Engineering the Computer Science and IT

Edited by
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Preface

It has been many decades, since Computer Science has been able to achieve tremendous recognition and has been applied in various fields, mainly computer programming and software engineering. Many efforts have been taken to improve knowledge of researchers, educationists and others in the field of computer science and engineering. This book provides a further insight in this direction. It provides innovative ideas in the field of computer science and engineering with a view to face new challenges of the current and future centuries.

This book comprises of 25 chapters focusing on the basic and applied research in the field of computer science and information technology. Authors have made efforts to provide theoretical as well as practical approaches to solve open problems through their excellent research work. This book increases knowledge in the topics such as web programming, logic programming, software debugging, real-time systems, statistical modeling, networking, program analysis, mathematical models and natural language processing.

Basically this book opens a platform for creative discussion for current and future technologies in the field of computer science and engineering, these are essential for students, researchers, academicians and industry related people to enhance their capabilities to capture new ideas. Also they provide valuable solutions regarding information technology to an international community.

The editor and authors hope that this book will provide valuable platform for the new researchers and students who are interested to carry out research in the fields of computer science and information technology. Finally, we are thankful to I-Tech Education and publishing organization which provides the best platform to integrate researchers of the whole world though this book.

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Transatlantic Engineering Programs: An Experience in International Cooperation

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1. Introduction

Computing curricula are designed to promote the education of engineers and scientists using a sound theoretical basis and practices useful in the job market. The major objective of a well established curriculum is to provide a rigorous educational background, while giving students tools for future life-long learning. Typically, the faculty experience allows them to design curricula considering the fundamental concepts and basic principles of their discipline. However, feedback from future employers of graduates is critical to the design of modern curriculum fully matching the continuously changing job market demands.

Real-Time Software-Intensive Control systems (RSIC) are often safety-critical, and their reliability is paramount. There is an increasing importance and demand for efficient development of high quality RSIC systems. No other technology domain has experienced progress with more impact on engineering education. To keep up with this progress, engineering curricula require continuous modifications to prepare students for the technological challenges of the modern workplace. Rapid progress of computing technologies is the major reason programs like electronics, computer and software engineering, robotics, and control engineering need continuous updates.

An additional issue is the internationalization and globalization of complex systems development. Several large companies, specifically in the aerospace industry, engage international teams working in geographically diverse locations often using diverse standards, guidelines, and processes. It is advantageous for future engineers to understand the implications of international collaboration and to appreciate cultural differences.

The findings presented in this paper are results of a two-year long project called ILERT (International Learning Environment for Real-Time Software Intensive Control Systems), supported by the American Fund for Improvement of Postsecondary Education (FIPSE) and the European Commission, and executed by a consortium of one American and three European universities: Embry Riddle Aeronautical University (ERAU - Daytona Beach, FL, USA), AGH University of Science and Technology (AGH - Krakow, Poland), University of Technology (BUT - Brno, Czech Republic), and Université Joseph Fourier (UJF - Grenoble, France). The key documents resulting from the project are located at the project website (ILERT, 2009). This paper describes a methodology for the creation of a multinational engineering program, designed to produce graduates capable of working efficiently in multidisciplinary teams engaged in international collaboration on industrial RSIC projects -- projects that additionally may require conformance to specific standards mandated by regulatory authorities. Related issues explored in the ILERT project were identification of learning objectives and outcomes, analysis of credit transfer and program assessment, and development of a RSIC curriculum framework that could be easily adapted in diverse engineering curricula with different program emphases like software, control, communication, and digital systems.

The paper is structured as follows. We first describe the methodology leading to creation of an international engineering program based on the ILERT project experiences. The subsequent sections describe the components of the methodology: the identification of the curriculum learning objectives and outcomes, program assessment, student mobility and credit transfer, and the proposed curriculum framework.

2. Methodology

The development and implementation of international transatlantic engineering curricula was conducted in several phases (Kornecki 2009). The Atlantis-ILERT project defined three phases: Preparatory Phase, Research Phase, and Pilot Implementation Phase (see Fig. 1). The fourth phase (Long Term Application) started later as a separate project: Atlantis-DeSIRE^2.

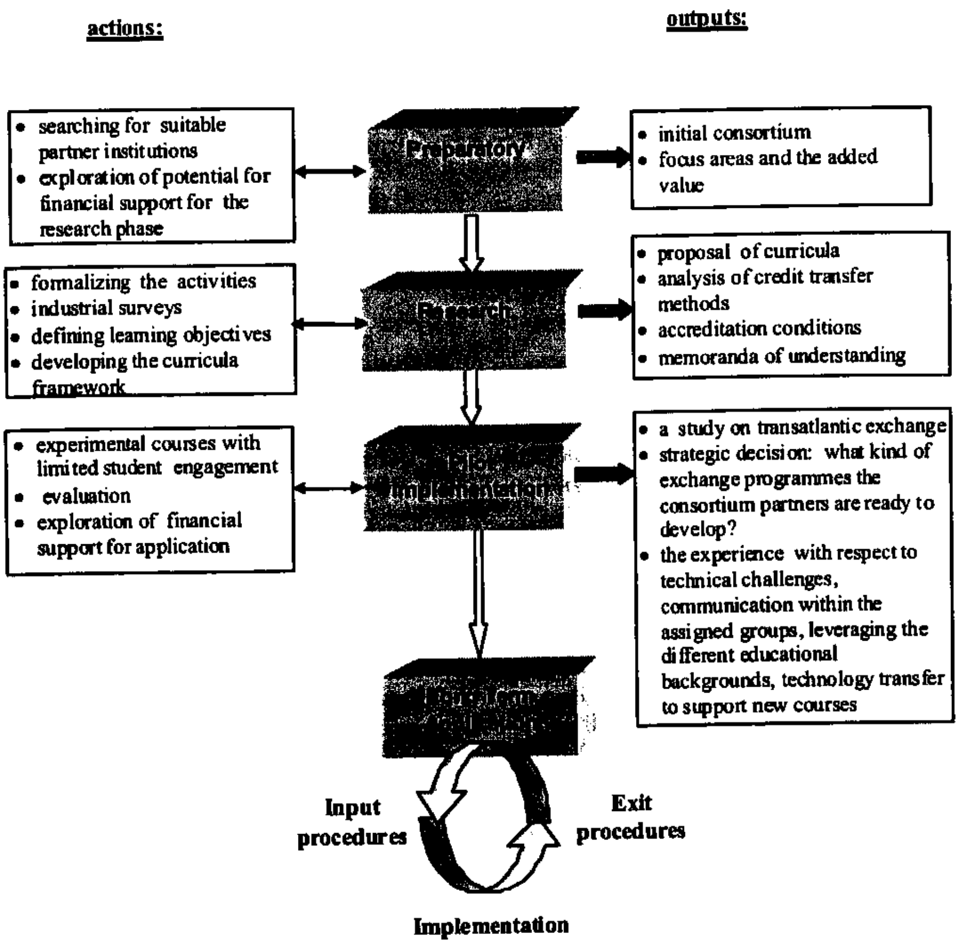

Fig. 1. Atlantis-ILERT Project Methodology

2.1 Preparatory Phase

The Preparatory Phase started with informal discussion between faculty of academic institutions of both sides of Atlantic about advantages of international relationships. The following identify the activities of this phase:

- Inventory of international informal personal contacts already existing in institutions.
- Brainstorming on the type of activities to be engaged and potential partners, defining goals and priorities (like curriculum-related cooperation and international exchanges of the faculty expertise).
- Proposing an initial consortium of universities offering expertise in the similar lines of engineering education. A common thread within the programs at all the partner institutions must be identified.

- Identifying the focus areas in the existing programs of the consortium partners. It was assumed that the selected courses from the focus areas must constitute a coherent value added, if selected by exchange students.
- Exploration of potential for financial support for research (including industry funding, international cooperation programs, international projects, international and national systems of grants).

The preparatory phase was concluded by formalities leading to establishing of the consortium of university partners and writing a successful proposal for funding the described here educational research project.

2.2 Research Phase

The research phase started with the analysis of industry requirements related to graduates in the proposed domain. The collected data were analyzed and the results were used to help identify academic program learning objectives and outcomes, thus preparing a base for creation of a new curriculum framework.

The following steps can be identified in this phase:

- **Defining learning objectives** and outcomes, developing the curriculum framework, exploring the partners' programs commonalities and laboratory infrastructure, comparing the curriculum content, and analyzing of the educational process assessment. The existing curricula were reviewed as a way of prioritizing and integrating the various elements, in order to fulfill the requirements of interdisciplinary specialization. It should be noted, that the existence of common characteristics does not imply automatic commonality among the ways in which individual institutions pursue common educational objectives. Universities often create their own procedures and methods. By reviewing existing programs and comparing them with industry needs, this research phase has identified missing topics and topics that could be strengthened. As the final outcome of this phase, a comprehensive list of courses related to the RSIC domain offered at all of the partner institutions was compiled.
- **Curriculum development** started with classifying courses into one of four categories: General Education (languages, humanities, social science), Math and Science (mathematics, physics), Basic (required towards the completion of the degree in the given line of study), and Advanced, which focuses on a selected engineering specialization. It was critical to identify and agree on the minimal number of contact hours required to complete the entire engineering program and the percentage of effort assigned to the four curriculum categories given above. This was followed by a practical case study adapting selected curricula of partner institutions by including components of interdisciplinary specialization, thus creating an engineering program acceptable to all partner organizations.
- **Credit transfer and accreditation issues.** The development of new curriculum framework in engineering may in turn require new approaches to their validation and accreditation. The transfer of credits and grades is a challenging undertaking for university systems, which are significantly different in Europe and the U.S. Existing and emerging structures for accreditation, quality control, and credit transfer (such as the European Credit Transfer and Accumulation Scheme) have been analyzed. It should

be noted that the proposed curriculum units must be reviewed according to ABET standards (and the applicable standards of Ministry of Higher Education in the European countries), focusing on the objectives and outcomes of the educational activity.

- **Students' mobility plan.** Based on the developed curricula, a general schedule of students' mobility between partners' institutions was proposed, opening the possibility of collaborating and enrolling in the courses offered in four partner sites.
- **Formalizing the activities** included signing formal agreements or memoranda of understanding, defining responsibilities and structure of communication.

2.3 Pilot Implementation Phase

Agreements between partner institutions, or "memoranda of understanding," in delivery and mutual recognition of courses were prepared at the beginning of this phase. During the pilot implementation phase, the experimental courses were created, instructional material was developed, and experimental concurrent delivery with limited student engagement was initialized. The participating students were supervised by coordinators from the partners' institutions. During this phase, a lot of experience was gained on the technical challenges, international cooperation, communication within the assigned groups, leveraging the different educational backgrounds in the interdisciplinary context, technology transfer, and interactions between international students and staff. The Final Report, including guidelines for extension of the approach for long-term application, is the most valuable output of this phase.

An important part of the pilot implementation phase is the analysis of the sources and mechanisms of financial support for future transatlantic educational collaboration. Generally, tangible and intangible resources, essential to the success of the project's future, must be considered. Tangible resources include finances, facilities, and time. Intangible resources include will, commitment, and the ability to sustain the effort to conclusion.

This phase can be concluded with important strategic analysis and decision-making: What kind of exchange programs would the consortium partners be able to develop? Would a partner institution initiate a dual degree program or develop one or more aspects of a current program with other international partners? The general goals, including number of mobility years and the number of mobility students must be decided at this stage.
The selection between single or dual degree programs or other forms of partner institution engagement should also be made (see Table 1).

2.4 Long Term Application Phase

In the long term application and evaluation phase, internal and external procedures are developed. The final agreement between partners on credit transfer, accreditation, tuition, and student selection must be accepted by all partner institutions. The agreement must also define: responsibility of institution and students, admission requirements, registration procedures, specific learning agreement form (e.g. one semester course, receives recognition upon return), tuition waiver, language/culture engagement of the students and logistic/administration details.

Student spends abroad	Expected results	Formal effects	Comments
One semester in a partner university	• single diploma in home institution • mobility students focus on an area of concentration not available at home institution • experiences related to cultural immersion	• US student receive special certificate of completion of a specific focus area • EU student receive appropriate entry in their Diploma and the Supplement identifying the focus area.	• bilateral agreements are necessary
Two-three semesters in the partner university	• two diplomas are received • students may receive a new specialization, not offered at single university • experiences related to cultural immersion	Dual degree	• more detailed bilateral agreements are necessary • requires full validation and accreditation of learning programs. • ethical issue: is it fair that student receives two diplomas without any increase of his work?

Table 1. Examples Of Final Partner Institution Engagement

The long-term mobility of students includes two cyclic steps: input and implementation procedures.

2.4.1 Input Procedures

a) Internal Procedures:

- Setting deadlines for the partners' institutions
- Distributing information on international mobility - to recruit students
- Performing internal selection procedures for applicants from the home university (eligibility, mandatory orientation, interviews, language skills)
- Performing placement procedures for incoming exchange students:
- Assigning the mentors to incoming students
- Internal selection of the teachers interested to participate in the mobility exchange.

b) External Procedures:

- Exchange information with the partner university on the selection results.
- Identify the courses available for overseas students during the mobility period
- Signing joint learning agreement forms.
- Procedures for practical issues such as housing, insurance, etc.

2.4.2 Implementation Procedures

a) Assistance to the Internal Applicants

- Explaining the program options and site/course selection
- Helping students with the application procedure.

b) Assistance to the External Applicants

- Helping with questions from students/teachers interested in mobility exchange (terms of exchange, reporting, application process).
- Facilitating mentoring process for incoming students
- Monitoring and reporting the students' progress

It should be noted that the long-term phase, in addition to continuous evaluation of the program, must include the exit and evaluation component, where the entire program is given to critique and scrutiny with the goal to learn the lessons and improve the process. The components of such evaluation will include the assessment and evaluation of the individual students at the end of the mobility period and the overall assessment and evaluation of the mobility exchange.

3. Identification of Learning Objectives and Outcomes

There is a general agreed upon set of non-technical skills and behaviors expected from engineering school graduates, such as oral and written communications, professional ethics, team skills, etc. The starting point for designing a specific program curriculum is to identify the technical knowledge areas and skills required from the graduating students. The program educational objectives can be defined in terms of the expected graduates' proficiency, specifying the profile of graduates and their competencies. An often used phrase when defining the objectives is that the graduates of the program "are able to" perform certain specific tasks. Examples may be: analyze the problem, elicit requirements, design a circuit, apply a method, use a tool, etc.

There are two common ways to define an objective. One is a "know how" objective: describing a task one performs. Another is a "knowledge" objective: describing a topic that one understands and is able to convey knowledge about. Examples of such would be:

- "Know How" to manage database: e.g. to install the database software, to manage users, to create/update/delete database record, etc.
- "Knowledge" of a database concept and model: e.g. to describe the attributes of a database logical model, to give examples of such models, to identify security vulnerabilities, to describe SQL syntax, etc.

The Accreditation Board of Engineering Technology, ABET, (ABET, 2007) defines Program Educational Objectives (PEO) and Program Outcomes (PO). Program Educational Objectives are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. An example of PEO would be: "graduates will pursue successful careers as professional software engineers". Program Outcomes are narrower statements that describe what students are expected to know and be able to do by the time of graduation. The PO relate to the skills, knowledge, and behaviors that students acquire in their matriculation through a program. An example would be: "graduates will be able to work effectively as part of a software development team." The PO can be assessed during the course of studies and immediately after students' graduation. The RSIC PEO and PO presented in this document were developed using the ABET interpretation.

A survey (Pilat, 2008), solicited from a representative sample of industry engaged in real-time software-intensive control systems, was designed to get feedback on what the employers expect graduates to possess in terms of skills and attitudes, as well as the knowledge of technical topics. The data collected from 43 companies in four countries (USA, France, Poland, and Czech Republic) were analyzed and the results were used to help identify academic program educational objectives and outcomes, thus preparing a base for creation of a new curriculum framework. The resulting objectives and outcomes, listed in (Kornecki, 2008), guided subsequent ILERT activities and the development of the RSIC Curriculum Framework.

4. Program Assessment

To help ensure achievement of program objectives and outcomes, an assessment and evaluation process, based on student performance and other indicators, must be in place. Considering long term impact, the assessment process for program educational objectives may involve instruments, such as the following:

- Surveys of alumni and their employers
- Feedback from an industry advisory board
- Alumni focus group meetings
- Examination of a successful industrial project, involving program alumni

A short-term focused assessment process for program outcomes might involve instruments, such as the following:

- Annual review of student performance in selected indicator courses by the program faculty
- Feedback from graduating seniors and recent graduates
- Feedback from an industry advisory board
- Discussion of the department curriculum committee
- Analysis of data reflecting student cooperative education activities, involvement in professional societies, choice of minor programs, etc.
- Student Portfolios

Table 2 describes a process for the assessment and evaluation of achievement of program educational objectives and program outcomes. This table provides a high-level description of the steps and activities that are part of the assessment process. This process is meant to provide a framework for carrying out assessment and evaluation; the actual process might vary from one RSIC program to another. The indicator courses, defined by the faculty, are critical in assessing program outcomes. Each program outcome should have one or more courses that contribute to its achievement. Performance in indicator courses also provides information to the faculty regarding performance in prerequisite courses.

A survey of graduating seniors and an exit interview can be a good source of information regarding the curriculum. While senior information is valuable, graduating seniors may lack sufficient context to correctly identify the degree to which the program achieves program outcomes; thus, information from the senior survey is considered only moderately reliable. In contrast, feedback from the program alumni employed for two or more years, as well as the feedback from industry employing graduates, provides stronger evidence of the degree to which the program has achieved the desired outcomes.

Step	Description	Schedule
Determine Constituencies	A discussion at the faculty meeting identifies the constituencies for the RSIC program. (e.g., students, employers, faculty)	Initially
Determine Objectives and Outcomes	Based on the needs of the constituencies, the faculty, determine RSIC Program Educational Objectives and Program Outcomes	Initially
Determine Assessment Items and Process	The program faculty identify what will be assessed and how and when achievement of objectives and outcomes will be evaluated (with the use of elements such as indicator courses, surveys, interviews, data collection methods)	Start of Assessment
Collect Data and Opinion	Information and opinion about achievement of Program Outcomes is collected.	Annually
Assess Program Outcomes	The data collected is used to assess whether the Program Outcomes are being achieved.	Annually
Evaluate Program Educational Objectives	The data collected is used to evaluate whether the PEOs of the RSIC program are achieved. There is a determination of whether the objectives need to be modified.	Every Three Years
Modify Program	Based on outcomes assessment and on the results of program educational objectives evaluation and review, the faculty make changes in the program, its educational objectives, and/or the program outcomes.	Every Three Years
Evaluate Assessment Process	The faculty evaluate the effectiveness of the assessment process and make changes as appropriate.	Every Three Years

Table 2. Assessment Process

5. Student Mobility and Credit Transfer

The credit systems are used not only to evaluate the students but also for mobility, i.e. the situation when a student leaves an institution to continue studies in another one. Such a situation is called permanent mobility (in Europe) or transfer student (in USA). With the impact of the Erasmus Program, a new type of transient mobility exists, when a student spends a semester, or a year, in a partner university. In such situation, the student gets the diploma from his home university, except in the case of double-degree curricula. The same situation exists in the USA also, allowing a student to spend part of his program in another institution as a visiting student. The procedures require an agreement between the exchange institutions that considers the content and learning outcomes of the partner curriculum.

When credits are used for mobility, the courses must be "equivalent". The rules of equivalence could vary between the institutions and academic programs but, generally, the student will keep academic record in the home university and adhere to the admission procedure in the host university. This admission procedure will be based on the actual contents and learning outcomes of the courses followed by the student in the sending institution.

When credits are used for students' evaluation, the situation is the same in the USA and in the Europe. Note that the European countries generally use their own national or local grading systems (Hilburn, 2008). The credits are given after a semester (or a term) to continue the academic program, or after the completion of the entire curriculum to be recorded in the final diploma.

5.1. In Europe

The European Credit Transfer System (ECTS) (Bologna Working Group, 2005) has been designed to facilitate the mobility of students among the member countries. The initial purpose was not to use ECTS as an accumulation system for life-long learning, nor to use them to characterize the level of the course. As a result of the Bologna declaration in June 1999, it was decided to use ECTS as an accumulation system.

The ECTS is designed to measure the actual workload of students for a given course. The workload reflects the quantity of work and includes all the pedagogical components such as lectures, seminars, independent and private study, preparation of projects and examinations, placements, dissertation work, etc. The workload measure is based on a student-centered approach. A complete year is equivalent to 60 ECTS credits. The credits are allocated on a relative basis, since the complete year is fixed. The student workload of a full-time study program in Europe amounts, in most cases, to 1500-1800 hours per year, so one ECTS credit reflects about 30 hours of workload for an average student.

Credits in ECTS can only be obtained after successful completion of the work required, and appropriate assessment of the learning outcomes achieved. Learning outcomes are sets of competencies, expressing what the student will know, understand or be able to do after completion of a process of learning.

The performance of a student is documented by a local/national grade. It is good practice to also add an ECTS grade, in particular in case of credit transfer. The ECTS grading scale ranks the students on a statistical basis. Therefore, statistical data on student performance is a prerequisite for applying the ECTS grading system. Grades are assigned among students with passing grades as follows: A best 10%, B next 25%, C next 30%, D next 25%, and F last 10%. A distinction is made between the grades FX and F that are used for unsuccessful students. FX means: "fail- some more work required to pass" and F means: "fail – considerable further work required". The inclusion of failure rates in the Transcript of Records is optional.

Since the ECTS does not measure the quality of performance, content, or level, certain additional rules must apply when ECTS is used as an accumulation system. In addition to the number of credits required, the type of the course and the level at which those credits must be obtained must be added. The levels are defined as:

- Basic Level Course - Introduction to a subject

- Intermediate Level Course - Expand basic knowledge
- Advanced Level Course - Further strengthen of expertise
- Specialized Level Course - To build up knowledge and experiences in a special field or discipline

The following types of courses are defined:
- Core course (part of the core of a major program of studies)
- Related course (supporting course for the core)
- Minor course (optional course or supplementary course)

These accumulation system features were preliminary work for the introduction of the European Qualification Framework (EQF).

To support the administration and management of student progress, the European Commission proposed accompanying documents:
- Application Form: the agreement to be signed by the partners.
- Learning Agreement: contains the list of courses to be taken, with the ECTS credits which will be awarded for each course.
- Transcript of Records: documents the performance of a student by showing the list of courses taken, the ECTS credits gained, local or national credits, if any, local/ECTS grades awarded; the transcript of records comprises information about the type of courses followed abroad, the duration of the course (one year (Y), one semester (1S) or one term (1T)), the local grades (in the national grading system), the ECTS grades and the ECTS credits.

Table 3 gives an example of a Transcript of Records, which means that the student followed the course "RT-M7 Security of information systems", the duration of the course was one semester, the local grade was 14/20, which stands for an ECTS grade of B (statistical, depending on the actual results of the whole class), and the amount of ECTS credits for this course is 4. The institutional or local grading system should be explained. For instance, in France, the grading system is equivalent to a percentage, but it is given in a scale on which the higher mark is 20 (14/20 for example means 70 %).

Course unit code	Title of the course unit	Duration of the course unit	Local grade	ECTS grade	ECTS credit
RT-M7	Security of information systems	1S	14/20	B	4

Table 3. Example of Transcript of Records

The Diploma Supplement is a document attached to a higher education diploma, providing a standardised description of the nature, level, context, content, and status of the studies successfully completed by the graduate. The purpose of the Diploma Supplement is to provide a description of the competences acquired by the students as a function of the various pedagogical sequences which were validated but also as a function of specific activities (special project, elective course, associations or student organizations engagement, social activities if there are recognized and validated by the instructor).

The Dublin descriptors are descriptors for qualifications awarded to students that signify completions of:

- higher education short cycle (within first cycle)
- Bachelor - first cycle
- Master - second cycle
- Doctorate – third cycle

Descriptors are associated with national frameworks of qualification. Table 4 describes competencies for each of the cycles. The implementation of the competences would vary across institutions.

These features were the preliminary work from the introduction of the European Qualifications Framework (EQF) for lifelong learning (European Commission, 2008). This framework defines three criteria:

- Knowledge: described as theoretical and/or factual,
- Skills: cognitive (use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments)
- Competencies: responsibility and autonomy.

For each of the criteria, eight levels have been defined, from the basic to the most advanced. The EQF proposes the following equivalence between the level of a course and the cycles of study:

- The descriptor for the higher education short cycle (within or linked to the first cycle), corresponds to the learning outcomes for EQF level 5.
- The descriptor for the first cycle in the Framework for Qualifications of the European Higher Education Area in the framework of the Bologna process corresponds to the learning outcomes for EQF level 6.
- The descriptor for the second cycle in the Framework for Qualifications of the European Higher Education Area in the framework of the Bologna process corresponds to the learning outcomes for EQF level 7.
- The descriptor for the third cycle in the Framework for Qualifications of the European Higher Education Area in the framework of the Bologna process corresponds to the learning outcomes for EQF level 8.

Descriptors draw upon other sources some of which are associated with national frameworks of qualification. The descriptors describe variable knowledge, skills, and competencies for each of the levels, and the implementation of the competences is different as a function of the level of the degree.

Competences	1 (Bachelor)	2 (Master)	3 (Doctorate)
Knowledge and understanding	supported by advanced text books with some aspects learned including knowledge at the forefront of their field of study	provides a basis or opportunity for originality in developing or applying ideas often in a research context ..	[includes] a systematic understanding of their field of study and mastery of the methods of research associated with that field..
Applying knowledge and understanding	[through] devising and sustaining arguments	[through] problem solving abilities [applied] in new or unfamiliar environments within broader (or multidisciplinary) context	[is demonstrated by the] ability to conceive, design, implement and adapt a substantial process of research with scholarly integrity .. [is in the context of] a contribution that extends the frontier of knowledge by developing a substantial body of work some of which merits national or international refereed publication ..
Making judgments	[involves] gathering and interpreting relevant data ..	[demonstrates] the ability to integrate knowledge and handle complexity, and formulate judgments with incomplete data ..	[requires being] capable of critical analysis, evaluation and synthesis of new and complex ideas..
Communication	[of] information, ideas, problems and solutions ..	[of] their conclusions and the underpinning knowledge and rationale (restricted scope) to specialist and non-specialist audiences (monologue) ..	with their peers, the larger scholarly community and with society in general (dialogue) about their areas of expertise (broad scope)..
Learning skills	have developed those skills needed to study further with a high level of autonomy ..	study in a manner that may be largely self-directed or autonomous..	expected to be able to promote, within academic and professional contexts, technological, social or cultural advancement ..

Table 4. Dublin Descriptor Competencies

5.2. In the USA

In the United States, there is no national policy or procedure for transfer and acceptance of credit between academic institutions; that is, there is no system similar to the ECTS for governing or administering the transfer of academic credit. Transfer policies and procedures vary from state to state, and from institution to institution. Hence, transfer of credit on a nation-wide basis is complex, and sometimes confusing and inconsistent. The list below describes a variety of transfer categories. These categories presume all colleges and universities are regionally accredited and are either public or independent (not-for-profit).

- Two-year (A.S "Associate of Science" degree and A.A "Associate of Arts" degree) to four-year colleges and universities – these transfer arrangements are often formalized by states or state systems. Students completing an associate of arts or associate of science degree from a community college often can receive full credit and junior standing at another state institution through articulation agreements. Transfer from two-year to four-year may also be by design, in what is called a "two plus two" arrangement. For this arrangement, the student completing the associate's degree moves directly into a coordinated upper level program to complete the bachelor's degree.
- Four-year to four-year colleges and universities – typically not covered by formal arrangements, these may be situations where students enrolled as a regular or "non-degree" students, accumulate credits and wish to transfer them to their "home" institution. The credits often will transfer (assuming a student has earned an acceptable grade), but may not meet specific requirements or may be accepted as elective credit or as "additive" credit (meeting no requirements but listed as transfer credits on your transcript).
- Four-year to two-year institutions – some students take a reverse path, possibly having completed some coursework at a four-year institution and now are seeking a degree at a two-year institution. There are also some "reverse two plus two" programs where a student completes coursework at a four-year institution and returns to a two-year institution to complete a program of study.
- Multiple credits from multiple institutions to a "home" institution – a student may take courses from a variety of institutions, hoping to "bank" them eventually at an institution and earn a degree. This can work, but credits earned in this fashion are subject to greater scrutiny – particularly if the student was not a regularly admitted student at the college or university where credit was earned.
- Proprietary (even when regionally accredited) to public and independent institutions – whether appropriate or not, students attempting to transfer credit from a proprietary institution to a public or independent college or university often face a loss of credit in the transfer process.
- Credits earned through assessment, prior learning, credit equivalency, and other non-traditional means to a "home" institution – there are significant differences in institutional policy regarding the acceptance of credits earned through alternative methods, both in terms of the number that might be acceptable and use of the credits.

Institutions and academic degree programs are accredited by various organization and agencies. Accreditation organizations (state, regional or professional) typically specify high-level requirements for acceptance of transfer credit. Here are two examples:

- The Southern Association of Colleges and Schools (SACS, 2007) is the recognized regional accrediting body in the eleven U.S. Southern states (Alabama, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Texas and Virginia) for those institutions of higher education that award associate, baccalaureate, master's or doctoral degrees. SACS specifies the following standard regarding transfer credit:

  The institution has a defined and published policy for evaluating, awarding, and accepting credit for transfer, experiential learning, advanced placement, and professional certificates *that is consistent with its mission and ensures that course work and learning outcomes are at the collegiate level and comparable to the institution's own degree programs. The institution assumes responsibility for the academic quality of any course work or credit recorded on the institution's transcript.*

- The Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET) is responsible for accrediting U.S. engineering programs. EAC specifies the following criterion regarding transfer credit (EAC, 2008):

  The institution must have and enforce policies for the acceptance of transfer students and for the validation of courses taken for credit elsewhere.

6. Curriculum Framework

The section describes the organization and content of the RSIC curriculum framework. The framework is a high-level curriculum specification describing the architecture and content of the RSIC curriculum, which is detailed enough to guide the development of a RSIC program and to support the RSIC objectives and outcomes (Kornecki, 2008); however, it is flexible enough to account for specializations, constraints, and requirements of various programs, institutions, and regions.

6.1 Curriculum Components

The basic organizational unit for the framework is a RSIC "component". A RSIC component is a curriculum unit which covers theory, knowledge, and practice that supports the RSIC curriculum objective and outcomes. Table 5 describes the RSIC components in six identified RSIC areas: Software Engineering, Digital Systems, Computer Control, Real-Time Systems, Networking, and Systems Engineering.

The proposed RSIC Curriculum Framework does not specify the way in which component topics might be formed into modules or courses. Component topics might be focused in one or two courses, or spread among several courses, along with other non-RSIC topics. The "Final Result" link at (ILERT, 2009) contains the full report on RSIC Curriculum Framework, which provides more detailed specifications for each component: prerequisite knowledge, component learning objectives, information about required facilities and equipment, and guidelines and suggestions for course design and delivery.

In addition to the RSIC components, a curriculum must support requirements for prerequisite knowledge and other material that is required for a graduate of the program to achieve the education objectives and graduation outcomes. It is recommended that the following non-RSIC courses or units be part of a RSIC curriculum, as part of entrance requirements or as courses to provide prerequisite knowledge or to supplement the components as part of a full degree program. The prerequisite knowledge includes such areas as Mathematics (Differential and Integral Calculus, Differential Equations, Discrete Mathematics, Statistics, Linear Algebra...), Physics (Mechanics, Electromagnetism, Thermodynamics, Fluids...), Electrical Engineering (Circuit Analysis, Basic Electronics...), Engineering Economics, and Introduction to Computer Science with Programming.

Software Engineering - SoftEng
software engineering concepts and practices, software lifecycle models, project management, software processes, software modeling and formal representation; software requirements; software architectural and module design; software construction methods and practices, testing and quality assurance; software maintenance; and notations and tools
Digital Systems - DigSys
concepts, methods, techniques, and tools used to support the design of combinational and sequential digital circuits and the design of fault tolerant and advanced networked hardware components.
Computer Control - CompCtrl
concepts of feedback control, time and frequency domains, continuous and discrete models of dynamical systems, state analysis, stability, controllability and observability, controller design, implementing control algorithms in real-time, integrated control design and implementation, use of analysis and design tools
Real-Time Systems - RTSys
timing and dependability properties of software intensive systems, RTOS concepts and applications, concurrency, synchronization and communication, scheduling, reliability and safety
Networking - Network
data communication, network topology, analysis and design, information security, algorithms, encryption, bus architectures, wireless, distributed control and monitoring, etc.
System Engineering - SysEng
system engineering concepts, principles, and practices; system engineering processes (technical and management); system requirements, system design, system integration, and system testing; special emphasis on the development of a RSIC system and the integration of RSIC system elements

Table 5. RSIC Components

In addition to the above areas, there may be institutional, regional, or national requirements in areas of "general education"; for example, there may be requirements for oral and written communication, for arts and humanities, or for the social sciences. These areas also support the RSIC curriculum objectives and outcomes concerned with ethical and professional responsibility, effective communications skills, ability to work as part of a team, and life-long learning.

6.2 Curriculum Structure

The project consortium discussed the potential curricula to include the RSIC curricular areas. The consortium partners not only represents computing programs at four schools from different countries; it represents four programs that provide focus and depth in diverse areas of computing: ERAU - software engineering, AGH - controls and automatics, UJF - networking and telecommunication, and BUT - digital systems.

To verify the practicality and efficacy of the RSIC Curriculum Framework, each ILERT partner analyzed how the Framework could be applied to their program. The challenge was to maintain the program integrity and at the same time include all necessary elements of the

RSIC Framework. Obviously, different programs will treat the RSIC areas differently. For example, the ERAU program may include more courses/units dedicated to software engineering, while AGH will have more content dedicated to controls. Tables 6, 7, 8, and 9 show examples of curricula (semester by semester) in the four partner organizations that meet the above criteria including one or more RSIC components. We abstract from the concrete course names and classify them into eleven categories. Six of them correspond with RSIC components: **SoftEng, DigSys, CompCtrl, RTSys, Network,** and **SysEng**. The other categories include courses that are fundamental to engineering education and are usually considered as prerequisites for RSIC components:

- **Math** - calculus for engineers, differential equations, mathematical logic, discrete mathematics, and probability and statistics.
- **Physics** - general physics, and more specific topics from, e.g. chemistry, mechanics, and fluid theory (includes also preliminary courses in electrical engineering)
- **CompSc** - programming, computer algorithms and data structures, programming languages, operating systems, computer organization.
- **Elective** - technical courses that are outside the RSIC areas, such as advanced databases, compiling techniques, computer graphics, etc. and non-technical elective courses.
- **GenEd** - ethics, philosophy, history, economics, technical writing, communication skills, presentation skills.

Year 1		Year 2		Year 3		Year 4	
Sem 1A	**Sem 1B**	**Sem 2A**	**Sem 2B**	**Sem 3A**	**Sem 3B**	**Sem 4A**	**Sem 4B**
CompSc	CompSc	**SoftEng**	SoftEng	SoftEng	SoftEng	**SysEng**	SysEng
Math	Math	CompSc	**DigSys**	SoftEng	SoftEng	SoftEng	TechElect
Math	Math	Physics	Physics	DigSys	**RTSys**	Practice	TechElect
GenEd	GenEd	GenEd	Math	**CompCtrl**	**Network**	GenEd	OpenElect
GenEd	GenEd	Math	Physics	Network	Math	GenEd	GenEd

Table 6. RSIC Software Engineering Oriented Curriculum (ERAU)

Year 1		Year 2		Year 3		Year 4	
Sem 1A	**Sem 1B (2)**	**Sem 2A (3)**	**Sem 2B (4)**	**Sem 3A (5)**	**Sem 3B (6)**	**Sem 4A (7)**	
Math	Math	**DigSys**	DigSys	DigSys	CompCtrl	CompCtrl	
Math	Math	**CompCtrl**	CompCtrl	CompCtrl	CompCtrl	CompCtrl	
Physics	Physics	Physics	Physics	CompCtrl	CompCtrl	SoftEng	
GenEd	Math	**RTSys**	**SysEng**	SysEng	CompCtrl	RTSys	
GenEd	GenEd	Math	CompCtrl	SysEng	SysEng	SysEng	
CompSc	CompSc	SoftEng	Physics	CompCtrl	CompCtrl	Project	
CompCtrl	**SoftEng**	Math	Physics		**Network**		

Table 7. RSIC Control Oriented Curriculum (AGH)

Year 1		Year 2		Year 3		Year 4
Sem 1A	**Sem 1B**	**Sem 2A**	**Sem 2B**	**Sem 3A**	**Sem 3B**	**Sem 4A**
Math	Math	CompSc	SoftEng	SoftEng	Network	B.S. Thesis
Physics	Physics	CompSc	Network	DigSys	DigSys	
DigSys	**DigSys**	DigSys	CompSc	**SysEng**	CompCtrl	
SoftEng	**SoftEng**	DigSys	**CompCtrl**	**RTSys**	Term Project	
SoftEng	DigSys	**Network**	CompCtrl	Network		
GenEd	GenEd	GenEd	GenEd	GenEd	GenEd	

Table 8. RSIC Digital System Oriented Curriculum (BUT)

Year 1		Year 2		Year 3		Year 4	
Sem 1A	**Sem 1B**	**Sem 2A**	**Sem 2B**	**Sem 3A**	**Sem 3B**	**Sem 4A**	**Sem 4B**
Math	Math	Math	Physics	SoftEng	TechElect	**DigSys**	SoftEng
GenEd	GenEd	GenEd	Network	GenEd	GenEd	GenEd	EMC
Physics	Physics	Physics	**SysEng**	Network	Project	DigSys	**CompCtrl**
CompSc	**SoftEng**	Network	Project	Network		Physics	DigSys
Network	**Network**	Network		Network		**RTSys**	Project

1. *The program represents three year of a bachelor program and the 1st year of a 2-year master program.*
2. *The project is sometimes completed in industry (in particular in the last year of the bachelor or masters' programs).*

Table 9. A RSIC Network Oriented Curriculum (UJF)

A capstone design project is a key feature of most (if not all) undergraduate engineering curricula. Because of the complexity and criticality of the RSIC curriculum and its international nature, a team project is essential and challenging. Such course shall have the following features:

- Distributed student teams, with members from four partner institutions, design, develop and test a multi-robot system involving search and communication.
- The project made use of the material from all six of the RSIC components areas.
- Teams followed a defined process, use proven engineering practices, and document all work.

7. Conclusions

We believe the Atlantis-ILERT project has strengthened international cooperation and the global links in engineering education. The Project Methodology discussed in this paper summarizes and formalizes the lessons learned by the project partners, and presents principles and practices that can be used by other international collaborative groups seeking to develop curricula that serve the global community.

The RSIC curriculum framework not only provides a model for development of curricula that are critical to so much of human endeavor, but also serves as a meta-model for general curriculum development. The framework elements (industrial survey, objectives and outcomes, assessment process, architecture, and curriculum content) characterize the structure, scope, and content that we believe should be part of any curriculum development project.

Finally, a significant side effect of the ILERT project has been the increased understanding and appreciation by the project partners of the importance of working across borders and oceans to educate the world's future engineers. We are hopeful that the ILERT project will influence not only the technical capability of these engineers, but will better prepare them for work in a global community.

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