and the new European Qualifications Framework (EQF) [4-6], mapping the CDIO into the eight EQF levels.

SURVEY

The survey has been prepared and made freely available online on the web site of the Department of Aerospace Engineering. E-mails have been sent to lists of alumni to let them know about this initiative, to ask them to fill in the survey and to advertise the initiative among the alumni of the Department.

The survey includes personal information to be filled at the beginning. In particular, some general information are asked, such as the time to job after degree, the knowledge of foreign languages, if the respondent has spent any time abroad, or has took a Ph.D. or any type of specialization courses after the degree in Aerospace Engineering at the Politecnico di Milano. The respondent could chose to write his/her name and e-mail address, or to fill the survey in an anonymous way. The questions related to the personal information are reported in Figure 1.

Personal info
Name:
Family name:
Year when you started to study at Politecnico di Milano:
Graduation year:
Graduation mark:
Details of any other specialization you got in the engineering field after the degree at Politecnico di Milano (type of specialization, University, year, graduation mark…):
How much time after graduation you got your first occupation:
Present occupation:
E-mail address:
Knowledge of foreign languages and their level:
Study experience at foreign universities (where and how long):
Industry stages (where and how long):

Figure 1. Personal info at the beginning of the survey

The survey is then divided in two parts.

The first part includes the questions reported on the example "Establishing the Desired Levels of Proficiency for Graduating MIT Engineers at the CDIO Syllabus Second Level" of the CDIO Syllabus (Figure 2) [1-2]. The survey asks questions for each topic in the Syllabus at the second level of detail (X.X-level). The questionnaire asks the respondent to rate the acquired and the expected level of proficiency of a graduating engineer. In particular, for each second-level Syllabus topic, respondents are asked to indicate the acquired and the expected proficiency level using a 5-point scale. Figure 3 shows the rating scale, that designate absolute level of competence acquired and expected in the activities or experiences of engineers. They are not relative measures of skills compared with other

graduating engineers. For example, *5 To be able to lead or to innovate in* requires a level of proficiency attained by experts in a particular discipline or area, so to indicate a life long learning.

The second part consists of some specific questions, reported in Figure 4, related to the programs of the courses at the Politecnico di Milano. In this case, both quantitative and qualitative responses are solicited.

PART 1: CDIO
2.1 ENGINEERING REASONING AND PROBLEM SOLVING
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY
2.3 SYSTEM THINKING
2.4 PERSONAL SKILLS AND ATTITUDES
2.5 PROFESSIONAL SKILLS AND ATTITUDES
3.1 TEAMWORK
3.2 COMMUNICATIONS
4.1 EXTERNAL AND SOCIETAL CONTEXT
4.2 ENTERPRISE AND BUSINESS CONTEXT
4.3 CONCEIVING AND ENGINEERING SYSTEMS
4.4 DESIGNING
4.5 IMPLEMENTING
4.6 OPERATING

Figure 2. CDIO Syllabus (X.X-level)

1 To have experienced or been exposed to
2 To be able to participate in and contribute to
3 To be able to understand and explain
4 To be skilled in the practice or implementation of
5 To be able to lead or innovate in

Figure 3. Level of proficiency

PART 2: Student career
General satisfaction about the chosen degree
Most important disciplines from the working experience
Evaluation of teaching methods
Evaluation of examination methods

Figure 4. Questions of the survey related to student career

ANALISYS OF THE ALUMNI

A total number of 215 alumni answered to the survey in a time period of about six months. It is not a high number, but it is already significant to be able to perform some analyses of the obtained answers. The number of alumni is reported in Figure 5 divided for graduation year. It is evident that the highest number of answers is obtained from alumni graduated in the recent years.

Among the 215 alumni that completed the survey, male alumni were 93% and female alumni 7%. The very low percentage of female reflects the low percentage of female students in Aerospace Engineering at the Politecnico di Milano. About 29% of them are employed in either aircraft or space companies, 17% are working in universities (most in aerospace engineering departments; Ph.D. students and temporary researchers are included), while a rough half of alumni (52%) is employed in industrial areas other than aerospace.

The survey has shown also that more than 80% of the alumni found an employment in less than 6 months after the graduation, as reported in Figure 6.

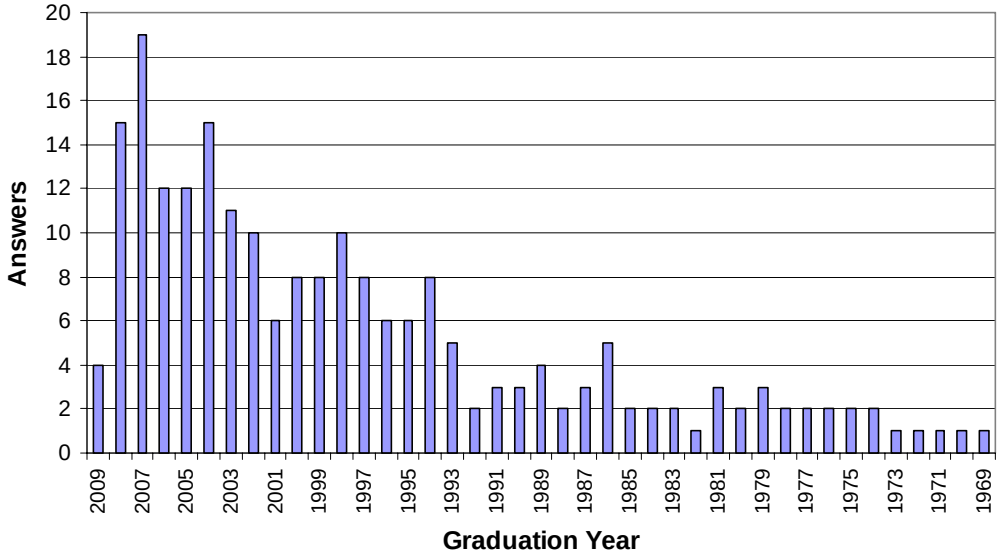

Figure 5. Graduation year of the alumni

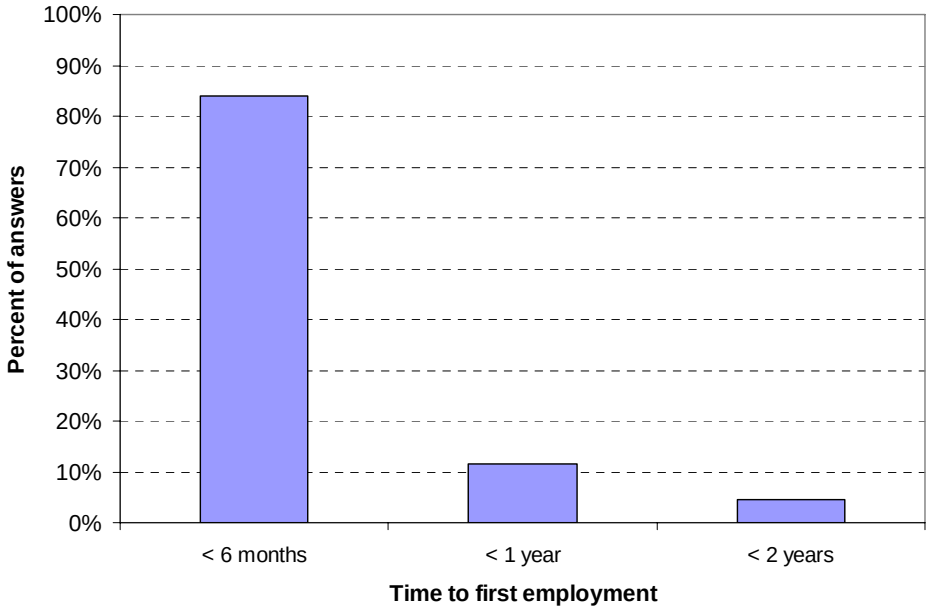

Figure 6. Time to first employment

The survey contains also questions regarding study period at a foreign university, stage by an industry or specialization obtained after the graduation. The answers are reported in Figure 7. It is possible to note, that about 20% of the alumni had a study period at a foreign university. More than 30% had a stage at an industry, and more than 30% had a specialization after graduation.

Figure 8 reports the answers related to the general satisfaction about the chosen degree. The question is divided in two parts: the satisfaction at graduation and the satisfaction at the time of the survey completion. It is possible to note that only 45% percent of alumni was highly satisfied about the chosen degree. In any case, this satisfaction slightly decreases in the years after the graduation for alumni with positive satisfaction level (high and average) while, on the contrary, it slightly increases for alumni with negative satisfaction level (sufficient and poor) at the graduation time. The current average satisfaction level (with a score ranging from 1, the "poor" answer, to 4, the "high" one) is 3.2 against 3.3 just after the graduation.

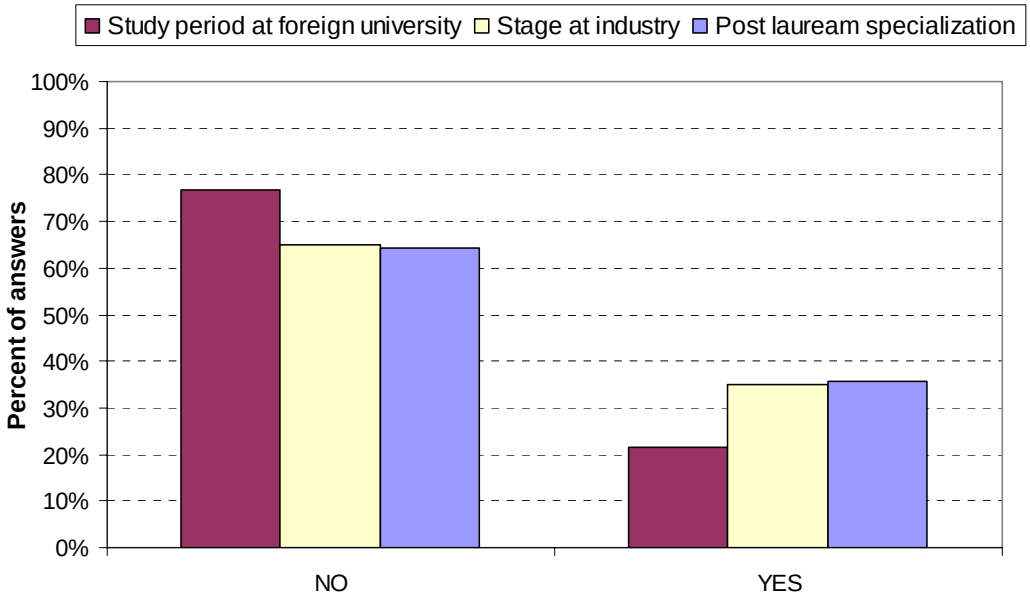

Figure 7. Study by foreign university, stage by industry or specialization

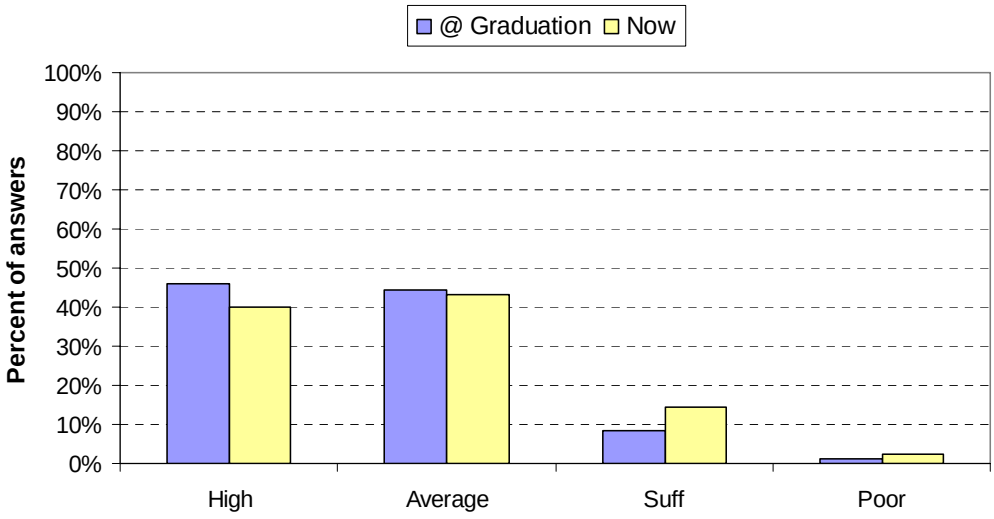

Figure 8. Satisfaction level

SURVEY RESULTS

Figure 9 shows the results of the survey regarding the level of proficiency for the CDIO Syllabus topics. The results are divided according to the acquired and the expected level of proficiency.

The alumni evaluated higher the expected levels of proficiency with respect to the acquired ones. An examination of Figure 9 reveals that in the comparisons of expected proficiency, *Personal Skills and Attitudes* (2.4), *Professional Skills and Attitudes* (2.5), *Engineering Reasoning and Problem Solving* (2.1) and *Communications* (3.2) are the most highly ranked topics, with proficiency level between 3.5 and 4. They are immediately followed by *Experimentation and Knowledge Discovery* (2.2), *System Thinking* (2.3), *Multi-Disciplinary Teamwork* (3.1) and *Designing* (4.4) that present a proficiency level around 3.5. *External and Societal Context* (4.1) and *Enterprise and Business Context* (4.2) are the two topics that were lower rated.

The expected levels of proficiency were evaluated also in terms of differences among the different answers. The scatter of expected level of proficiency is reported in Figure 10.

An evaluation was also performed to consider the expected level of proficiency for alumni graduated before 1995 and after 1995. The results are reported in Figure 11. The alumni graduated after 1995 constantly answered higher level of proficiency for all the CDIO Syllabus topics. It is not clear if it is due to higher expectation or to the lower number of answers for alumni graduated before 1995.

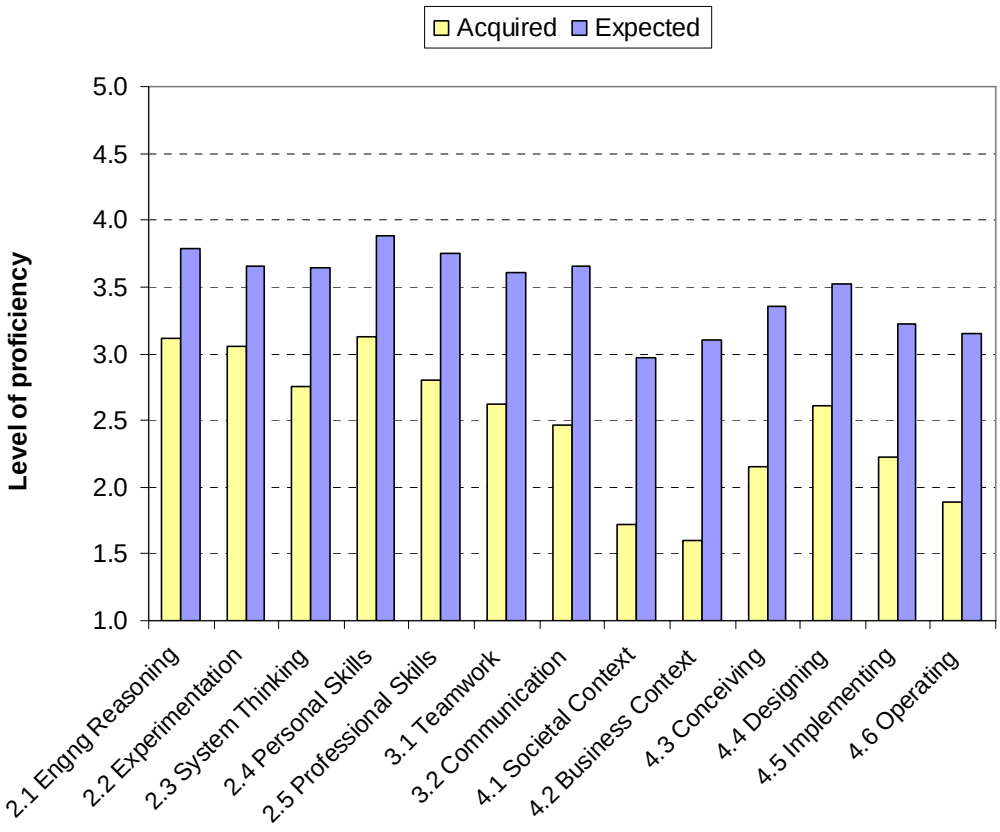

Figure 9. Acquired and expected level of proficiency

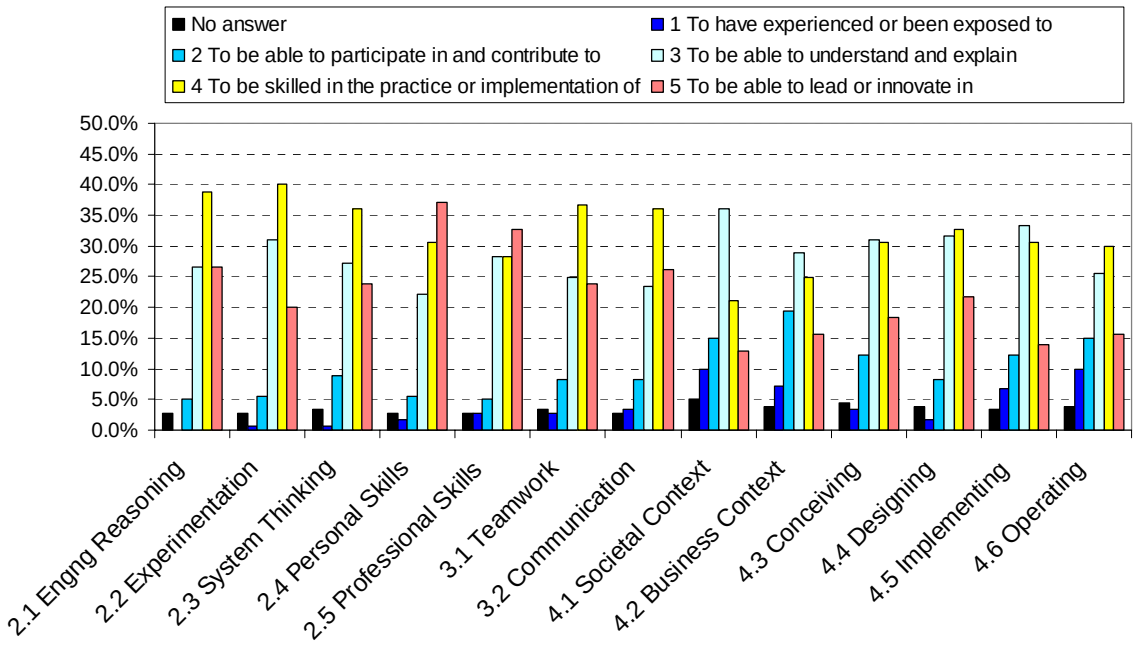

Figure 10. Scatter of expected level of proficiency among the different answers

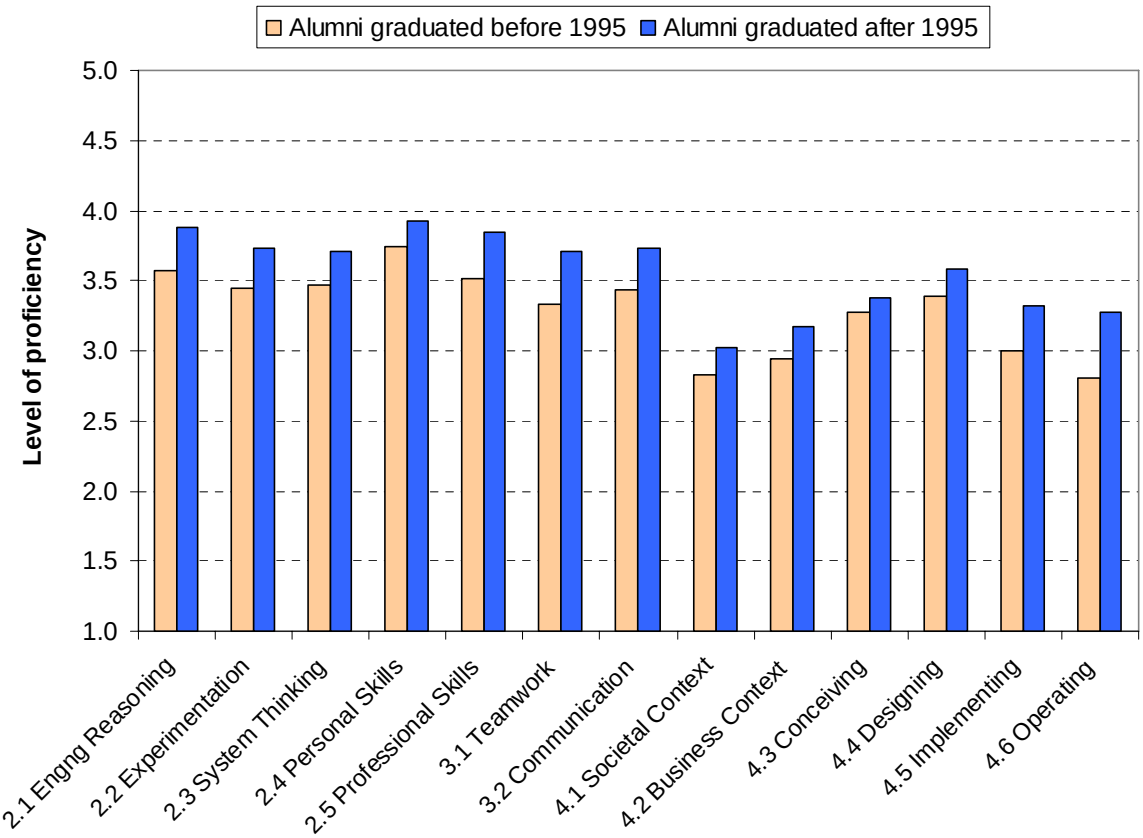

Figure 11. Expected level of proficiency for alumni graduated before and after 1995

The results were also evaluated considering the male and female alumni, as shown in Figure 12. It is possible to note that the female alumni have usually lower expected level of proficiency respected to the male alumni, except for *Engineering Reasoning and Problem Solving* (2.1), and for *Conceiving and Engineering System* (4.3), *Designing* (4.4), and *Implementing* (4.5).

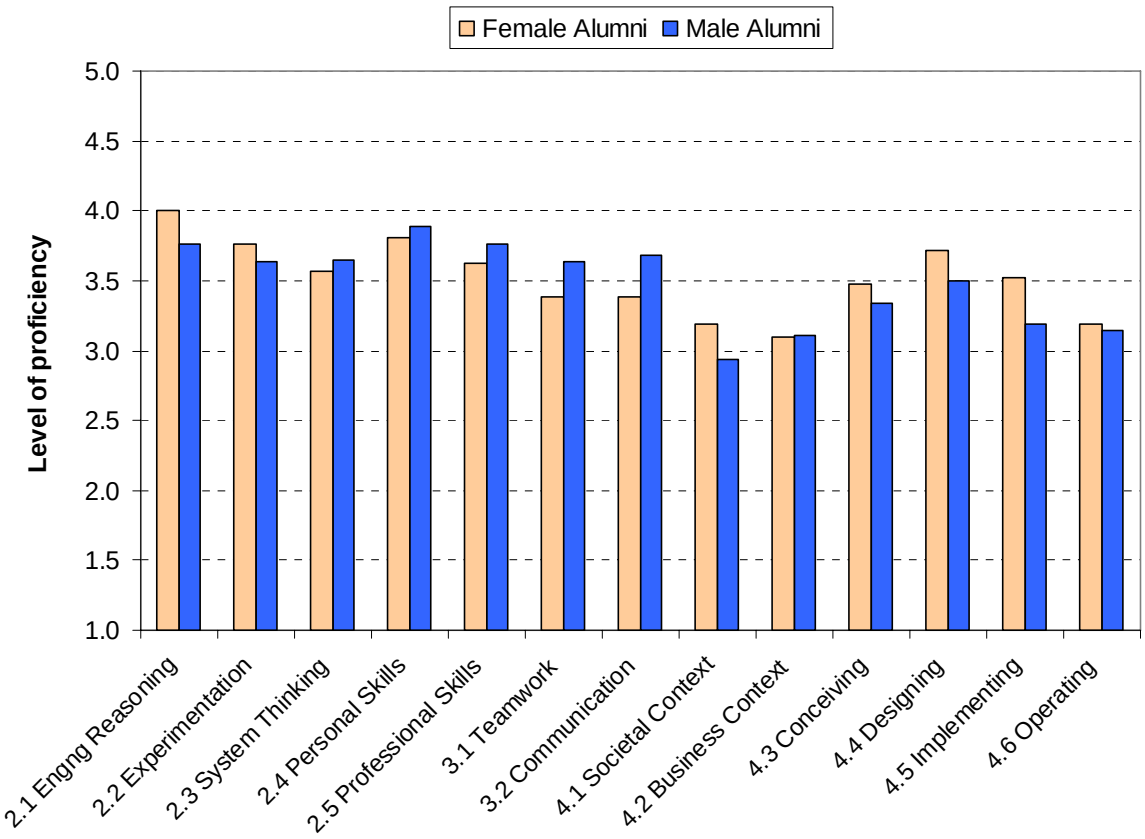

Figure 12. Expected level of proficiency for male and female alumni

The results of the survey are finally compared with those ones obtained by similar surveys performed in the past at MIT, Department of Aero and Astro, and at Queen's University Belfast, School of Mechanical and Manufacturing Engineering, reported in [2]. In this way, it is interesting to compare the proficiency expectations in countries with different cultures and different university systems. The results are reported in Figure 13.

The agreement across Universities is, in general, very good for all topics. The expected level of proficiency is higher for all topics at Politecnico di Milano. Major disagreement occur for *System Thinking* (2.3), *External and Societal Context* (4.1) and *Enterprise and Business Context* (4.2), as there is a considerably higher expected level of proficiency especially compared to MIT program.

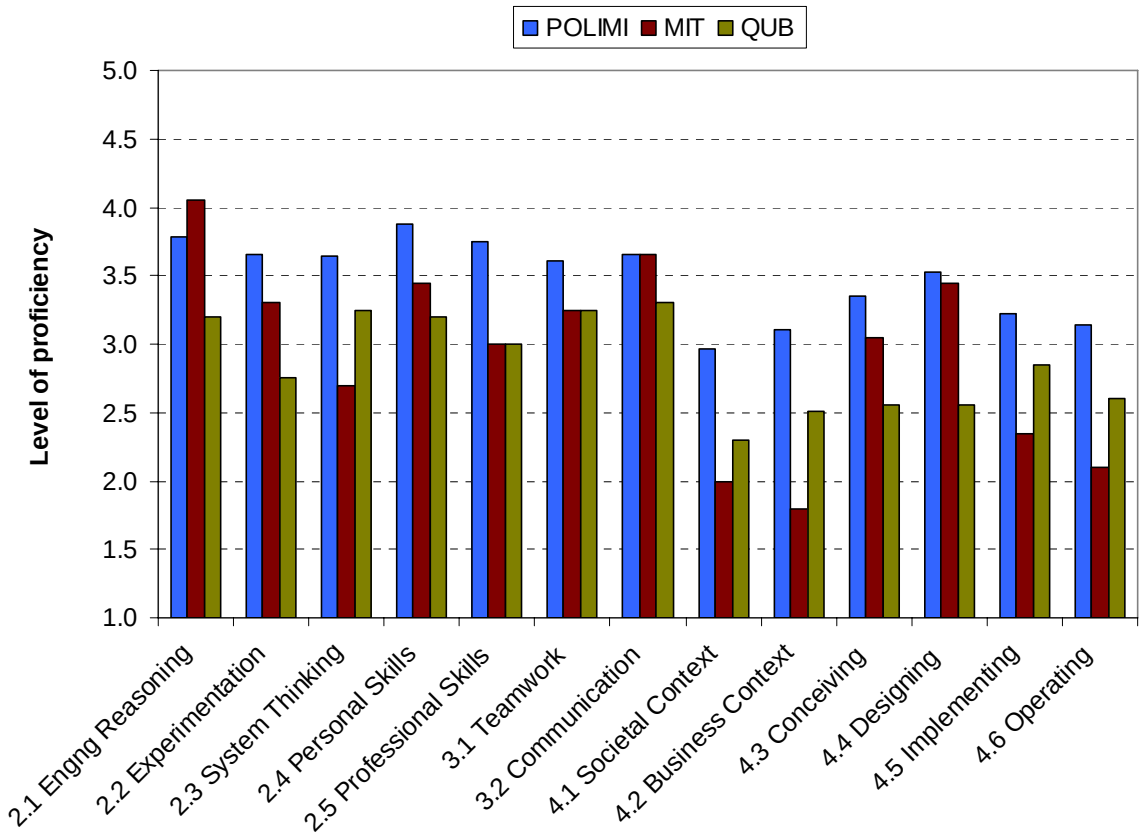

Figure 13. Comparison of results for alumni of Politecnico di Milano, MIT and Queen's University Belfast

EQF-CDIO CORRESPONDENCE MODEL

The new *European Qualifications Framework* (EQF) [6] aims to provide a reference system to build qualifications readable across Europe. The EQF has been introduced as "a common European reference framework which links countries' qualifications systems together, acting as a translation device to make qualifications more readable and understandable across different countries and systems in Europe. It has two principal aims: to promote citizens' mobility between countries and to facilitate their lifelong learning".

The EQF introduces 8 reference levels, spanning the full scale of qualifications acquired in general, vocational as well as academic education and training, from basic levels (e.g. Level 1 for school leaving certificates) to advanced levels (e.g. Level 8, nominally Doctoral degrees). Each level is described in term of learning outcomes, defined as "a statement of what a learner knows, understands and is able to do on completion of a learning process".

Learning outcomes are specified in the EQF in three categories:
- *Knowledge* (K), described as theoretical and/or factual;
- *Skills* (S), described as cognitive (involving the use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments);
- *Competence* (C), described in terms of responsibility and autonomy.

Figure 14 shows the descriptors provided by the EQF and indicating, for each level, “the learning outcomes relevant to qualifications at that level in any system of qualifications”. However the levels the European Commission directly relates to the Framework for Qualifications of the European Higher Education Area range from 5th to 8th, where “each cycle descriptor offers generic statement of typical expectations of achievements and abilities associated with qualifications that represent the end of that higher education cycle”.

The Erasmus Mundus project “DOCET / EQF-CDIO Correspondence model for the recognition and enhancement of engineering degrees” (December 2008 – May 2010) [3] has built a correspondence model between CDIO syllabus and the EQF, mapping the CDIO into the eight EQF levels.

The analysis, carried out inside the DOCET project, has shown that the EQF suggests three main dimensions to characterize different levels of learning outcomes: the *Autonomy and Responsibility* to be demonstrated in accomplishing tasks or performing various activities; the *Context* in which Knowledge, Skills, and Competencies are applied to/in; a set of *Action Verbs*, expressing the ability to apply Knowledge and Skills, and to demonstrate Competencies. The guidance to identify a full list of Knowledge/Skill/Competence areas that every engineer should master has been taken inside by the CDIO Syllabus at X.X level, also because these outcomes offer a set of goals not only for the undergraduate engineering studies but also in a lifelong learning perspective.

The Action Verbs have been used to mainly describe the learning outcomes. In particular, a correspondence has been developed among the Action Verbs extracted from the EQF and a subset of the Action Verbs used in CDIO and taken from Bloom’s taxonomy [7]. The starting point for establishing this correspondence has been the five point Bloom scale used also in the survey. On this scale, level 1 is called “Exposure”, which corresponds to no Bloom level. CDIO level 2 is Knowledge and level 3 is Comprehension. Level 4 combines Application and Analysis, while level 5 similarly merges Synthesis and Evaluation. The correspondence model EQF-CDIO based on the chosen Action Verbs is shown in Figure 15.

It can be noted that, in order to avoid confusion, there is no verb that is shared by two EQF levels. In detail, EQF level 8 draws its verbs exclusively from the “stronger verbs” of Bloom Synthesis and Evaluation (CDIO level 5). EQF level 7 gets its verbs from some of the “weaker” verbs from CDIO/Bloom level 5 plus some of the “stronger” verbs from CDIO/Bloom level 4, in order to place it between 4 and 5 on the CDIO/Bloom scale. Likewise for EQF level 5 using verbs from CDIO/Bloom levels 3 and 4. This list of Action Verbs has been then used in the DOCET project to detail tables and examples of learning outcomes.

The expected level of proficiency obtained by the survey at the Department of Aerospace Engineering at the Politecnico di Milano has been compared to the EQF levels, thanks to the EQF-CDIO correspondence based on the Action Verbs. Even if it is a matter of fuzzy logics, due to the scale and, especially, to the effects of the individual interpretation of questions and possible answers, some interesting considerations can be drawn.

It is possible to note that for most of the CDIO Syllabus topics the expected level of proficiency is between 3 and 3.5, corresponding to EQF level 5. For the topics with expected level of proficiency between 3.5 and 4 the EQF level is equal to 6. Only an expected level of proficiency higher than 4 would correspond to a EQF level 7, while EQF level 7 would nominally correspond to a Master degree, that is the degree of the alumni of the survey.

The EQF descriptors seem consequently too ambitious when compared to the actual situation and also to the expected level of proficiency. Besides, a full correspondence is not evident between the expected levels of the European Higher Education Area and the corresponding EQF levels.

EQF Level	Knowledge	Skills	Competence
8	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields.	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice.	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research.
7	Highly specialized knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research. Critical awareness of knowledge issues in a field and at the interface between different fields.	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to integrate knowledge from different fields.	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches. Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams.
6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles.	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialized field of work or study.	Manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or study contexts. Take responsibility for managing professional development of individuals and groups.
5	Comprehensive, specialized, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge.	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems.	Exercise management and supervision in contexts of work or study activities where there is unpredictable change. Review and develop performance of self and others.
4	Factual and theoretical knowledge in broad contexts within a field of work or study.	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study.	Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change. Supervise the routine work of others, taking some responsibility for the evaluation and improvement of work or study activities.

Figure 14. EQF descriptors (levels 4 – 8)

EQF Level	CDIO 5 Level Scale					
	2	3	4		5	
	Bloom Verbs					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
8					Create Synthesize Improve	Evaluate
7				Appraise	Revise Propose Formulate Plan Design Manage	Critique Defend
6			Select Apply Conduct Execute Demonstrate	Analyze		
5		Classify Discuss Interpret	Utilize Prepare Practice	Compare		
4		Identify, Explain Locate, Report	Employ			

Figure 15. EQF-CDIO correspondence based on Action Verbs

CONCLUSIONS

The results of a survey performed at the Department of Aerospace Engineering of the Politecnico di Milano are here presented. The survey was performed to evaluate the program so to assess the student knowledge and skills, and to determine the expected levels of student proficiency according to CDIO Syllabus. It has been conducted among the alumni, also with leadership positions in industries, as well as with faculty positions in universities.

The results have been used also inside the Erasmus Mundus project “DOCET / EQF-CDIO Correspondence model for the recognition and enhancement of engineering degrees” (December 2008 – May 2010), that has the aim to build a correspondence model between CDIO syllabus and the EQF.

The survey data together with the qualitative comments will be used to design the new programs course that have to be implemented in the next years in the Italian Universities, according to the so called “270 system” given by the Italian Ministry of University. The program in Aerospace Engineering at the Politecnico di Milano will be built taking into account the requirements of the EQF, and will be adjusted according to the specific needs of its graduates and of the stakeholders.

ACKNOWLEDGEMENTS

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Biographical Information

Chiara Bisagni received her Master’s Degree in Aeronautical Engineering at Politecnico di Milano in 1993, and her Ph.D. in Aerospace Engineering at Politecnico di Milano in 1997. In 1998, she was EU Research Assistant at DLR in Braunschweig (Germany) through a TMR Marie Curie Research Training Grant of the Training and Mobility of Researchers Program of the EU. From 1999 to 2006 Chiara Bisagni was Assistant Professor, and since 2006 she is Associate Professor in Aerospace Structures and Materials at the Department of Aerospace Engineering of Politecnico di Milano. In 2006/2007 Chiara Bisagni was Visiting Associate Professor in the Department of Mechanical Engineering of the Massachusetts Institute of Technology (MIT), USA, as a holder of a Fulbright Grant.

Gian Luca Ghiringhelli received his Master’s Degree in Aeronautical Engineering at Politecnico di Milano in 1980. From 1984 to 1998 he was Assistant Professor and from 1998 to 2002 he was Associate Professor at the Department of Aerospace Engineering of Politecnico di Milano. Since 2002 he is Full Professor. Gian Luca Ghiringhelli is Head of the Program Course for the degrees in Aerospace and Aeronautical Engineering.

Sergio Ricci received his Master’s Degree in Aeronautical Engineering at Politecnico di Milano in 1986, and his Ph.D. in Aerospace Engineering at Politecnico di Milano in 1989. From 1992 to 2003 Sergio Ricci was Assistant Professor, and since 2003 he is Associate Professor at the Department of Aerospace Engineering of Politecnico di Milano. Since 2007 he is Director of the Ph.D. course in Aerospace Engineering.

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