THREE YEARS OF CDIO/ACM BASED INFORMATICS ENGINEERING UNDERGRADUATE PROGRAM AT ISEP

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ABSTRACT

Since 1985 Instituto Superior de Engenharia do Porto (ISEP) offers undergraduate programs in the area of Informatics Engineering. During 2003-2006, the Informatics Engineering Department of ISEP worked on the reformulation of its programs using, as main frameworks, the Association for Computing Machinery (ACM) Computing Curricula and the CDIO Initiative™.

This document describes how CDIO was important in the reformulation of Informatics Engineering programs at ISEP and how it is being applied since then. The CDIO impacts will be explained and discussed in terms of study plan, program syllabus, curricula organization, program operation and external undergraduate evaluation.

KEYWORDS

CDIO, ACM, informatics, engineering, computing curricula, syllabus.

INTRODUCTION

Since 1985 Instituto Superior de Engenharia do Porto (ISEP) offers undergraduate programs in the area of Informatics Engineering. In 1998, after an extensive reformulation process based on the ACM Computing Curricula 1991 [1], a revised undergraduate program and a new graduate program in Informatics Engineering were introduced. In 2003 the Portuguese Professional Engineering Association (*Ordem dos Engenheiros* [2]) accredited the undergraduate+graduate programs for six years.

Anticipating the Bologna higher education reform [3] which occurred in 2006, ISEP started its Bologna reformulation process in 2003. During the 2003-2006 period, the Informatics Engineering Department of ISEP worked on the reformulation of its programs using, as main frameworks, the Association for Computing Machinery (ACM) Computing Curricula [4] and the CDIO Initiative [5].

In this document, the Context section describes the Bologna engineering programs lectured and general CDIO impacts at ISEP. The next section explains, for the 2003-2006 period, how the

Informatics Engineering first cycle (LEI) was created and how CDIO influenced it. The following section concerns the operation of LEI between 2007 and 2010 and describes CDIO's contributions. 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 teachers 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:

First Cycle Bologna (3 year BSc)

- 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

Second Cycle Bologna (2 year MSc)

- 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 and influence 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);
* 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 [6] and others.

CREATION OF THE INFORMATICS ENGINEERING FIRST CYCLE AT ISEP

The Informatics program of ISEP started in 1985 with a small number of students and evolved, during the 1985-1997 period, into a successful 4 year undergraduate program with very high employability. In 1998 the Portuguese Government changed the higher education context and allowed polytechnics to lecture 5 year programs, divided into an initial 3 year bachelor program and a subsequent 2 year “licentiate” program. ISEP saw this context change as an opportunity to improve and reinforce its portfolio on engineering programs and decided to create new and more professionally oriented 3+2 engineering programs. In 2003, anticipating the Bologna higher education reform which occurred in 2006, ISEP started its Bologna reformulation process. During the 2003-2006 period, the Informatics Engineering Department worked on the reformulation of its programs using, as main frameworks, the Association for Computing Machinery (ACM) Computing Curricula [4] and the CDIO Initiative [5], as well as its extensive experience in lecturing professionally oriented informatics courses and programs. For the group in charge of this reformulation, it was consensual that the new “Bologna study plan” should evolve like depicted in Figure 1, increasing the percentage of project work (light boxes representing “scientific” courses and dark boxes “informatics” courses).

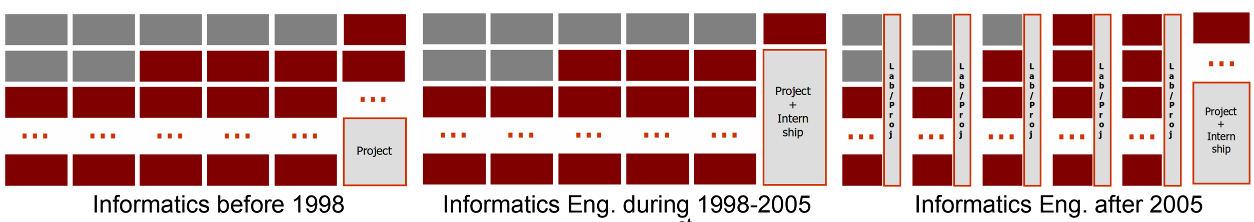

Figure 1. Evolution of Informatics (1st Cycle) in ISEP since 1985

The Informatics Engineering First Cycle (LEI) study plan was essentially inspired by the CDIO Generic Syllabus [7], but for the “Technical Knowledge and Reasoning” part the ACM Computing Curricula recommendations were used - an Overview Report and five Curriculum Reports on Computer Science, Computer Engineering, Information Systems, Information Technology and Software Engineering [4]. The most important contributions came from the “Computer Science Report” (2001 version) and the “Overview Report” (2005 version):

* The ACM “Computer Science” curriculum report provided the scientific skeleton of the new Informatics Engineering study plan, 19 courses in a total of 30, most of them having pre-requisites, which imposed limitations to the courses sequence;
* The remaining 11 courses were mainly derived from CDIO recommendations and the ACM “Overview Report”: 3 science-based courses, 2 information systems courses and 6

"design-build-test" courses (one per curricular semester, including the Capstone Project).

The ACM "Overview Report" also introduced a conceptual diagram that was very useful for the reformulation group: the "problem space" of each ACM proposed computing curricula (Figure 2, Figure 3 and left side of Figure 4).

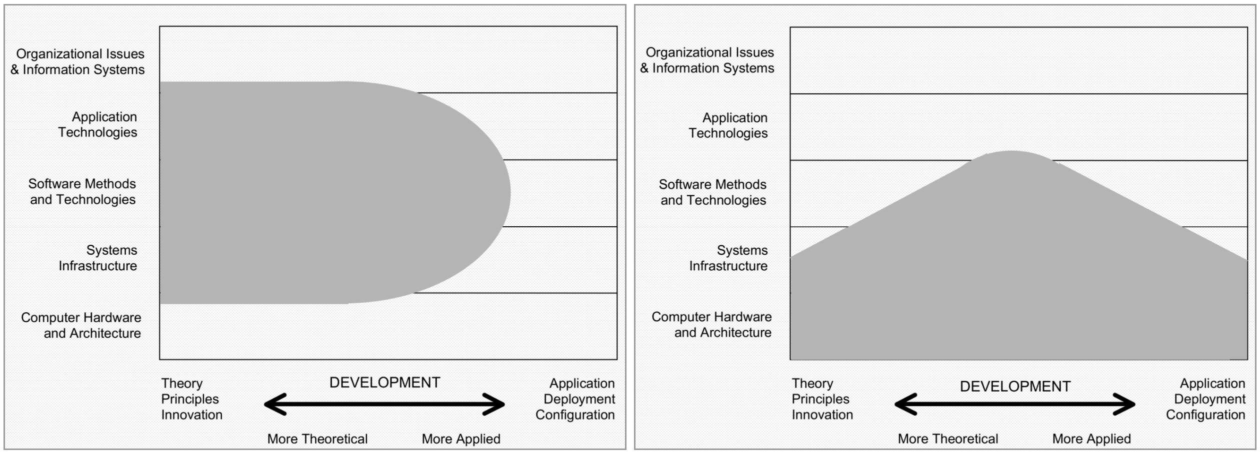

Figure 2. "Computer Science" and "Computer Engineering" problem spaces (Source: ACM)

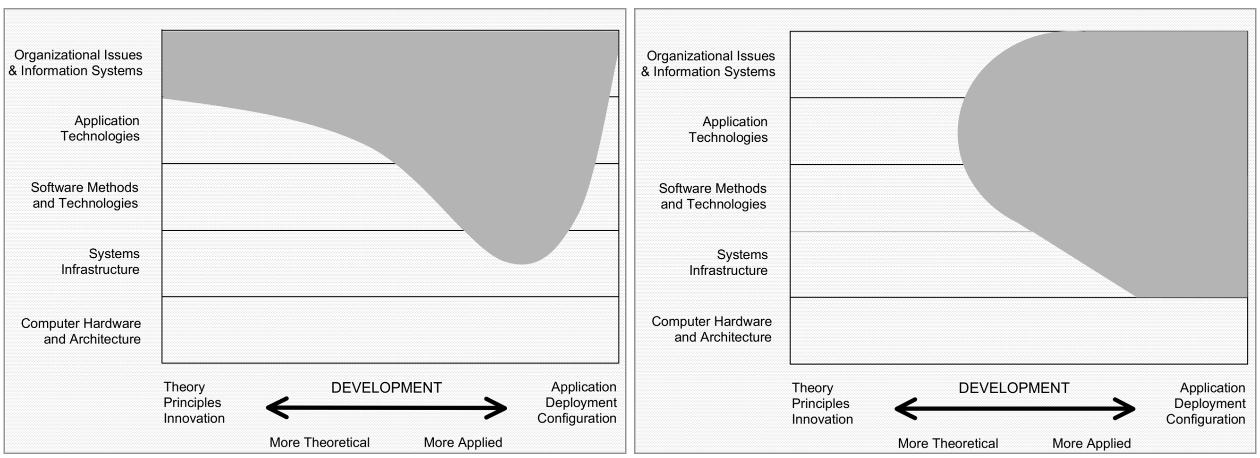

Figure 3. "Information Systems" and "Information Technology" problem spaces (Source: ACM)

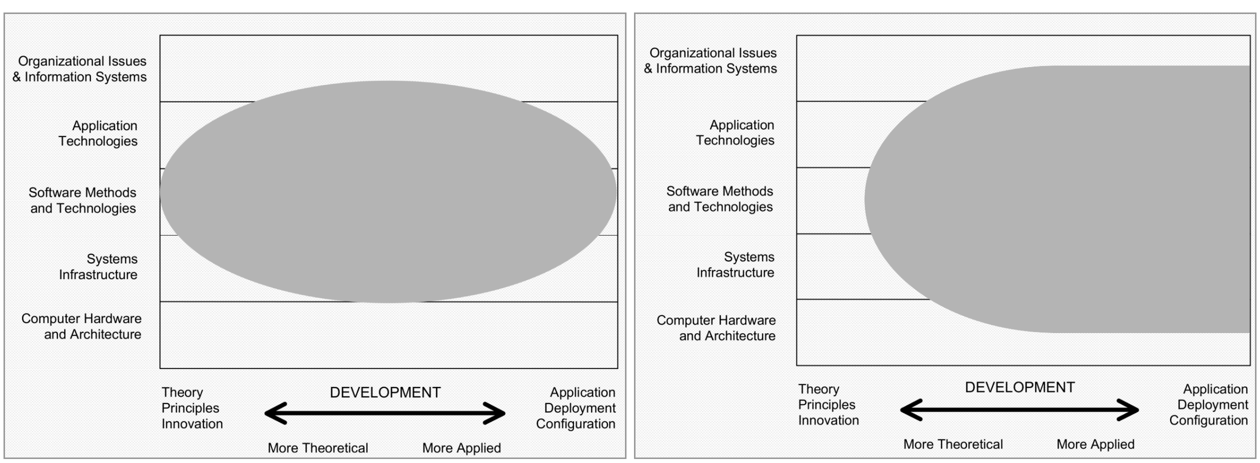

Figure 4. "Software Engineering" (Source: ACM) and "**Informatics Engineering**" problem spaces

The right side of Figure 4 shows the problem space to be covered by the professionally oriented Informatics Engineering ISEP program, where the rightmost part of the shaded area would be addressed by several "design-build-test" courses (problem based group project activities) and the capstone project. Figure 5 shows the resulting study plan that was officially approved in May 2006, in which an ECTU is one unit of curricular credit (ECTS [8]).

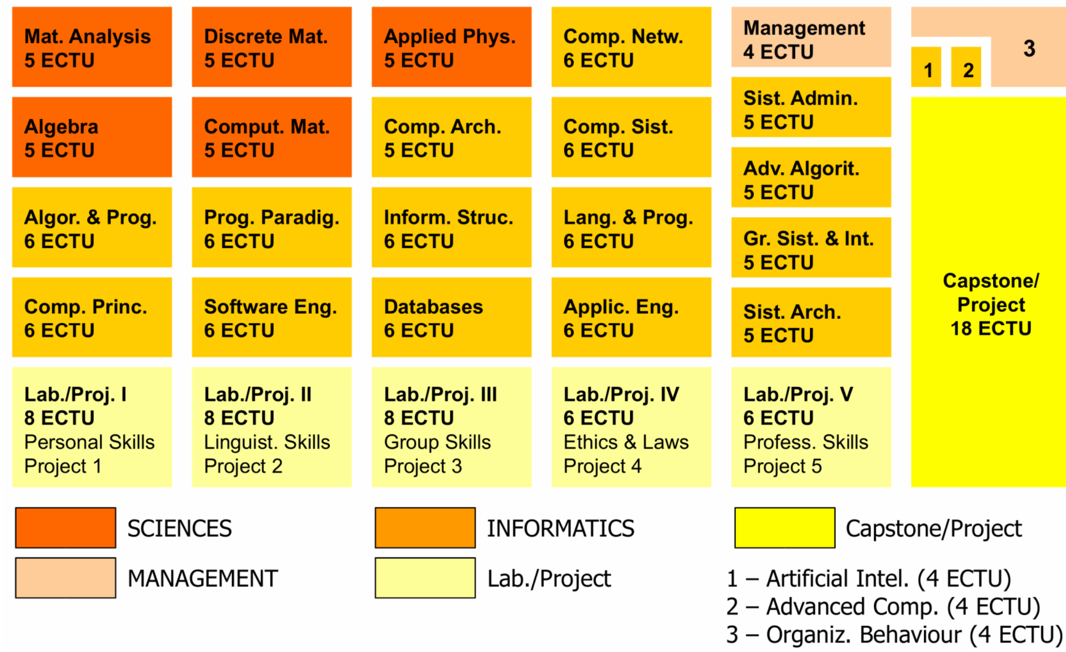

Figure 5. Informatics Engineering 1st Cycle (Bologna) study plan in 2006-2007

CDIO main contributions (standards, good practices, etc) to the study plan in Figure 5 were:

- An improved hands-on approach to informatics engineering – Standard 1;
- Integration of personal, group, professional and other skills – Standard 3;
- A course to introduce informatics engineering ("Computing Principles") – Standard 4;
- "Design-build-test" courses ("Lab./Projects" and "Capstone Project") – Standards 5 and 7;
- A process for the definition of global program outcomes – partially Standard 2;
- The balance between "science" and "engineering" courses in the first curricular year.

The new Informatics Engineering First Cycle (LEI) started in 2006-2007 and ran in parallel with the last curricular year of the old Informatics Engineering program. Students in the first or second curricular year of the old program were appropriately transferred to the new program.

OPERATION OF THE INFORMATICS ENGINEERING FIRST CYCLE AT ISEP

The first year of running LEI was atypical, because 2006-2007 was a transitional year between the old and the new programs. During 2006-2007 all LEI courses started, including the Lab./Project courses, which ran all along the semesters and not in the end due to the complexity of the transition, where more than 800 students were involved.

Changes to the Informatics Engineering First Cycle

A major change in LEI operation occurred during the transition from 2006-2007 to 2007-2008. Like originally intended, the Lab./Project courses were rescheduled to run in the last 4 weeks of each semester and the 12 initial weeks were allocated to "conventional" courses and "skills" modules.

The change from a 16 weeks classes semester to a 12+4 weeks, in which the last 4 weeks are fully devoted to problem based group projects, generated some anxiety in faculty, because it was a mostly new teaching/learning process. A lot of effort was put in addressing that anxiety by the department and program managers, with considerable success. Although the change created some initial perturbation, during 2007-2008 things settled down and the Lab./Project results since then have been very positive and encouraging.

Informatics Engineering First Cycle Syllabus

During 2006, while working on the Informatics Engineering second cycle (MEI) program, an effort was made to identify the minimum expected outcomes of both cycles. Figure 6 describes the identified outcomes for the first cycle (the "L" cells) and second cycle (the "M" cells). Being MEI the continuation of LEI, it was foreseen that the second cycle should improve significantly the knowledge, abilities and skills of the graduate students.

LEI+MEI Syllabus - Main Outcomes	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
1 TECHNICAL KNOWLEDGE AND REASONING	**L**	**L**	**L**	**L**	**M**	
1.1 KNOWLEDGE OF UNDERLYING SCIENCES	L	L	L			
1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE	L	L	L	L	M	
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE	L	L	L	L	M	
2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES	**L**	**L**	**L**	**L**	**M**	
2.1 ENGINEERING REASONING AND PROBLEM SOLVING	L	L	L	L	M	
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY	L	L	L	L	M	
2.3 SYSTEM THINKING	L	L	L	M		
2.4 PERSONAL SKILLS AND ATTITUDES	L	L	L	M		
2.5 PROFESSIONAL SKILLS AND ATTITUDES	L	L	L	L		
3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION	**L**	**L**	**L**	**M**		
3.1 TEAMWORK	L	L	L	M		
3.2 COMMUNICATIONS	L	L	L	M		
3.3 COMMUNICATIONS IN FOREIGN LANGUAGES	L	L	L	M		
4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT	**L**	**L**	**L**	**M**		
4.1 EXTERNAL AND SOCIETAL CONTEXT (*)	L	L	L	M		
4.2 ENTERPRISE AND BUSINESS CONTEXT (*)	L	L	L	M		
4.3 CONCEIVING AND ENGINEERING SYSTEMS	L	L	L	M		
4.4 DESIGNING	L	L	L	M		
4.5 IMPLEMENTING	L	L	L	L	M	
4.6 OPERATING	L	L	L	M		

Figure 6. Minimum expected outcomes for Informatics Engineering 1st and 2nd (Bologna) cycles

In June 2007 a group of people, leaded by the program manager, initiated the work on the first full version of the LEI Syllabus. The CDIO Generic Syllabus (ANNEX 1) was the starting point and after some group meetings, the first draft LEI Syllabus was produced and shown to faculty. After incorporating the initial feedback, faculty was requested to fill a questionnaire about the expected proficiency levels. The results of this initiative were analyzed, processed and transferred to successive draft versions, until the last one was approved by faculty in May 2008 (LEI Syllabus version 1.0). It should be remarked that this syllabus also included feedback from professional people that was teaching in LEI (ANNEX 2). Work on MEI Syllabus started in the beginning of 2009 and a first draft version was produced in July 2009 (ANNEX 3).

Consolidation of the Informatics Engineering First Cycle

The first full undergraduates from LEI finished in 2008-2009 by completing the curricular Capstone Project course during July to November 2009. In the Capstone Project, more than 80% of the students developed a viable solution to an informatics engineering problem outside ISEP. As such, results from the Capstone Project course can be considered as a quality indicator for the LEI teaching/learning process and for the program societal/professional adequacy and relevancy. The graphs in Figure 7 and Figure 8 show results from the inquiries to all External Supervisors (2005-2006, 2007-2008 and 2008-2009) and to all ISEP Supervisors (2005-2006 and 2008-2009) in the Capstone Project course.

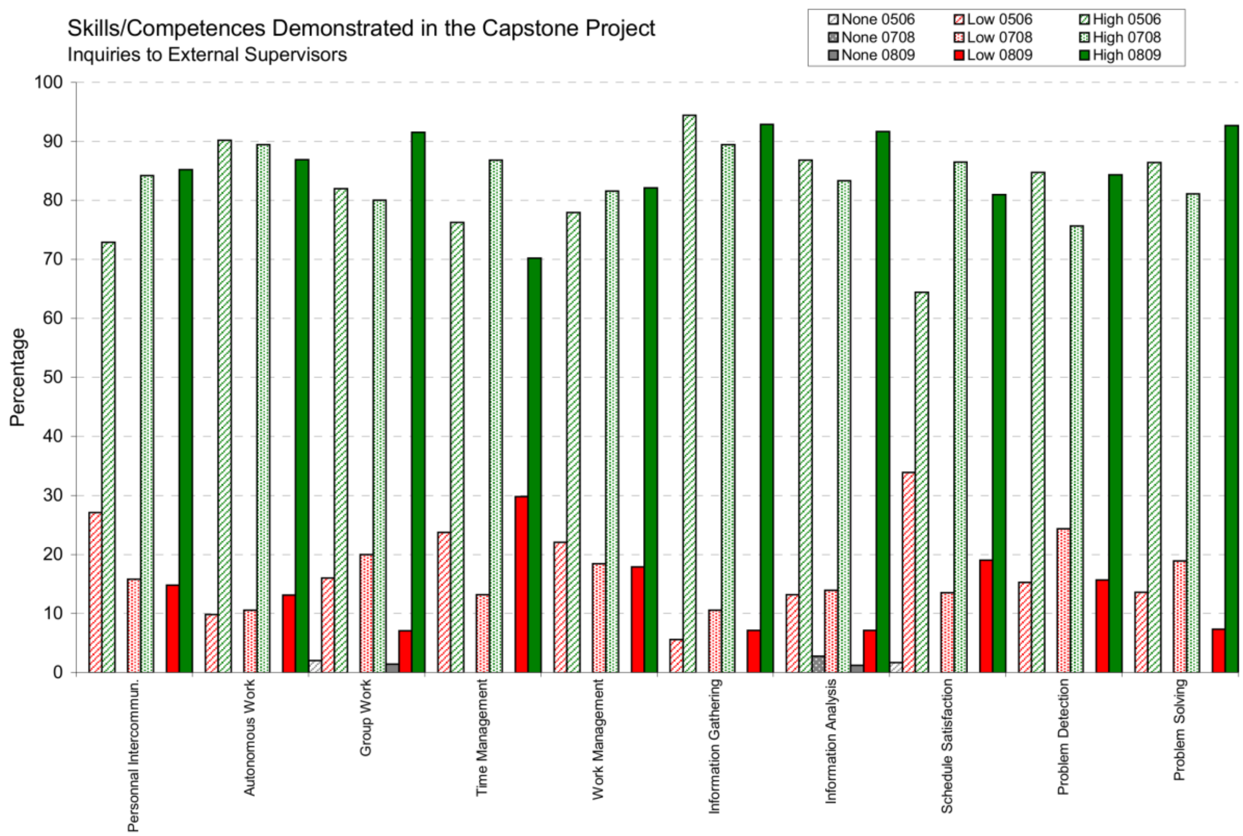

Figure 7. Skills/Competences as evaluated by Capstone Project External Supervisors in 2005-2006, 2007-2008 and 2008-2009

The evaluated categories are: Personal Intercommunication, Autonomous Work, Group Work, Time Management, Work Management, Information Gathering, Information Analysis, Schedule Satisfaction, Problem Detection and Problem Solving. Figure 7 shows LEI first cycle undergraduates being no worse than in the previous program, and improving at Personal Intercommunication, Group Work, Information Analysis and Problem Solving.

The results shown in Figure 8 were obtained from inquiries based on the ACM Computing Curricula Areas (ANNEX 4) and compare 2005-2006, the last year of the old program, with LEI in 2008-2009. The categories in which LEI shows significant progress are: Create a Software

User Interface, Design an Application, Use a Database System and Do Small-Scale Programming.

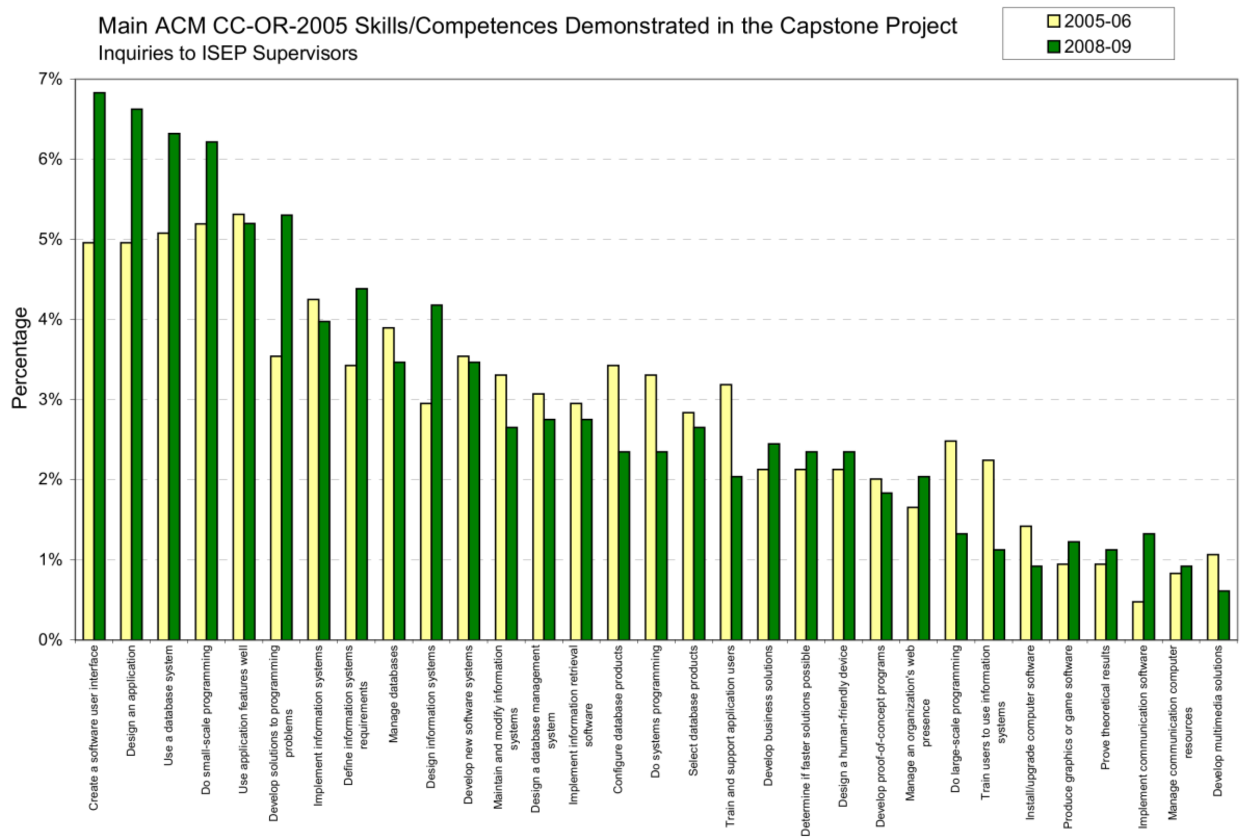

Figure 8. ACM Computing Curricula Skills/Competences as evaluated by Capstone Project LEI Supervisors in 2005-2006 and 2008-2009

These output indicators show that the deployment of LEI in the last 3 years was successful. It should be noted that all this was achieved without supplementary funding or extra resources other than those belonging to the department.

	CDIO Standards Implementation at LEI-ISEP	Level (0-4)
1	The Context	3
2	Learning Outcomes	2
3	Integrated Curriculum	3
4	Introduction to Engineering	3
5	Design-Implement Experiences	4
6	Engineering Workspace	3
7	Integrated Learning Experiences	3
8	Active Learning	2
9	Enhancement of Faculty Skills Competence	0
10	Enhancement of Faculty Teaching Competence	1
11	Learning Assessment	2
12	Program Evaluation	1

Figure 9. LEI and state of CDIO Standards in 2009

In terms of CDIO application and standards compliance, we acknowledge that there is still a long way to go. Figure 9, about the state of LEI CDIO Standards implementation at LEI during 2009, shows where improvement was mostly needed: Standards 9, 10 and 12.

There are still many challenges facing CDIO implementation at LEI, especially regarding the lack of multipurpose working spaces, too much surface learning, insufficient faculty skills and how to efficiently manage the large number of students (more than 1100 in 2008-2009).

Figure 10 shows an ongoing initiative that aims to tackle the complexity of managing such a large number of students and a very heterogeneous faculty: adopt an integrated model / process orientation for LEI, without changing significantly the study plan and the curricular contents. The first results of this initiative will only be available after the end of 2009-2010…

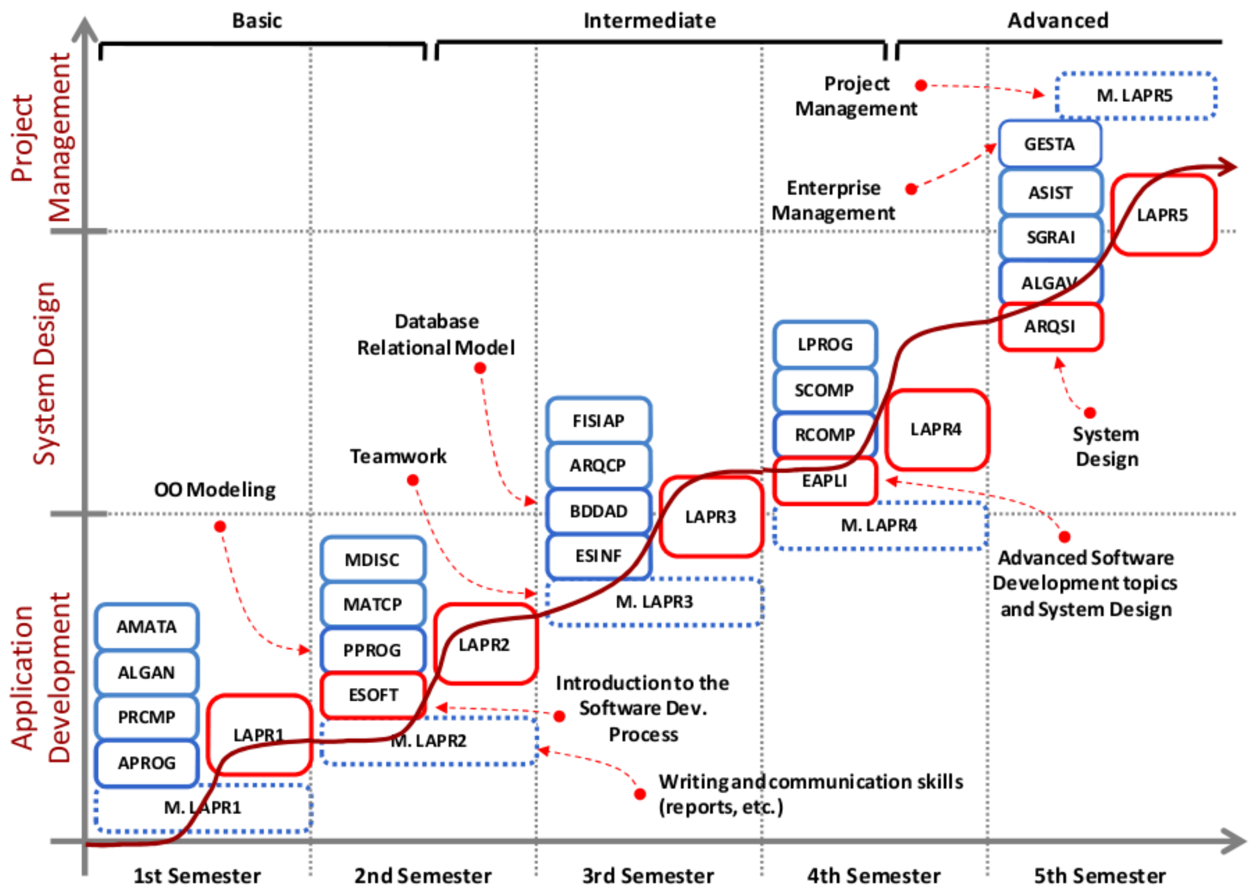

Figure 10. An Integrated Model / Process Orientation for LEI

CONCLUSION

As stated before, ISEP has adopted CDIO in 2007 and that adoption is going on, although at different speeds in the various departments and programs. Figure 11 shows the number of CDIO inspired/compliant courses in first cycle programs during 2008-2009. LEI is the most committed to apply CDIO, having 11/30 courses in which CDIO influence is significant.

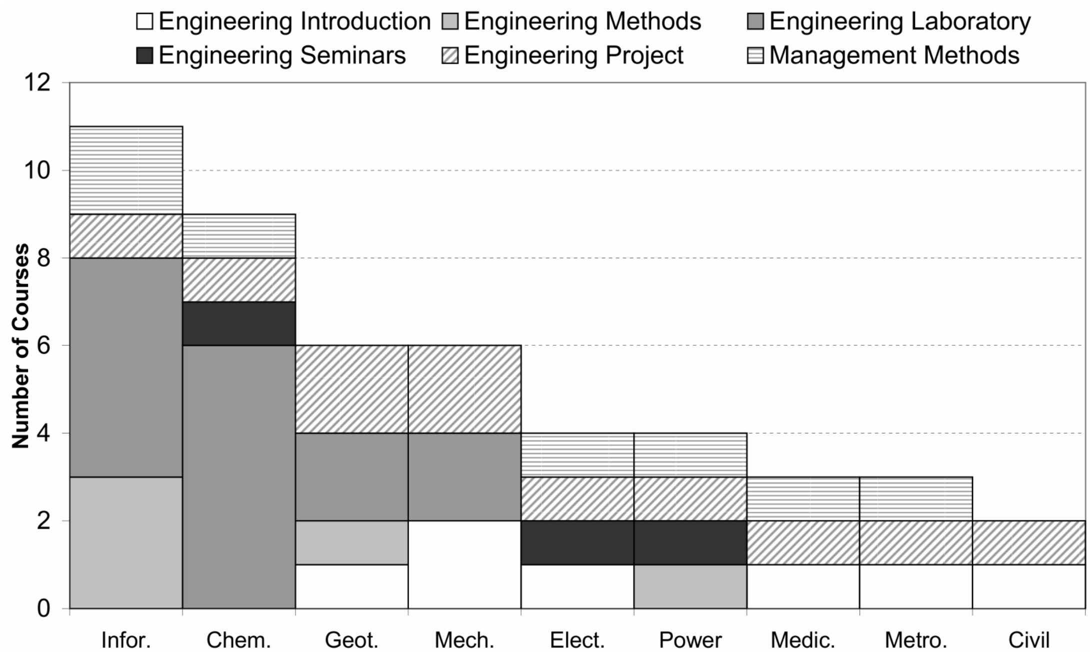

Figure 11. CDIO inspired/compliant courses in ISEP first cycle programs during 2008-2009 (Informatics Engineering is the leftmost column)

Many new Bologna engineering second cycles have started at ISEP during 2008-2010 in which CDIO ideas and practices have impregnated the study plan and the curricula. The same will happen in the new programs that will start in September 2010. It will take some years before a large scale and rigorous assessment of CDIO impacts is possible at ISEP. For the moment, the Informatics Engineering Department is the most committed one and benefits from CDIO adoption and application are showing off…

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[8] European Credit Transfer and Accumulation System (ECTS), http://ec.europa.eu/education/lifelong-learning-policy/doc48_en.htm

Biographical Information

António Costa is Accreditation/Certification Coordinator in ISEP. He was the Director of Informatics Engineering programs during 2002-2007. He also was the responsible for the reformulation of Informatics Engineering programs. He currently is the CDIO contact person for ISEP.

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ANNEX 1 – THE CDIO GENERIC SYLLABUS TOPICS FOR LEVELS 1-3

1 TECHNICAL KNOWLEDGE AND REASONING
1.1 KNOWLEDGE OF UNDERLYING SCIENCES
1.1.1 Mathematics
1.1.2 Physics
1.1.3 Other Engineering Subjects
1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
1.2.1 Algorithms
1.2.2 Application Programs
1.2.3 Computer Programming
1.2.4 Information Management (Database)
1.2.5 IT Resource Planning
1.2.6 Hardware and devices
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE
1.3.1 Human-Computer Interface
1.3.2 Information Systems
1.3.3 Intelligent Systems
1.3.4 Networking and Communications
1.3.5 Systems Development Through Integration
2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
2.1 ENGINEERING REASONING AND PROBLEM SOLVING
2.1.1 Problem Identification and Formulation
2.1.2 Modeling
2.1.3 Estimation and Qualitative Analysis
2.1.4 Analysis With Uncertainty
2.1.5 Solution and Recommendation
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY
2.2.1 Hypothesis Formulation
2.2.2 Survey of Print and Electronic Literature
2.2.3 Experimental Inquiry
2.2.4 Hypothesis Test and Defense
2.3 SYSTEM THINKING
2.3.1 Thinking Holistically
2.3.2 Emergence and Interactions in Systems
2.3.3 Prioritization and Focus
2.3.4 Trade-offs, Judgment and Balance in Resolution
2.4 PERSONAL SKILLS AND ATTITUDES
2.4.1 Initiative and Willingness to Take Risks
2.4.2 Perseverance and Flexibility
2.4.3 Creative Thinking
2.4.4 Critical Thinking
2.4.5 Awareness of One's Personal Knowledge, Skills and Attitudes
2.4.6 Curiosity and Lifelong Learning
2.4.7 Time and Resource Management
2.5 PROFESSIONAL SKILLS AND ATTITUDES
2.5.1 Professional Ethics, Integrity, Responsibility and Accountability
2.5.2 Professional Behavior
2.5.3 Proactively Planning for One's Career
2.5.4 Staying Current on World of Engineer
3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
3.1 TEAMWORK
3.1.1 Forming Effective Teams
3.1.2 Team Operation
3.1.3 Team Growth and Evolution
3.1.4 Leadership
3.1.5 Technical Teaming
3.2 COMMUNICATIONS
3.2.1 Communications Strategy
3.2.2 Communications Structure
3.2.3 Written Communication
3.2.4 Electronic/Multimedia Communication
3.2.5 Graphical Communication
3.2.6 Oral Presentation and Inter-Personal Communications
3.3 COMMUNICATIONS IN FOREIGN LANGUAGES
3.3.1 English
3.3.2 Languages of Regional Industrialized Nations
3.3.3 Other Languages
4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
4.1 EXTERNAL AND SOCIETAL CONTEXT
4.1.1 Roles and Responsibility of Engineers
4.1.2 The Impact of Engineering on Society
4.1.3 Society's Regulation of Engineering
4.1.4 The Historical and Cultural Context
4.1.5 Contemporary Issues and Values
4.1.6 Developing a Global Perspective
4.2 ENTERPRISE AND BUSINESS CONTEXT
4.2.1 Appreciating Different Enterprise Cultures
4.2.2 Enterprise Strategy, Goals and Planning
4.2.3 Technical Entrepreneurship
4.2.4 Working Successfully in Organizations
4.3 CONCEIVING AND ENGINEERING SYSTEMS
4.3.1 Setting System Goals and Requirements
4.3.2 Defining Function, Concept and Architecture
4.3.3 Modeling of System and Ensuring Goals Can Be Met
4.3.4 Development Project Management
4.4 DESIGNING
4.4.1 The Design Process
4.4.2 The Design Process Phasing and Approaches
4.4.3 Utilization of Knowledge in Design
4.4.4 Disciplinary Design
4.4.5 Multidisciplinary Design
4.5 IMPLEMENTING
4.5.1 Designing the Implementation Process
4.5.2 Hardware Manufacturing Process
4.5.3 Software Implementing Process
4.5.4 Hardware Software Integration
4.5.5 Test, Verification, Validation and Certification
4.5.6 Implementation Management
4.6 OPERATING
4.6.1 Designing and Optimizing Operations
4.6.2 Training and Operations
4.6.3 Supporting the System Lifecycle
4.6.4 System Improvement and Evolution
4.6.5 Disposal and Life-End Issues
4.6.6 Operations Management

ANNEX 2 – THE LEY SYLLABUS TOPICS FOR LEVELS 1-3, MAY 2008 VERSION

1 TECHNICAL KNOWLEDGE AND REASONING
1.1 KNOWLEDGE OF UNDERLYING SCIENCES
1.1.1 Mathematics
1.1.2 Physics
1.1.3 Other Engineering Subjects
1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
1.2.1 Algorithms and Computer Programming
1.2.2 Software Engineering
1.2.3 Information Management (Database)
1.2.4 Computer Systems and Networks
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE
1.3.1 Computer Programming
1.3.2 Human-Computer Interface
1.3.3 Intelligent Systems
1.3.4 Information Systems
1.3.5 Networking and Communications
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2.3.1 Thinking Holistically
2.3.2 Emergence and Interactions in Systems
2.3.3 Prioritization and Focus
2.4 PERSONAL SKILLS AND ATTITUDES
2.4.1 Creative Thinking/Critical Thinking
2.4.2 Time and Resource Management
2.4.3 Perseverance and Flexibility
2.4.4 Lifelong Learning
2.5 PROFESSIONAL SKILLS AND ATTITUDES
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3.3.1 English
3.3.2 Other Languages
4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
4.1 ENTERPRISE AND SOCIETAL CONTEXT
4.1.1 Roles and Responsibility of Engineers
4.1.2 Understanding the Impact of Engineering in a Global Perspective
4.1.3 Working Successfully in Organizations
4.2 CONCEIVING AND ENGINEERING SYSTEMS
4.2.1 Setting System Goals and Requirements
4.2.2 Defining Function, Concept and Architecture
4.2.3 System Modeling Process
4.3 DESIGNING
4.3.1 The Design Process
4.3.2 Utilization of Knowledge in Design
4.3.3 Disciplinary Design
4.3.4 Multidisciplinary Design
4.4 IMPLEMENTING
4.4.1 Software Implementing Process
4.4.2 Hardware Software Integration
4.4.3 Test, Verification, Validation and Certification
4.4.4 Implementation Management
4.5 OPERATING
4.5.1 Training and Operations
4.5.2 Supporting the System Lifecycle
4.5.3 Operations Management

ANNEX 3 – MEI SYLLABUS TOPICS FOR LEVELS 1-3, JULY 2009 DRAFT VERSION

1 TECHNICAL KNOWLEDGE AND REASONING
1.1 KNOWLEDGE OF UNDERLYING SCIENCES
1.1.1 Mathematics
1.1.2 Physics
1.1.3 Other Engineering Subjects
1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE
1.2.1 Algorithms
1.2.2 Application Programs
1.2.3 Computer Programming
1.2.4 Information Management (Database)
1.2.5 IT Resource Planning
1.2.6 Hardware and devices
1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE
1.3.1 Human-Computer Interface
1.3.2 Information Systems
1.3.3 Intelligent Systems
1.3.4 Networking and Communications
1.3.5 Systems Development Through Integration
1.3.6 Information Security
1.3.7 Systems' Usability
1.3.6 Computer Systems
1.3.7 Distributed Systems
1.3.8 Image Treatment and Integration
1.3.9 Audio Treatment and Integration
1.3.10 Video Treatment and Integration
2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES
2.1 ENGINEERING REASONING AND PROBLEM SOLVING
2.1.1 Problem Identification and Formulation
2.1.2 Modeling
2.1.3 Estimation and Qualitative Analysis
2.1.4 Analysis With Uncertainty
2.1.5 Solution and Recommendation
2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY
2.2.1 Hypothesis Formulation
2.2.2 Survey of Print and Electronic Literature
2.2.3 Experimental Inquiry
2.2.4 Hypothesis Test and Defense
2.3 SYSTEM THINKING
2.3.1 Thinking Holistically
2.3.2 Emergence and Interactions in Systems
2.3.3 Prioritization and Focus
2.3.4 Trade-offs, Judgment and Balance in Resolution
2.4 PERSONAL SKILLS AND ATTITUDES
2.4.1 Initiative and Willingness to Take Risks
2.4.2 Perseverance and Flexibility
2.4.3 Creative Thinking
2.4.4 Critical Thinking
2.4.5 Awareness of One's Personal Knowledge, Skills and Attitudes
2.4.6 Curiosity and Lifelong Learning
2.4.7 Time and Resource Management
2.5 PROFESSIONAL SKILLS AND ATTITUDES
2.5.1 Professional Ethics, Integrity, Responsibility and Accountability
2.5.2 Professional Behavior
2.5.3 Proactively Planning for One's Career
2.5.4 Staying Current on World of Engineer

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION
3.1 TEAMWORK
3.1.1 Forming Effective Teams
3.1.2 Team Operation
3.1.3 Team Growth and Evolution
3.1.4 Leadership
3.1.5 Technical Teaming
3.2 COMMUNICATIONS
3.2.1 Communications Strategy
3.2.2 Communications Structure
3.2.3 Written Communication
3.2.4 Electronic/Multimedia Communication
3.2.5 Graphical Communication
3.2.6 Oral Presentation and Inter-Personal Communications
3.3 COMMUNICATIONS IN FOREIGN LANGUAGES
3.3.1 English
3.3.2 Languages of Regional Industrialized Nations
3.3.3 Other Languages
4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT
4.1 EXTERNAL AND SOCIETAL CONTEXT
4.1.1 Roles and Responsibility of Engineers
4.1.2 The Impact of Engineering on Society
4.1.3 Society's Regulation of Engineering
4.1.5 Contemporary Issues and Values
4.1.6 Developing a Global Perspective
4.2 ENTERPRISE AND BUSINESS CONTEXT
4.2.1 Appreciating Different Enterprise Cultures
4.2.2 Enterprise Strategy, Goals and Planning
4.2.3 Technical Entrepreneurship
4.2.4 Working Successfully in Organizations
4.3 CONCEIVING AND ENGINEERING SYSTEMS
4.3.1 Setting System Goals and Requirements
4.3.2 Defining Function, Concept and Architecture
4.3.3 Modeling of System and Ensuring Goals Can Be Met
4.3.4 Development Project Management
4.4 DESIGNING
4.4.1 The Design Process
4.4.2 The Design Process Phasing and Approaches
4.4.3 Utilization of Knowledge in Design
4.4.4 Disciplinary Design
4.4.5 Multidisciplinary Design
4.4.6 Multi-Objective Design (DFX)
4.5 IMPLEMENTING
4.5.1 Designing the Implementation Process
4.5.3 Software Implementing Process
4.5.4 Hardware Software Integration
4.5.5 Test, Verification, Validation and Certification
4.5.6 Implementation Management
4.6 OPERATING
4.6.1 Designing and Optimizing Operations
4.6.2 Training and Operations
4.6.3 Supporting the System Lifecycle
4.6.4 System Improvement and Evolution
4.6.5 Disposal and Life-End Issues
4.6.6 Operations Management

ANNEX 4 – INQUIRY ABOUT ACM COMPUTING CURRICULA SKILLS/COMPETENCES

ACM Computing Curricula Area	Skills / Competences Demonstrated
Algorithms	Prove theoretical results
	Develop solutions to programming problems
	Develop proof-of-concept programs
	Determine if faster solutions possible
Application programs	Design a word processor
	Use word processor features well
	Train and support word processor users
	Design a spreadsheet
	Use spreadsheet features well
	Train and support spreadsheet users
Computer programming	Do small-scale programming
	Do large-scale programming
	Do systems programming
	Develop new software systems
	Create safety-critical systems
	Manage safety-critical projects
Hardware and devices	Design embedded systems
	Implement embedded systems
	Design computer peripherals
	Design complex sensor systems
	Design a chip
	Program a chip
	Design a computer
Human-computer interface	Create a software user interface
	Produce graphics or game software
	Design a human-friendly device
Information systems	Define information system requirements
	Design information systems
	Implement information systems
	Train users to use information systems
	Maintain and modify information systems
Information management (Database)	Design a database mgt. system
	Use a database system
	Implement information retrieval software
	Select database products
	Configure database products
	Manage databases
	Train and support database users
IT resource planning	Develop corporate information plan
	Develop computer resource plan
	Schedule/budget resource upgrades
	Install/upgrade computers
	Install/upgrade computer software
Intelligent systems	Design auto-reasoning systems
	Implement intelligent systems
Networking and Communications	Design network configuration
	Select network components
	Install computer network
	Manage computer networks
	Implement communication software
	Manage communication resources
	Implement mobile computing system
	Manage mobile computing resources
Systems Development Through Integration	Manage an organization's web presence
	Configure & integrate e-commerce software
	Develop multimedia solutions
	Configure & integrate e-learning systems
	Develop business solutions
	Evaluate new forms of search engine