ELECTRONICS AND ELECTRICAL ENGINEERING
ISSN 1392 – 1215 *2010. No. 6(102)*
ELEKTRONIKA IR ELEKTROTECHNIKA

TELECOMMUNICATIONS SCIENCE

TELEKOMUNIKACIJŲ MOKSLAI

Mixed Integration of CDIO skills into Telecommunication Engineering Curricula

E. Sayrol, R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas, J. O'Callaghan, J. Pegueroles, E. Pla, L. Prat, G. Sáez, J. Sardà, C. Tallón
Escola Tècnica Superior d'Enginyeria de Telecomunicació de Barcelona,Universitat Politècnica de Catalunya. Barcelona Tech, Campus Nord UPC, ed B3,
c/Jordi Girona 1-3,08034 Barcelona, Spain, phone: +344016832. e–mails: elisa.sayrol@upc.edu, rbb@eel.upc.edu, ealarcon@eel.upc.edu

Introduction

At Telecom BCN, the School of Telecommunication Engineering of Barcelona at Universitat Politècnica de Catalunya (UPC), Barcelona Tech, we started three years ago the design of new curricula into the frame of the European Higher Education Area (Bologna process). The adaptation to the Bologna process has allowed us to perform an in-depth reorganization and to identify the appropriate learning outcomes.

Under a new strategic plan, we set up the main goals to design the new curricula. Learning outcomes from well-known models used in several universities in Europe and the United States (ABET, Tuning, CDIO,...) were analyzed. We compared them with the requirements established by our Institute of Science Education and the requirements for verification of academic qualifications set by the Spanish laws. Reports of industry representatives and public institutions were also taken into account [1].

In this paper, we first show comparisons among representative models of skills, including the ones that are mandatory in Spain and in our University. CDIO has been chosen as a paradigm for new curricula design and their syllabus have been fundamental to identify the learning outcomes of our study plans.

Afterwards, we will explain how ten generic skills have been chosen as a common characteristic of all our 4-year bachelor degrees. These generic skills at different levels of difficulty define skill pathways though the curricula involving all subjects. Every subject may contribute to the learning of several skills at a given level and actively contribute to develop and assess two of them. On the other hand, four specific project courses have been scattered along the curricula, at the second semester of each academic year to reinforce concepts and prepare students to work in a company or business environment.

Comparison of skills given by different frameworks

In order to choose a significant and reduced number of skills towards covering all aspects of the education of engineers we perform different comparison between different frameworks. Some of the skills are mandatory in our University and in our country, some others are very well-known across prestigious universities in Europe and the US.

Our comparison tables have its main focus in the second level of the CDIO syllabus [2] and are shown in Figures 1, 2 and 3. The following conclusions can be drawn.

Comparison of CDIO second level skills with UPC required skills. As shown in Figure 1, UPC skills [3] are restricted to the so-called soft skills, leaving the aspects related to the practice of engineering to the field of specific skills (content), different for every engineering discipline and therefore not included.

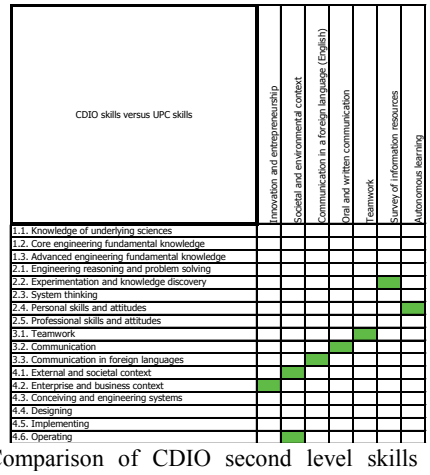

Fig. 1. Comparison of CDIO second level skills with UPC required skills. Common skills are indicated

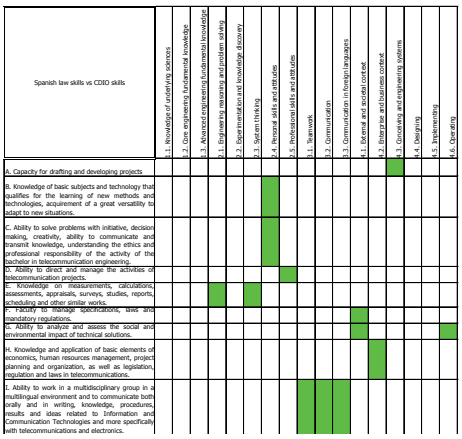

Fig. 2. Comparison of Spanish laws for telecommunication engineering curricula and CDIO second level skills

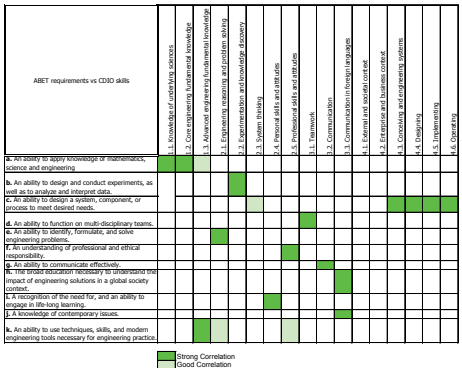

Fig. 3. Comparison of ABET requirements and CDIO second level skills [3]

However, other standards and recommendations emphasize common skills across all engineering studies. In any case, we observe that if the CDIO skills were chosen, UPC soft skills would be covered.

Comparison of Spanish laws for telecommunication engineering curricula and CDIO second level skills. Spanish bachelor degrees in engineering that lead to professional activities are regulated by law. In particular for telecommunications (electrical) engineering degrees [4] the laws specify some generic skills as well as some specific skills. Generic skills in this case include soft skills and some generic engineering skills. Specific skills are related to the traditional contents of curricula. Our goal in this case is to compare generic skills of the Spanish law requirements and the second level of CDIO skills. We see that CDIO again can cover these requirements with a more simple approach. CDIO goes beyond by considering skills like *System Thinking and Conceiving* and *Engineering Systems* that are not explicitly considered in the Spanish law. We also observed in another comparison, not included here, that UPC skills were insufficient to cover Spanish law generic skills.

Comparison of ABET requirements and CDIO second level skills. This comparison is reproduced here from [2]. Although these two frameworks are quite close there are some advantages in using CDIO. CDIO is more clearly organized and contains more level of details when implementation is required, providing measurable goals that are critical to curriculum design and assessment. ABET was also compared to Spanish law generic skills in our study. We also observed that *Enterprise and Business Context* skills are not so explicitly covered by ABET.

As a conclusion, CDIO skills, shown here in their second level for comparison, are quite convenient since they cover all aspects of engineering required by our University system and the Spanish law, as well as covering other well-know frameworks like ABET. Furthermore CDIO skills are clear and concise.

Definition of generic skills at Telecom BCN

Once CDIO was identified, the second step was to define a reduced number of generic skills as expected by our University.

The process we followed is summarized in Figure 4. CDIO generic competencies are grouped in two columns. A common block to all career tracks (left) that combined with specific skills on the central column, give rise to different engineering profiles. Orange continuous line ellipses indicate skills covered, although partially, by UPC requirements. Green dashed ellipses identify two groups [Engineering Reasoning and Problem Solving, experimentation, system thinking] and [Conceiving, Designing, Implementing, Operating] that should be addressed in order to cover all professional profiles.

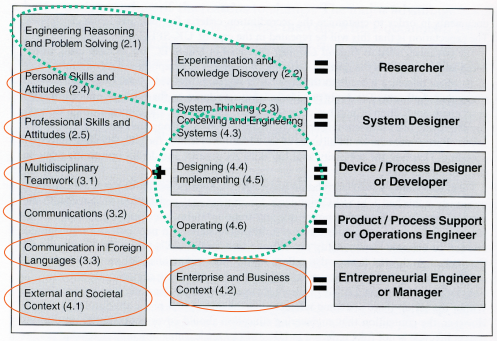

Fig. 4. Adapted from [3]. Combinations of generic skills that give rise to identifying distinct profiles partially covered by UPC skills (orange) and areas to be covered (green)

Thus, in addition to generic skills proposed by UPC:

1. Innovation and entrepreneurship;
2. Societal and environmental context;
3. Communication in a foreign language (English);
4. Oral and written communication;
5. Teamwork;
6. Survey of information resources;
7. Autonomous learning.

Three additional skills were chosen to be compliant with all frameworks:

8. Ability to identify, formulate and solve engineering problems;
9. Ability to conceive, design, implement and operate complex systems in the field of Information and Communication Technologies;
10. Experimentation and knowledge of instrumentation.

These three additional generic skills can be further described as follow:

8. Ability to identify, formulate and solve engineering problems.

Ability to pose and solve engineering problems in the ICT field with initiative, decision making and creativity. Ability to develop a method of analysis and problem solving systematic and creative.

9. Ability to conceive, design, implement and operate complex systems in the field of ICT.

Ability to cover the entire life cycle (conception, design, implementation and operation) of a product, process, system or service in the ICT field. This includes writing and project development in the area of expertise, knowledge of the basic materials and technologies, decision making, management of activities under the project, conducting measurements, calculations and assessments, management of specifications, regulations and mandatory standards, assessment of social and environmental impact of technical solutions, economic and material evaluation, human resources involved in the project, with a systemic and integrated perspective.

10. Experimentation and knowledge of instrumentation.

Ability to function comfortably in a lab environment in the ICT field. Ability to operate instrumentation and tools in the telecommunication and electronic engineering field. Understand and operate with manuals and specifications. Ability to assess the errors and limitations associated with measurements and simulation results.

The last skill could be considered included in the 8 and 9 but it was the desire of our faculty to keep explicitly one of the most positive aspects of our previous curriculum, conceived in 1992, which was the commitment to experimentation

All skills are defined in three levels of difficulty. Here we show an example for skill 8.

8.1 (basic level). Identify the complexity of the issues addressed in the different subjects. Properly raise the solution from a proposed problem statement. Identify different options for resolution. Choose an option, implement and identify, change if a solution is not reached. Come up with available tools or methods to verify if a solution is correct or at least consistent. Identify the role of creativity in science and technology.

8.2 (medium level). Identify, model and create problems from open situations. Explore alternatives for resolution, choose the best alternative according to a criterion. Manage approximations. Propose and implement methods to validate the usefulness of the solutions. Have a vision of a complex system and the interactions between its components.

8.3 (advanced level). Identify and model complex systems. Identify appropriate methods and tools to set the appropriate equations or descriptions associated with the models and solve them. Conduct qualitative analysis and approximations. Define the uncertainty of the results. Propose hypotheses and experimental methods to validate them. Establish and manage commitments. Identify and prioritize key components. Develop critical thinking.

The seven generic UPC skills in its three levels of achievement are described in [3].

Introducing generic skills in the Telecommunication Engineering Curricula

Once the generic skills are chosen the curricula structure is established. The following conditions are taken into account:

- No specific subjects devoted exclusively to generic skills are desired;
- It is recommended that each academic year, generic skills are simultaneously treated from different subjects;
- It is not advisable to overload subjects;
- It is advisable to assign at least one generic skill to each subject;
- Vertical coordination is required to deal with skill achievement by the students.

Thus, skills pathways were defined by involving all subjects. Every subject may contribute to the learning of several of the ten skills at a given level (basic, medium, advanced) and should actively contribute to develop and assess two of them. This approach is in accordance with various frameworks and in particular the CDIO initiative proposes to build an integrated curriculum, with the skills embedded in the subjects.

CDIO also proposes to insert different subjects along the curriculum exclusively devoted to projects (built-in experiences) in which, naturally, there are various skills, both personal and interpersonal, as well as specific engineering skills that are put into practice. In particular, it is recommended to carry out a specific subject in the first year of studies where an introduction to engineering and a first project help students to identify the context in which they will develop their training and properly focus on other subjects. It is, in short, to consider generic skills as a learning context of engineering and not its content, which will consist of the specific competences of the different subjects.

Thus, the curriculum includes in its structure a number of subjects devoted to develop projects that should not be seen as containers of skills but they must have a triple impact:

- Consolidate the learning of subject content to be pursued in parallel and above;
- Encourage the student;
- Working in the engineering context and, therefore, provide a framework to develop naturally most of the generic and specific skills.

Subjects devoted to projects ensure proper achievement of the objectives and provide an adequate conceptual basis at every academic level. They are reinforced with seminars on very specific aspects of project management, information management and teamwork. These seminars are spread throughout the curriculum within the subject project with the aim of putting the concepts into practice right away.

We then define the following groups of subjects.

1. Project subjects.

In the first year. Introduction to ICT Engineering. The main features are the following. It introduces the engineering discipline. It sets fundamental basis identifying tasks, skills and framework in engineering. It

motivates learning skills. Generic skills are first introduced such as oral and written communication, teamwork, introduction to CDIO. Training sessions in economics and business and a short project is addressed

During the second, third and fourth year. Basic Project in Engineering (second year), Advanced Project in Engineering (third year), Final Degree Project (fourth year). The main features are the following. They introduce complexity in a gradual way. They can fit all the skills that should be allocated and prioritized. Specific seminars are given (patents, conflict management, sustainability, etc.). Admits projects targeting diverse professional orientations: research, technical design of product, process or service, product and economic aspects.

2. Subjects with active methodologies:

Subjects that carry out active learning activities, laboratory (experimental), Cooperative learning; Problem based learning or case study; Short projects and work with oral presentations and written report

3. Subjects with a more "classical" approach:

They can promote the insertion of any of the skills. Identify issues that they take place nowadays, related to formulation and problem solving and enhance the relationship of skills with a selection of appropriate examples and case studies, giving information on the context of the problem and looking to guide the analysis as part of the design process (Design-Oriented Analysis)

Specific study plans with the described approach can be obtained from our web page.

Conclusions

The new curricula adapted to EHEA at Telecom BCN, have a structure that encourages the learning of generic skills through a blended formula. First all subjects include a reduced number of skills that define vertical pathways so every one of the Telecom BCN skills are practiced at least in three different subjects in three different levels. Second, project subjects are defined at every academic year to strengthening the learning of the contents of other subjects and to develop generic skills naturally through activities close to the practice of engineering. This scheme is compatible with the standards defined by the CDIO initiative, which Telecom BCN has joined in July 2009.

References

1. **ETSETB.** Solicitud de verificación de la titulación // Grado en Ciencias y Tecnologías de Telecomunicación por la Universitat Politècnica de Catalunya ETSETB, 2008.
2. **Crawley E. F., Malmqvist J., Östlund S., Brodeur D.** Rethinking engineering education: the CDIO approach. – Springer, 2007.
3. **Institute of Science Education, ICE–UPC** [Online: http://www.upc.edu/ice/portal–de–recursos/publicacions_ice/quaderns–per–treballar–les–competencies–genériques–a–les–assignatures].
4. **Ministry of Science and Innovation.** Boletin Oficial del Estado n 44. Orden CIN 352/2009.

Received 2010 05 10

E. Sayrol, R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas, J. O'Callaghan, J. Pegueroles, E. Pla, L. Prat, G. Sáez, J. Sardà, C. Tallón. Mixed Integration of CDIO skills into Telecommunication Engineering Curricula // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 6(102). – P. 127–130.

Spain has been intensively involved in designing engineering curricula for the last two years and next academic year all engineering schools will be deploying all bachelor programs adapted to the EHEA and to the Spanish laws. The different frameworks that set the conditions of the process of drawing up new curricula emphasize the use of competency-based learning and the insertion of certain generic skills within the structure of the new plans. In the school of Telecommunication Engineering of Barcelona, the CDIO initiative (Conceive-Design-Implement-Operate) first developed jointly by MIT and some Swedish Universities, has been chosen as paradigm for new engineering curricula design. We used a mixed approximation to integrate CDIO skills into the study plans. In this paper we will explain the approach to include generic skills when designing new curricula. Ill. 4, bibl. 4 (in English; abstracts in English, Russian and Lithuanian).

Е. Саюрол, Р. Брага, Е. Аларкон, М. Цабрера, А. Цалверас, Ю. Комеллас, Ю. О. Цалагхан, Ю. Пегюеролес, Е. Пла, Л. Прат, Г. Саез, Ю. Сарда, Ц. Таллон. Интеграция CDIO способности в учебных программах телекомуникационной инженерии // Электроника и электротехника. – Каунас: Технология, 2010. – № 6(102). – С. 127–130.

Описываются особенности учебного процесса в университетах Испании. В качестве исследования выбрана телекоммуникационная инженерная школа, в которой внедрена CDIO система. Предлагается взгляд на данные учебных программ. Ил. 4, библ. 4 (на английском языке; рефераты на английском, русском и литовском яз.).

E. Sayrol, R. Bragós, E. Alarcón, M. Cabrera, A. Calveras, J. Comellas, J. O'Callaghan, J. Pegueroles, E. Pla, L. Prat, G. Sáez, J. Sardà, C. Tallón. Įvairių CDIO įgūdžių integracija į telekomunikacijų inžinerijos mokymo programą // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 6(102). – P. 127–130.

Pastaruosius dvejus metus Ispanijoje intensyviai kuriamos inžinerijos mokymo programos pagal EHEA ir Ispanijos įstatymus. Ateinančiais metais visos inžinerijos mokyklos siūlys adaptuotas mokymo programas. Kuriant naujas studijų programas buvo naujai įvertinti iškelti tikslai. Barselonos telekomunikacijų inžinerijos mokykla buvo pasirinkta kaip pavyzdinė. CDIO įgūdžiai buvo įtraukti į studijų planus. Pateikiama nuomonė, kaip panaudoti bendrus įgūdžius kuriant naują mokymo programą. Il. 4, bibl. 4 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).