CDIO AS A FOUNDATION FOR PROGRAM ACCREDITATION/CERTIFICATION IN PORTUGAL

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ABSTRACT

This document describes two initiatives for accreditation/certification of first and second cycles Bologna programs in Portugal. One initiative was started by the National Agency for Program Evaluation and Accreditation and is mandatory for all Bologna running programs. The other initiative was launched by the Portuguese Professional Engineering Association and aims to certificate, at the European level, engineering Bologna second cycles with the EUR-ACE quality seal. Both initiatives are essentially evidence-based and stress the importance of having a running quality assurance system to support and monitor program execution.

ISEP experience with the CDIO and EUR-ACE engineering frameworks is also described and strong points highlighted. In the end, we propose that combining CDIO and EUR-ACE may bring added value, because CDIO is more oriented to program operation and EUR-ACE more oriented to program management. We also propose the CDIO Syllabus as the link between CDIO and EUR-ACE, because program syllabus is a relevant document in those frameworks and CDIO describes very clearly how to produce and maintain a syllabus.

KEYWORDS

CDIO, engineering, accreditation, certification, EUR-ACE.

INTRODUCTION

In 2009 the Portuguese universities and polytechnics were confronted with two initiatives for accreditation and/or certification of first and second cycles Bologna programs [1].

The accreditation initiative was started by the National Agency for Program Evaluation and Accreditation (A3ES [2]) and is mandatory for all Bologna running programs. The results from this accreditation process will be announced before the end of 2011 and further accreditations will have to be renewed each five years, at most. If a study cycle is not accredited, it will not be eligible for public funding.

The other initiative was launched by the Portuguese Professional Engineering Association (*Ordem dos Engenheiros* [3]) and aims to certificate sets of Bologna first and second cycles on engineering with the EUR-ACE quality seal [4]. As stated in [5], the principal aim of the EUR-ACE project is to develop a framework for the “accreditation of engineering degree programs in the European Higher Education Area”.

After ISEP joined CDIO [6] in 2008, the Dean of Instituto Superior de Engenharia do Porto (ISEP) decided that CDIO should be the foundation for program accreditation and/or certification. In ISEP, the first department to adopt CDIO as the teaching/learning framework (2006) was Informatics Engineering, which reformulated its Bologna first and second cycles study plans based on the Association for Computing Machinery (ACM) Curricula Recommendations [7] and on the CDIO Initiative. Since then all departments in ISEP have been adopting, with variable extents, the standards and good practices of CDIO.

In this document, the Context section describes how CDIO is currently put into practice in all running engineering cycles of ISEP. The next section explains the frameworks of A3ES accreditation and EUR-ACE certification activities. The following section addresses the benefits and limitations of adopting CDIO as an educational context for engineering education at ISEP and how that may help getting successful accreditation/certification results. The Conclusion section synthesizes what has been achieved and resumes the most important findings and ideas.

CONTEXT

Instituto Superior de Engenharia do Porto (ISEP) is one of the 5 largest engineering schools in Portugal with more than 6200 students, 420 faculty and 130 staff. It is located at Porto and in 2009-2010 lectures 10 first cycle and 10 second cycle Bologna programs. In 2010-2011 it is expected that 2 new Bologna cycles will start lecturing, totaling 22 engineering programs:

<u>*First Cycle Bologna (3 year BSc)*</u>

- Civil Engineering
- Computer Engineering and Medical Instrumentation
- Electrical Engineering - Power Systems
- Computer and Electrotechnical Engineering
- Metrology and Instrumentation Engineering
- Geoenvironmental and Geotechnical Engineering
- Informatics Engineering (*)
- Mechanical Engineering
- Mechanical Automotive Engineering
- Chemical Engineering
- Systems Engineering (*) – will start in 2010-2011
- Chemical and Biological Industry Quality Engineering

<u>*Second Cycle Bologna (2 year MSc)*</u>

- Computer and Medical Instrumentation
- Mechanical Constructions

- Metrology and Instrumentation
- Electrical Engineering - Power Systems
- Computer and Electrotechnical Engineering
- Geoenvironmental and Geotechnical Engineering
- Informatics Engineering (*)
- Chemical Engineering
- Operations and Process Management
- Construction Technology and Management
- Sustainable Energies – will start in 2010-2011

In the list above three programs (*) were designed in accordance with CDIO recommendations, while others have been adapting their structure and operation to CDIO. Although ISEP decided to adopt and apply the CDIO Initiative in 2007, the Informatics Engineering Department had already applied CDIO good practices in 2005 during the reformulation process of the first cycle program on Informatics Engineering, and, since then, other departments have been following it. The most important aspects of CDIO application at ISEP are:

- Introductory engineering courses in almost all programs
- Workspaces / laboratories available in all programs
- Lots of problem / project based curricular work
- Many extra curricular institutional activities for students
- Active learning largely dominant in classes
- Periodic project based teamwork in many programs
- Capstone “professional” project in most programs
- Student integration into R&D units of ISEP (both at first and second cycles)

Figure 1 shows CDIO inspired/compliant courses in first cycle programs during 2008-2009.

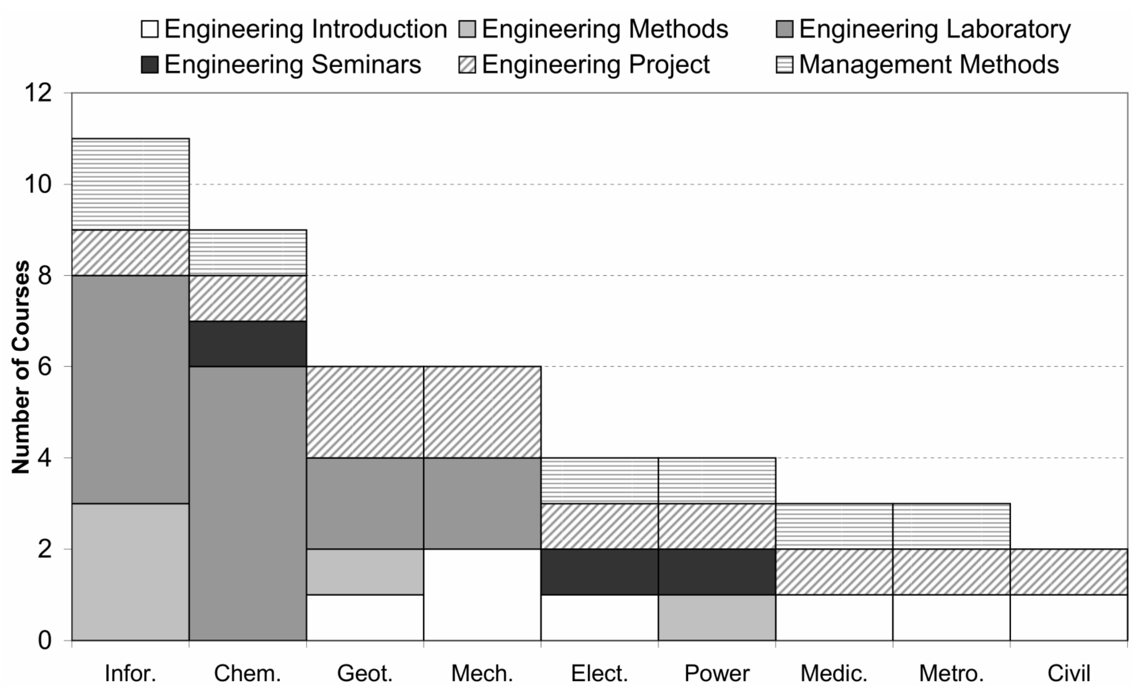

Figure 1. CDIO inspired/compliant courses in ISEP first cycle programs during 2008-2009

In ISEP, CDIO also triggered and promoted activities like:

- Pedagogical support group - Focus on pedagogical support to educational activities;
- Technological support group - Promote the use of complementary (technological) educational resources by faculty and motivate/encourage students for alternative and more pro-active learning processes;
- Teacher participation in events for improving pedagogical practice: IEEE Real-World Engineering Projects [8], etc.

In late 2008 ISEP proposed a new "Systems Engineering" first cycle Bologna program that included most of CDIO program recommendations. The program, designed by a team of CDIO adopters in ISEP and the top management staff of the biggest Portuguese entrepreneurial association (*Associação Empresarial de Portugal*), was finally approved in May 2009 and is expected to start in September 2010.

ACCREDITATION AND CERTIFICATION OF ENGINEERING STUDY CYCLES

In 2005, a report from ENQA [9] presented a set of results and recommendations for quality assurance in the European Higher Education Area. The corresponding standards for quality assurance were concerned with ensuring the quality of the educational process in all higher education programs, including all Bologna compliant engineering programs. Since then, this document has been very important in defining the context for all European accreditation and certification activities.

In the remainder of this section a brief analysis of the A3ES accreditation and the EUR-ACE certification context will be presented, and relevant issues for ISEP and CDIO will be highlighted.

Portuguese Accreditation (A3ES)

The A3ES accreditation process is essentially evidence-based and the final decision will depend on the verification and validation of an extensive and structured set of evidences, described as "measures" and "targets" [10]. The following list shows the accreditation conditions and the number of evidences defined for each item:

1. MISSION AND OBJECTIVES OF THE STUDY CYCLE (6)
2. INTERNAL ORGANISATION AND QUALITY ASSURANCE MECHANISMS
    - 2.1. Internal Organization (2)
    - 2.2. Quality Assurance Mechanisms (4)
3. MATERIAL RESOURCES AND PARTNERSHIPS
    - 3.1. Material resources (3)
    - 3.2. Partnerships (3)
4. ACADEMIC AND NON-ACADEMIC STAFF
    - 4.1. Qualification of the academic staff (3)
    - 4.2. Allocation of the academic staff (3)
    - 4.3. Non-academic staff (2)
5. STUDENTS
    - 5.1. Characterization of the students (5)
    - 5.2. Teaching/Learning environment (4)
6. PROCESSES

6.1. Objectives of Teaching, Curricular Structure and Syllabus (3)
6.2. Organization of Curricular Units (3)
6.3. Teaching/Learning methodologies (3)

7. RESULTS
   7.1. Academic Results (2)
   7.2. Results of the scientific, technological and artistic activity (1)
   7.3. Other Results (4)

Although we expect that CDIO will help to improve overall ISEP performance, the following A3ES accreditation conditions are especially important in terms of CDIO:

Quality assurance mechanisms

- There is a quality assurance system with a designated responsible;
- This system includes the collection of information and the monitoring and periodic evaluation of the study cycle as well as the check of qualifications and competences of the academic staff;
- The results of the assessments are largely discussed and used to improve the quality of the study cycle;
- The quality assurance system has been certified.

Teaching objectives, curricular structure and syllabus

- There is a periodic mechanism for revision of the curricular structure to ensure the scientific updating of the study cycle and of the work methodologies;
- The curricular structure is compatible with the Bologna process;
- The objectives of the study cycle were implemented and are easily measured.

Organization of the curricular units

- There is an effective coordination between the curricular units and their contents in order to ensure their coherence with the defined objectives;
- The objectives of each curricular unit are known by the academic staff and students;
- The competences to be acquired in each curricular unit are defined.

Teaching/learning methodologies

- The teaching methodologies and the didactic techniques are adapted to the teaching objectives and facilitate the student participation in research;
- The average of the needed study time corresponds to the estimated credits (ECTS [11]);
- The student evaluation is made by considering the objectives of each curricular unit.

European Certification (EUR-ACE)

The EUR-ACE certification framework [5] focuses on six program outcomes to certify engineering based Bologna second cycles:

- *Knowledge and Understanding* - The underpinning knowledge and understanding of science, mathematics and engineering fundamentals are essential to satisfying the other program outcomes. Graduates should demonstrate their knowledge and understanding of their engineering specialization, and also of the wider context of engineering;
- *Engineering Analysis* - Graduates should be able to solve engineering problems consistent with their level of knowledge and understanding, and which may involve

considerations from outside their field of specialization. Analysis can include the identification of the problem, clarification of the specification, consideration of possible methods of solution, selection of the most appropriate method, and correct implementation. Graduates should be able to use a variety of methods, including mathematical analysis, computational modeling, or practical experiments, and should be able to recognize the importance of societal, health and safety, environmental and commercial constraints;

- *Engineering Design* - Graduates should be able to realize engineering designs consistent with their level of knowledge and understanding, working in cooperation with engineers and non-engineers. The designs may be of devices, processes, methods or artifacts, and the specifications could be wider than technical, including an awareness of societal, health and safety, environmental and commercial considerations;
- *Investigations* - Graduates should be able to use appropriate methods to pursue research or other detailed investigations of technical issues consistent with their level of knowledge and understanding. Investigations may involve literature searches, the design and execution of experiments, the interpretation of data, and computer simulation. They may require that data bases, codes of practice and safety regulations are consulted;
- *Engineering Practice* - Graduates should be able to apply their knowledge and understanding to developing practical skills for solving problems, conducting investigations, and designing engineering devices and processes. These skills may include the knowledge, use and limitations of materials, computer modeling, engineering processes, equipment, workshop practice, and technical literature and information sources. They should also recognize the wider, non-technical implications of engineering practice, ethical, environmental, commercial and industrial;
- *Transferable Skills* - The skills necessary for the practice of engineering, and which are applicable more widely, should be developed within the program.

This initiative acknowledges CDIO as a valid framework for engineering education, emphasizing the relevance of the CDIO syllabus as a best practice and effective tool [12]. This certification process is also based on the verification and validation of a large set of evidences, and most of them can be correlated with CDIO standards.

Although all six program outcomes apply to both first and second cycle programs, there are important differences in the requirements at the two levels, which are particularly relevant to those learning activities that contribute directly to the three program outcomes concerned with engineering applications (Engineering Analysis, Engineering Design and Investigations). Students entering a certified second cycle program will normally have graduated from certified first cycle programs, but each institution should provide opportunities for students entering without such a qualification to demonstrate that they have satisfied the first cycle requisites.

EUR-ACE certification is also evidence-based and uses a structured set of evidences, which depend on the following list of certification conditions (with number of evidences for each item):

1. NEEDS, OBJECTIVES AND OUTCOMES
    - 1.1 Needs of the Interested Parties (1)
    - 1.2 Educational Objectives (1)
    - 1.3 Program Outcomes (2)
2. EDUCATIONAL PROCESS
    - 2.1 Planning (1)
    - 2.2 Delivery (2)

2.3 Learning Assessment (1)

3. RESOURCES AND PARTNERSHIPS
   - 3.1 Academic and Support Staff (2)
   - 3.2 Facilities (4)
   - 3.3 Financial Resources (1)
   - 3.4 Partnerships (1)
4. ASSESSMENT OF THE EDUCATIONAL PROCESS
   - 4.1 Students (2)
   - 4.2 Graduates (2)
5. MANAGEMENT SYSTEM
   - 5.1 Organization and Decision-making Processes (1)
   - 5.2 Quality Assurance System (3)

In the ANNEX 1, which presents both accreditation/certification conditions at a glance, it is easy to see the similarities and differences between A3ES and EUR-ACE.

CDIO VERSUS PROGRAM ACCREDITATION AND CERTIFICATION

During a presentation in the 2006 International CDIO Conference, Edward Crawley showed a slide (Figure 2) that resumed in a simple and objective way how the CDIO generic syllabus would contribute to fulfill high level qualification descriptors like the Dublin Descriptors [13]. CDIO was mainly created to improve the process of engineering education and that certainly includes the satisfaction of accreditation and certification requisites. For ISEP this has always been a strong motivation, amongst others, for CDIO adoption and application.

DUBLIN DESCRIPTORS X CDIO

CDIO Syllabus

Second Cycle Dublin Descriptors	1.1 Knowledge of underlying sciences	1.2 Core engineering fundamental knowledge	1.3 Advanced engineering fundamental knowled.	2.1 Engineering reasoning and problem solving	2.2 Experimentation and knowledge discovery	2.3 Systems thinking	2.4 Personal skills and attitudes	2.5 Professional skills and attitudes	3.1 Teamwork	3.2 Communication	3.3 Communication in foreign languages	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	DUBLIN DESCRIPTORS ADDRESSED
Dublin Descriptor #1	X	X	X															✓
Dublin Descriptor #2				X	X	X												✓
Dublin Descriptor #3						X		X				X						✓
Dublin Descriptor #4										X								✓
Dublin Descriptor #5							X											✓

ADDITIONAL REQUIREMENTS ACHIEVED

Figure 2. How the CDIO Generic Syllabus fulfills the Dublin Descriptors

The A3ES general accreditation framework for Bologna first and second cycles is mainly based on the Bologna Process framework and Portuguese laws, whose qualifications requisites are derived from the Dublin Descriptors, and other requisites concerning “internal organization and quality assurance” and the “educational process”. A3ES chose a framework based on learning outcomes, which are pre-requisites for the implementation of quality assurance systems in higher education. As such, a clear and comprehensive definition of each program learning outcomes is necessary both for satisfying A3ES accreditation criteria and to support a quality assurance system in ISEP.

Since 2006, ISEP first and second cycle programs were adapted or created to satisfy the requirements of the Bologna Process, which included the definition of global learning outcomes for each program. One CDIO’s the best practices is the definition of a structured program syllabus, which basically solves the problem of defining the learning outcomes for a program. Currently in ISEP only some programs have formally started the definition of its syllabus, of which the most developed are the Informatics Engineering first cycle (completed) and second cycle (first draft done). It is also worth mentioning that since 2008-2009 all curricular units’ course descriptions include a section on learning outcomes, in many cases detailing skills, abilities and competences. The existence of many CDIO inspired/compliant courses (Figure 1) is another positive contribution for a successful accreditation.

In [14], Feyo Azevedo addressed the question if “High Level Qualifications Frameworks” and the “EUR-ACE Frameworks Standards” fitted together. He also identified three major levels of descriptors:

1. High level descriptor of competences, of general nature, describing global qualifications associated to degrees – examples: *Bologna Process*, *EQF* [15] and *A3ES*;
2. Sectoral descriptors, grouped into scientific and technological areas, with direct relations to professions – examples: *EUR-ACE*, *ABET* [16] and *CDIO*;
3. Contents descriptors, characterizing main or core curricula contents and methods – example: *ACM Computing Curricula* [7] for computer science based programs.

In [14] the author describes an extensive comparison of descriptors, showing that EUR-ACE is more useful than high level frameworks like Bologna or EQF and comparable to ABET and CDIO. Interestingly, the EUR-ACE documentation describes CDIO as a viable framework for engineering education and the CDIO generic syllabus as a good practice. In [17] Malmqvist presents a very objective and detailed comparison of quality assurance in CDIO and EUR-ACE, concluding that CDIO is more encompassing, more educationally extensive and more useful for guiding a continuous improvement process…

ISEP has been applying CDIO good practices since 2006, with greater emphasis at the Informatics Engineering Department, but slowly spreading to other departments. Recently the EUR-ACE initiative in ISEP has brought some ideas that were not addressed in CDIO and that seem to complement it very well. Most of these ideas concern the record keeping of information like the one shown in the following list (described in the EUR-ACE application form [3]):

- S04. COURSE FORMALISATION
- S05. INSTITUTIONAL STRATEGY CONCERNING THE COURSE
- S06. COOPERATION WITH OTHER INSTITUTIONS
- S07. GENERAL INFORMATION ABOUT THE COURSE: PART A
- S08. GENERAL INFORMATION ABOUT THE COURSE: PART B

- S09. COURSE PLAN
- S10. SUBJECT SHEET (see ANNEX 2)
- S11. COMPLEMENTARY ACTIVITY SHEET
- S12. OUTCOMES
- S13. LIST OF TEACHING STAFF: PERMANENT STAFF
- S14. LIST OF TEACHING STAFF: NON-PERMANENT STAFF
- S15. LIST OF STAFF IN CHARGE
- S16. COURSE DIRECTOR SHEET
- S17. TEACHING STAFF SHEET
- S18. TEACHING STAFF PERSPECTIVE
- S19. MOVEMENT OF STUDENTS
- S20. STUDENTS AND EMPLOYERS' EVALUATION
- S21. SUITABILITY OF PREMISES
- S22. PEDAGOGIC FACILITIES
- S23. COURSE MONITORING: RATES OF SUCCESS
- S24. COURSE MONITORING: DESIGN/PROJECT WORK
- S25. COURSE MONITORING: SELF-CONTROL
- S26. QUALITY PLAN

CONCLUSION

Three years after CDIO adoption at ISEP, it is possible to conclude that application of many CDIO practices has produced good results, especially in the Informatics Engineering first cycle, which pioneered that application in a systematic way and “spread the word”. Another conclusion is that CDIO is very suitable for improving the operational component of programs (engineering introduction courses, open laboratories, design-build experiences, experiental learning, etc).

EUR-ACE appeared only in 2008, but it seems to be suitable for the managerial component of programs. Being a sectorial engineering framework like CDIO, its recommendations for documenting a program execution are more appropriate for supporting a quality assurance system, either at program or institutional level. In 2010-2011 ISEP information system may incorporate some EUR-ACE suggestions, the most significant being the proposed format for all curricular units sheets. At program level, the use of some EUR-ACE document templates may also become more common.

Having CDIO for program operation and EUR-ACE for program management, the CDIO based syllabus may serve as the link between both components of a program. As in the past, the Informatics Engineering program will likely be the first one to experiment this combination of frameworks…

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ANNEX 1 – A Comparison of accreditation/certification conditions of Portuguese A3ES and European EUR-ACE

Similarly shaded boxes between the columns represent a qualitative match between groups of accreditation/certification conditions.

1. MISSION AND OBJECTIVES OF THE STUDY CYCLE (6)

2. INTERNAL ORGANISATION AND QUALITY ASSURANCE MECHANISMS
2.1. Internal Organization (2)
2.2. Quality Assurance Mechanisms (4)

3. MATERIAL RESOURCES AND PARTNERSHIPS
3.1. Material resources (3)
3.2. Partnerships (3)

4. ACADEMIC AND NON-ACADEMIC STAFF
4.1. Qualification of the academic staff (3)
4.2. Allocation of the academic staff (3)
4.3. Non-academic staff (2)

5. STUDENTS
5.1. Characterization of the students (5)
5.2. Teaching/Learning environment (4)

6. PROCESSES
6.1. Objectives of Teaching, Curricular Structure and Syllabus (3)
6.2. Organization of Curricular Units (3)
6.3. Teaching/Learning methodologies (3)

7. RESULTS
7.1. Academic Results (2)
7.2. Results of the scientific, technological and artistic activity (1)
7.3. Other Results (4)

Note: A3ES accreditation applies to all first and second cycles in Portugal and is mandatory.

1. NEEDS, OBJECTIVES AND OUTCOMES
1.1 Needs of the Interested Parties (1)
1.2 Educational Objectives (1)
1.3 Program Outcomes (2)

2. EDUCATIONAL PROCESS
2.1 Planning (1)
2.2 Delivery (2)
2.3 Learning Assessment (1)

3. RESOURCES AND PARTNERSHIPS
3.1 Academic and Support Staff (2)
3.2 Facilities (4)
3.3 Financial Resources (1)
3.4 Partnerships (1)

4. ASSESSMENT OF THE EDUCATIONAL PROCESS
4.1 Students (2)
4.2 Graduates (2)

5. MANAGEMENT SYSTEM
5.1 Organization and Decision-making Processes (1)
5.2 Quality Assurance System (3)

Note: EUR-ACE certification applies only to second cycles in Portugal and is not mandatory.

ANNEX 2 – Example of EUR-ACE Course Sheet

EUR-ACE / Curricular Unit Sheet (Part1)

S10. SUBJECT SHEET – R5/R6

INSTITUTION:	
COURSE:	
SUBJECT/UNIT:	

I - IDENTIFICATION				
ACADEMIC YEAR –	SUBJECT AREA/GROUP * -		INTERNAL CODE –	
YEAR:	SEM:	CONTACT TIME - HOURS/WEEK:	ECTS:	LEVEL (B/I/A)**:
FORMAL PREREQUISITES:				
SUBJECT WEBSITE URL:				

TEACHING STAFF				
	NAME	POSITION	ACADEMIC BACKGROUND	% OCC.
IN CHARGE				
OTHER				

*Fundamental Subjects (B), Engineering Science (C), Specialty (S), Option (O), Complementary subjects (P).
** Basic/Intermediate/Advanced

II – AIMS, SYNOPSIS, CHARACTERIZATION

Background (max. 600 characters) –
Provide an overview of the technical and scientific fields that justify this Unit

Aims (max. 750 characters) –
Namely pedagogic objectives and how this Unit contributes for the Course

Contents (max. 1000 characters)
Describe programme of a theoretical and practical nature as appropriate

EUR-ACE / Curricular Unit Sheet (Part2)

S10. SUBJECT SHEET – R5/R6

INSTITUTION:	
COURSE:	
SUBJECT/UNIT:	

Main Teaching Material
Namely main textbooks and other basic support texts

Complementary Teaching Material
Complementary references of books, papers and technical information, as appropriate

Teaching/Learning Tools
Software, e-learning tools, etc..

Previous knowledge assumed as acquired

Material	Source
Describe in rows expected knowledge	AND Identify Units where they are taught

Teaching/learning methodology
Namely describe innovative methods

Characterization of objectives and program
A – Estimated percent distribution of scientific and technological contents
- Scientific component (establishes and develops scientific bases) – ??
- Technological component (apply to design and process operation) - ?? %

Characterization of objectives and program
B – Outcomes – in conformity with EUR-ACE criteria
Describe what the student is expected to 'understand' or 'know' or 'be able to do' after this module and with relation to the six outcomes of the EUR-ACE framework standards:
Knowledge and Understanding –
Engineering Analysis –
Engineering Design –
Investigations –
Engineering Practice –
Transferable Skills -

III – ASSESSMENT PROCEDURE

Self Assessment –
Example sheets, paper & pencil versus computer-aided worked examples.

Teacher´s Assessment –