Chapter 26

Competences Required by Industry from Early-Career Engineering Graduates – Developing Management & Leadership Skills in Engineering Education

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A survey was conducted with the emphasis on the requirements of today's industry concerning graduates from Bachelor's and Master's engineering programs. By means of a standardized questionnaire combined with expert interviews held with over 25 leaders from typical companies (different size, field of industry) a portfolio analysis has been developed showing the importance of approximately 50 competence criteria from an industry perspective. All together over 6000 answers have been evaluated. The survey led to a gap analysis revealing the major deviations between expected/required skills and actual performance of the engineering graduates with a maximum of three years' industry experience. Based on the findings a program for the education of engineering students at both Bachelor's and Master's level has been developed.

THE NEED FOR MANAGEMENT AND LEADERSHIP EDUCATION IN ENGINEERING PROGRAMS

As globalization and competitive pressure steadily increase, there is a growing demand for engineers who don't just have excellent competence in their field of specialization but also general competences in the area of key skills, business administration, management & leadership. The following list of comments is directly quoted from a key-note speech from K. Ayadi at the 2007 iNEER conference in Coimbra, Portugal:

- "We need engineers with great minds, and great ideas, able to act as leaders not simply followers and executors of work directed by others."
- "Do engineers have the potential to be leaders? Are they trained to be leaders? This ability is a derivation of interpersonal communication, problem-solving and conflict management skills."
- "Successful leadership is what separates successful projects from failures. Leadership failure is one of the top reasons for overall business failure: 40 percent of projects fail because of lack of leadership (World Bank)."
- "Reinvent education at all levels to boost creativity and innovation."
- "We have to admit that only a few engineers have succeeded in becoming leaders in their respective working areas: Engineers tend to focus on 'details' and not on the big picture."
- "Changing engineers' attitudes and behaviors require the change of education paradigm: Education in many countries remains to some extent dominated by an information based curriculum and a teaching style which doesn't favor questioning, exploration and autonomous learning. Success in today's knowledge-based economy requires that graduates are educated on the basis of critical thinking and problem solving approach -> Rethink engineering education."
- "Several studies carried out in many countries have proven that there still exists a gap between the range of skills that graduates are equipped with and the skills and qualifications that are sought after by employers."

While hard technical skills are important, there has been increasing demand from industry in recent years for their employees to have broader skills [1]. Hasbullah and Sulaiman [2] cited a survey conducted in 1996 which stated that more than two thirds of 1400 interviewed CIOs rated soft skills as very important.

A similar emphasis is placed by various authors stressing the importance of major revisions in engineering curricula (e.g. [3], [4]) by reacting to the lack of soft skills that are basic for a professional. Also accreditation agencies reflect the industry's requirements by strongly considering soft skills in their guidelines. For example, the Accreditation Board for Engineering and Technology, which was renamed in 2005 simply as ABET, as the sole agency responsible for accreditation of educational programs in engineering in the United States, is reaffirming a set of "hard" engineering skills but is also introducing a set of "professional" skills as equally important including communicative or teamwork skills [5]. A comparable development is to be seen in German-speaking countries. ASIIN [6], the German equivalent of the American accreditation board, also highlights the importance of a holistic education by integrating technical, business and social aspects in engineering curricula.

In a first step lecturers from the Management Center Innsbruck (MCI) developed an integrated, multi-level education program in the area of soft skills [7]. This program is being successfully implemented now. A text book containing the major aspects of the program was published in 2008 [8]. As a second step, several courses related to the development of management and leadership skills were also implemented in the Bachelor's and Master's curriculum [9]. Specific aspects of the institution (MCI) are highlighted in the following subsection.

THE MCI EDUCATIONAL APPROACH

In 1994, the "Universities of Applied Sciences (UAS)" in Austria were integrated into the structures of the Higher Education (HE) Systems in the German-speaking countries [10]. A UAS degree program is "equivalent to but different from" a traditional university degree program and is characterized in particular by its close relations with trade and industry, its practical orientation and customer focus, a strictly organized program schedule and a highly service-oriented approach. Being organized on a private-law basis the MCI's UAS degree programs are officially accredited under public law. The degree programs at MCI include:

- Practice-oriented training and education at university level,
- A science-based approach,
- A strictly organized schedule with a limited program duration,
- An optional semester abroad at one of MCI's many partner universities,
- Close relations with trade and industry through lecturers, joint projects and internships,
- An officially accredited degree conforming to EU HE standards,
- Eligibility to take up doctoral degree programs at Austrian universities.

SURVEY

Introduction & Overview

A survey was conducted in order to find out the actual requirements of today's industry concerning graduates from Bachelor's and Master's engineering programs. The emphasis of the survey was on improving/fine-tuning the current approach in teaching key skills in engineering programs. The survey was supported by the institute of strategic management at the University of Innsbruck. By means of a standardized questionnaire combined with expert interviews held with over 25 leaders from relevant companies a portfolio analysis was developed showing the importance of approximately 50 criteria from an industry perspective.

The companies that participated in the survey were from a broad range of industry sectors. The company sizes were as follows:

- 50 % over 5000 employees
- 25 % 500-5000 employees
- 20 % 50-500 employees
- 5 % less than 50 employees

All these companies recruit a significant number of engineers every year. All together these 30 companies hired approximately 1,000 engineers in the past three years (including Bachelor and Master engineering graduates from the MCI). Emphasis of the study was on the evaluation of the perception related to the competences of early graduates with an average attendance of less than three years in the company. The standardized survey was sent to various leaders from engineering departments as well as human-resource management. Approximately 100 questionnaires were sent out and ~ 80% were returned. The survey contained a quantitative part focusing on the evaluation of the following six competence categories:

1. Professional & Methodological Competence
2. Business Administration/Management Skills & Law
3. Leadership & Strategy
4. Self Management
5. Social Competence/Interpersonal Skills
6. Communication & Presentation

In addition, each criterion was subdivided in to 6-10 sub-categories. For each category the importance of the competence criterion and the average performance of the graduate were quantified. This led to a gap analysis showing the major deviations between required skills and actual performance. All together over 6000 answers were evaluated. Further more open questions allowed the participants to express their general perception of the strengths and weaknesses of engineering education mainly related to the German-speaking world.

Category 1: Professional & Methodological Competence

The radar chart in Figure 1 shows an importance – performance analysis of eight competence sub-categories related to "Professional & Methodological Competence". Using the Germanic convention, 1 indicates the best and 5 the worst.

By way of an illustrative example for interpreting radar charts, in Figure 1 the criterion "technical knowledge" is perceived as being very important (1.2 on a scale from 1…..5 -> thick line) whereas the actual average performance is seen as 2.1 (also on a scale from 1 being very good to 5 unsatisfactory - -> dots). The subcategories were listed/ranked according to the "importance criterion" in clockwise direction, starting with "technical knowledge" being the most important going down to "specialization" being less important. All of the following radar charts are to be understood in a similar fashion.

The major divergence between what industry requires and what universities deliver seems to be in the following areas:

- Transferable Skills
- Analytical Skills
- Street Smart – the ability to handle new situations

Industry is pretty much satisfied with the "technical expertise", which they consider as very important. Many interview partners said that a good general knowledge in the respective engineering field is more important than a high degree of "specialization". However, the capability to solve problems in a structured and solution-oriented way is perceived to be very important.

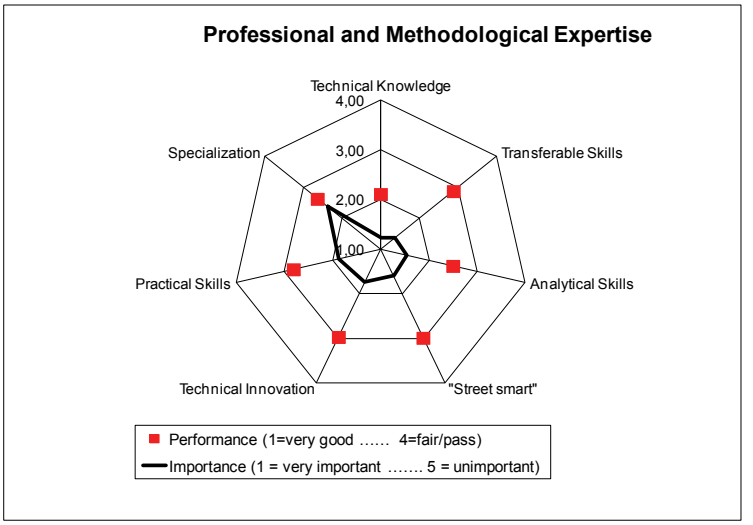

FIGURE 1
CATEGORY 1: PROFESSIONAL & METHODOLOGICAL COMPETENCE

Category 2: Business Administration/Management Skills & Law

The second category is related to all the non-technical aspects of engineering education. It includes the handling of business accounting, marketing and fundamentals in law, but also key skills in management such as project, process, quality or change management. Figure 3 shows that mainly project and process/quality management skills are considered as very important. The respondents clearly stated that marketing or human-resource

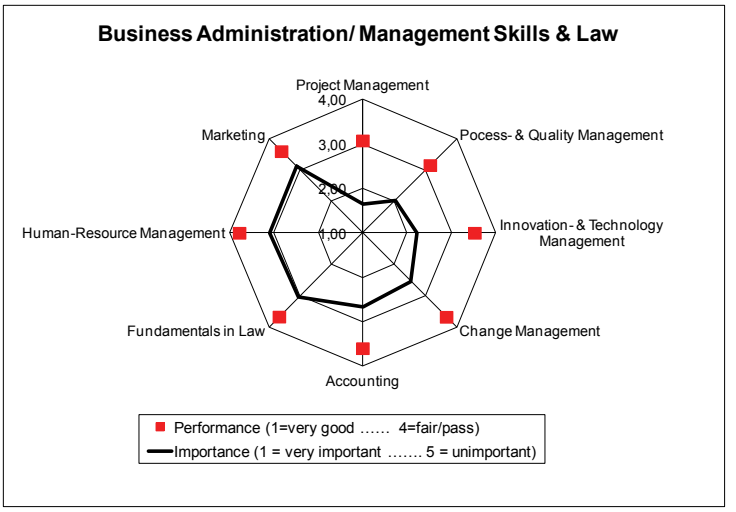

FIGURE 2
CATEGORY 2: BUSINESS ADMINISTRATION/MANAGEMENT SKILLS & FUNDAMENTALS IN LAW

management skills are in general not very important in the early career period. One person explicitly said that an engineer does not have to understand a balance sheet, yet he should be able to calculate investment decisions.

Category 3: Leadership & Strategy

While the second competence category was more related to management issues, the third category addresses leadership and strategy issues. Number 1 in the importance graph is related to leadership aspects in projects. Very often young engineers are confronted with project work and sooner or later are nominated as project leaders. There seems to be a major gap between what industry expects and how the young engineers actually perform. That is also valid for general leadership skills e.g. group leaders or department heads. Strategic issues such as strategy development, entrepreneurship or business planning were ranked as less important for young engineers that work in medium-sized or even big companies. A final remark should be made concerning the "development of ideas", which seems to be as important as leadership-related issues.

Many interview partners confirmed that leadership aspects are very often missing. The graduates seem to be well educated in technical aspects, yet they lack qualities such as communication, self management, problem solving, creativity as well as management & leadership competences.

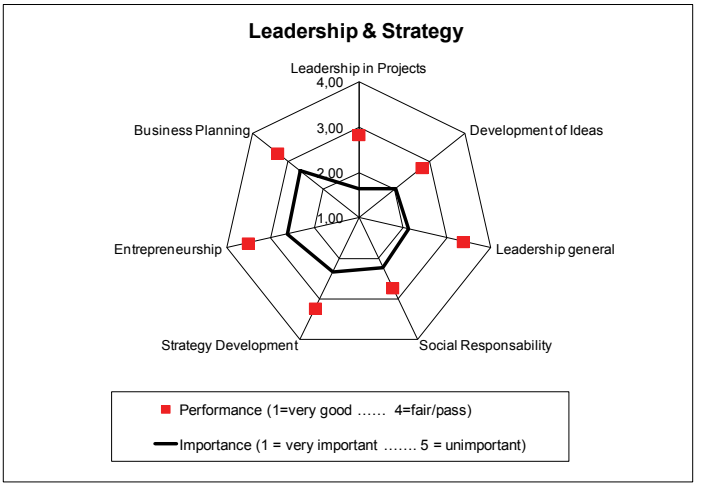

FIGURE 3
CATEGORY 3: LEADERSHIP & STRATEGY

Category 4: Self Management

The importance of self management seems to be completely underestimated. Compared to all the other criteria discussed so far, all the aspects of this category were considered between very important and important. Many young engineers are faced with the challenge of working on different projects at the same time. Time pressure is a major problem for many early graduates. Prof. Malik, one of the major management experts in

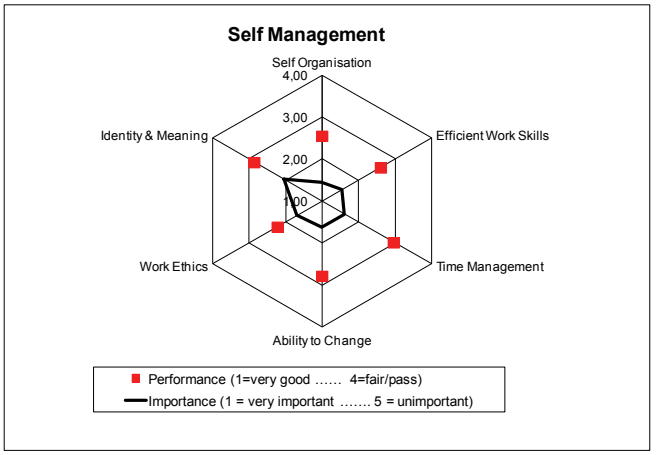

FIGURE 4
CATEGORY 4: SELF MANAGEMENT

Europe, said that self-management skills will be as important as "reading & writing" skills.

According to Figure 4 there is also a significant gap between actual and required performance, especially in the area of work skills, time management and self organization. Working in a globalized environment also requires a high capacity and ability to change. This is something that engineers need to adapt to as well.

Category 5: Social Competence/ Interpersonal Skills

In a very similar way to the issues highlighted in category 4, the importance of social competence and interpersonal skills seems to be completely underestimated. Also here, each sub-criterion is ranked between very important and important. The biggest gap seems to be related to team competence and the ability to handle conflicts. Although being ranked as less important, the inter-cultural competence of young engineers is perceived to be not very satisfactory.

Category 6: Communication & Presentation

Due to the fact that all the companies addressed do international business, language skills–especially "English"–are considered as most important. On the other hand, skills in other languages seem to be relatively unimportant, if communication in English is satisfactory. There seems to be a huge gap between required and actual competence related to rhetoric & presentation. Engineers tend to be focused on numbers but less on communication, yet a modern engineering curriculum should give enough room to foster these competencies. Also the ability to express oneself clearly in a written form seems to be very important.

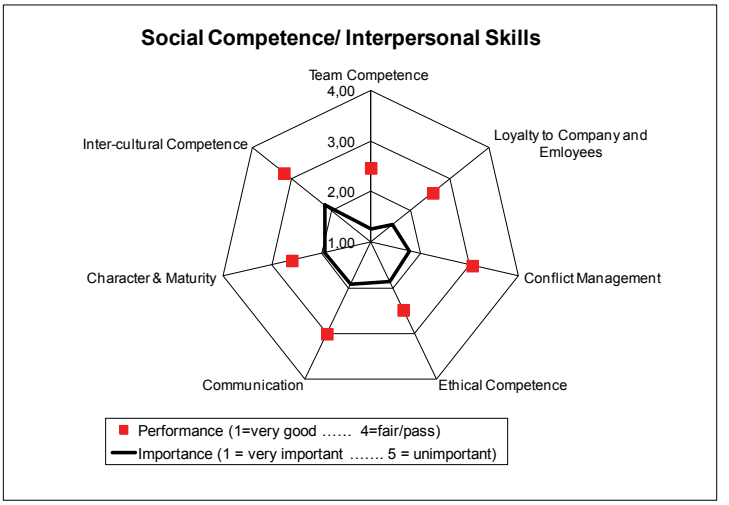

FIGURE 5
CATEGORY 5: SOCIAL COMPETENCE/INTERPERSONAL SKILLS

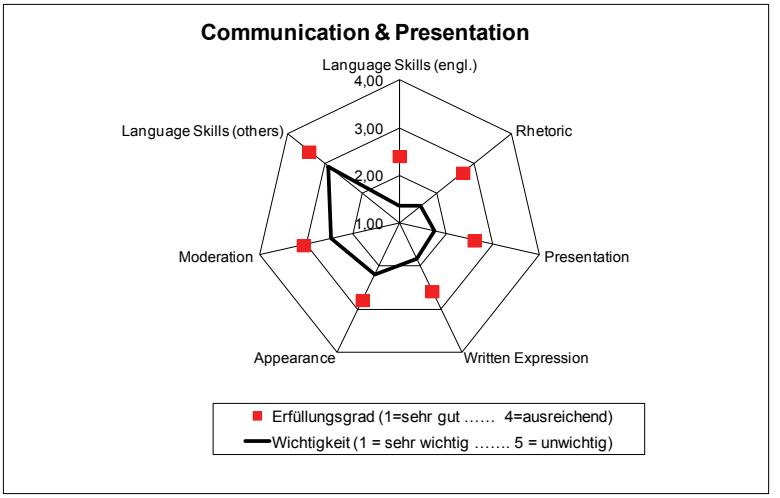

FIGURE 6
CATEGORY 6: COMMUNICATION & PRESENTATION

PROGRAM DEVELOPMENT

Based on the findings from the survey the current approach in teaching key skills at the MCI was reassessed. Originally it was designed by an interdisciplinary curriculum team including regularly employed full professors and external lecturers. The feedback from students and industry so far was quite satisfactory - however, a detailed scientific

analysis, regarding which skills are required and should be included in the curriculum, was lacking.

The survey, as well as the program development, was supported by two external lecturers with very broad experience in academia, business consulting and human-resource development. Dr. Bunz has a Ph.D. in Social Sciences and a degree in Business Administration & Economics. He conducted a study on the self-concepts and career paths of Germany's DAX 30 CEO's and board chairmen [11]. The results turned out to strengthen the diagnostic findings about the crucial aspects of successful leadership: although expertise is a prerequisite in any kind of professional career, becoming a successful leader encompasses far more than that. These additional factors are still not valued enough to be integral parts of today's programs for excellence.

R. Wiedenbrueg has a degree in electrical engineering from Univ. Aachen. He looks back to a 17 year industry career at Siemens, where he assumed the role as recruiting manager, being responsible for the Siemens early-career high-potential development program worldwide. The head of the development team and main author of this paper is also an engineer with a broad industry background and a post graduate MSc in Management.

The goals of the project were as follows:

- To review the current soft skills & management lectures for engineering students;
- To improve the current concept based on a detailed survey addressing the real shortfalls and needs;
- To develop a high-level study program for Bachelor & Master Programs;
- To continuously improve the educational material by taking into account market trends and the results of the student evaluation forms; and
- To award students a special certificate for having successfully completed the whole study program.

PROGRAM STRUCTURE

The program is based on the findings/outcome of the survey. The survey (including the interviews) clearly indicated that the competence gaps need to be addressed on multiple levels. Dealing only with personal aspects (e.g. social & soft skills) is obviously not enough. The student/graduate has to be prepared for the necessary organizational key skills such as project and process management. The other logical dimension is linked to the aspects, "efficiency – doing things right" and "effectiveness – doing the right things". Focus of the first aspect is on the operational level, the second aspect is tackling more the strategic side. These 2 dimensions form a 2 x 2 matrix shown in Figure 7. Each segment contains courses that are designed in such a way that the competence gaps are addressed in a reasonable manner.

Therefore the program consists of the following four modules. Each module includes three courses with an attendance of two days each. Taking into account the preparation and follow up times, each course is worth 1 ECTS credit, and therefore equivalent to 25 working hours. However, it is easily expandable by including additional reading material as well as a seminar report to increase the learning transfer. Hence each module (containing three seminars) could be worth 5 ECTS Credits. The authors recommend that

module 1 and 3 are allocated in the Bachelor Program whereas module 2 and 4 are more geared towards the Master.

All four modules sum up to a work load between 12 and 20 credits depending of the amount of time one university wants to invest in the development of key skills educations. In relation to a total work load of 300 ECTS for attaining a Master's in engineering, the ratio is less than 7 % of the total study time investment.

PEDAGOGICAL APPROACH/EDUCATIONAL OBJECTIVE

According to Marsch [12] "The graduate of the future is expected to exhibit a totally different range of skills from their forebears." This challenge can only be faced by a wide range of measures. The educational objective of the MCI engineering programs is to holistically equip the graduate with crucial competences such as technical, methodical and social competences in order to facilitate a better transfer from university to the business world. It can be said that at the MCI a general "entrepreneurial approach" is fostered in the engineering degree programs as well as a strong focus on transnational practice [13, 14]. The goal is to confront the student with non-technical skills in such a way that it also has an impact on the other engineering courses and modules. In Project Management for example, an introduction to the relevant aspects is given by a project management key expert during the two-day training course. This lays a solid foundation in theory (best of knowledge) and allows the effective and efficient transfer to the other engineering courses, where project management is needed. The same is true for the other courses/topics. Attendance in all courses is mandatory.

FIGURE 7
PROGRAM STRUCTURE

The seminars are taught by different professors, lecturers and business leaders. Each of them has a unique didactic and pedagogical approach using various methods such as

upfront teaching, personal reflection phases, teamwork, and case studies. Assessment methods are designed to meet the particular requirements of each module. These methods vary from 100% examination to 100% continuous assessment. Currently the balance amounts to approximately 70% examination and 30% continuous assessment.

Discussions among professors of the engineering program have indicated that the parallel approach of management training alongside the other engineering courses is a mean to increase the effectiveness of the other technical courses, where these skills are also needed.

It must be clearly stated that the program is not an add-on to the engineering curriculum but an integral part of it. In terms of the learning support, a blended learning setting is implemented and technically supported by integrated learning management and co-operation and communication tools that strongly support and ease the knowledge transfer between students and lecturers. This kind of an active teaching and learning co-operation is part of the general pedagogical self-image at MCI [15].

DEGREE OF NOVELTY

It is true that the development of generic, non-technical skills has been embedded in many engineering programs for at least 10 years [16]. A simple internet search shows that particularly in the English-speaking world many universities offer additional (optional) courses in engineering programs in order to address business issues for the engineering community. An outstanding example might be the Engineering and Business school at Aston University, which has run the very successful and award-winning Master's Engineering management program: MSc Supply Chain Management.

Also in the German-speaking world many academic institutions offer some training in the field of business administration & management. An investigation into the key skills course programs offered in engineering curricula of other German universities showed that there is a rather diverse collection of independent modules and courses.

The unique aspect of the MCI program, though, is the fact that three MCI lecturers with different backgrounds have worked together in order to developed a concise educational program in this field in the course of several months, which is currently becoming an integral part of the technical B.Sc/M.Sc at the MCI. The team-based development of these courses also helped to reduce work duplication and to cross-fertilize ideas and means between university and industry to make a significant impact on engineering education.

The literature review showed that at least in the German-speaking world, there is not yet a single textbook available that offers such a broad variety of aspects specifically addressed to the engineering community. Therefore, the program equips the engineering student/graduate with a basic expertise in general management, while consuming less than 7% of the total curriculum (ECTS of Bachelor's & Master's together).

OUTCOME, CONCLUSIONS, NEXT STEPS

Based on methodologies of Felder et al. [17], the education program is still in the implementation phase at the MCI. Several goals have been achieved so far:

- A core team of one full-time professor and two external lecturers from different backgrounds has been formed to develop and further improve the education concept, based on industry requirements. The discussions with engineering

students give a clear indication that the support and acceptance of these modules especially in the framework of the MCI is generally high.

- Managers and leaders of relevant companies appreciate the training concept and recognize the holistic approach of the Engineering program at the MCI. They value the contribution of this concept as an important part of the education of engineering students.
- A student evaluation review of about 68 seminars (~800 evaluation forms) showed excellent results. The average evaluation grade was 1.44 on a scale from 1 = very good – 5 = fail [18].

An ongoing (re-)assessment of the Management Education Program is necessary to further improve the programs.

Given that engineering education has evolved since its origins" [19, 20] and that it finds its strengths in being resilient and flexible, the authors express their confidence that this approach is a valuable contribution for future engineering education. The main thrust is thus on better equipping young engineers for the globalized and fast-moving world of the 21st century.

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