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ICT security curriculum or how to respond to current global challenges

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Abstract

The paper presents some results obtained through the implementation of the Erasmus LLP "SALEIE" (Strategic Alignment of Electrical and Information Engineering in European Higher Education Institutions). The aim of the project was to bring together experts from European universities to enhance the competitiveness of Electrical and Information Engineering (EIE) education within Europe, especially in relation to modern global technical challenges and to provide higher education models in a few EIE fields in accordance with these challenges. One of the outcomes of the project was a new ICT Security curriculum for bachelor and master levels. The research

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methodology comprised such stages as: identifying the most important current global challenges, conducting a survey related to existing EIE programs in order to establish the top-level criteria for an EIE curriculum, analysing the results of the survey, obtaining the industry feedback related to technical and non-technical skills required for the specific field, and proposing a new curriculum for ICT Security programmes to respond to the modern technical challenges and to meet the needs of the industry, students, academics and graduates.

Keywords: Electrical and Information Engineering, ICT Security, global challenges, curriculum

1. Introduction

The Strategic Alignment of Electrical and Information Engineering in European Higher Education Institutions project, "SALEIE", (SALEIE, 2015) brought together a group of European universities experts aiming to provide higher education models in the Electrical and Information Engineering (EIE) disciplines who were qualified to explore this technical area and identify current significant technical challenges at the global level. The project team had the technical support of the "European Association for Education in Electrical and Information Engineering" (EAEEIE). The partners involved in this project have participated in a series of European Union funded projects over the past 15 years all of which have contributed to the ongoing development of education in EIE across Europe, examples of such projects are ELLEIEC (2015) and THEIERE (2003).

Identified as a priority objective within the European Union's "Strategic framework for European cooperation in education and training", is the need to increase the percentage of young people with higher education studies to 40% (ET 2020, 2009). The reason which underlies this objective is that by 2020, more than 20% of jobs will require higher level skills "in order to provide the learners with experience closer to the reality of the working environment" (ET 2020, 2009). European Commission documents (2012) identify that there is a shortage in qualified professions in particular in the managerial and technical fields. It has been estimated that there will, for example, be between 384,000 and 700,000 ICT practitioner jobs that will not be able to be filled as a result of this shortfall and that the size of the shortfall could put the entire sector and the sectors that depend on ICT across the economy at risk.

To be competitive on the international labor market, Europe needs to be able to respond quickly and effectively to new technical challenges through new academic programmes. Focused on the Electrical and Information Engineering disciplines, one of the main aims of SALEIE project was to identify current relevant technical global challenges and to create model programmes and module curricula in some of these areas. Specifically, the SALEIE Project aims relating to global technical challenges were, repeated here for completeness, to:

- "Build a shared understanding of the skills and competence needs of graduates to help European Companies respond to the current global technical challenges.
- Enhance current understanding of academic programmes and modules in terms of technical content and level of learner achievement as a means of improving clarity of learner skills and competence for mobility, academic progression and employment.
- Build a common understanding of current practices and issues associated with marketing programmes and the support of students from unconventional backgrounds and those with special needs (SALEIE, 2015)."

Workpackage 3 (WP3) of the SALEIE project, titled "Global Challenges", had the aim of designing and developing module programmes and curricula for identified challenge areas that are optimised to the specific technical needs of each challenge, whilst not diluting the characteristics of European Higher Educational Institutions who may wish to adopt the programmes in the future. Poboroniuc et al. (2013), Poboroniuc et al. (2014a) and Poboroniuc et al. (2014b) addressed these subjects in their works. The main phases of the WP3 were:

- Identify the key technical challenges EIE graduates will face in their future employment in the sector, based on study of Poboroniuc, et al. (2013) and results of the Millennium Project (2009);
- Explore, through a questionnaire existing EIE programmes in the identified challenge areas, subjects which was partially addressed by Poboroniuc et al. (2014b);
- Gather industry feedback in terms of graduates' required technical and non-technical skills, subjects which was partially addressed by Poboroniuc et al. (2014b);
- Publish, through a report, the extent to which existing programmes are meeting current skills needs demands, some of results being mentioned by Poboroniuc et al. (2014b);
- Propose two curricula: "Renewable Energy and Information" and "Computer Technologies Security".

This paper presents a summary of the findings in respect of the identified challenges, a summary of the survey conclusions and details of the developed ICT Security curriculum at the bachelor and master levels.

2. Preliminary findings

The first stage of the workpackage, as stated above, was to identify the key technical challenges EIE graduates are likely to face, that is the challenges the sector imminently faces. The starting point for this investigation was the "15 Global Challenges" identified by the Millennium Project (2009). Focus group sessions within project meetings reduced the number of challenges the workpackage team could work on to 5. These 5 were those where there was sufficient technical expertise and more than one expert Higher Education Institution able to contribute to the development of appropriate curricula. The 5 selected challenges were:

- "ICT convergence challenges in education";
- "Science and technology including robotics";
- "Renewable Energy";
- "Clean water, sustainable development and climate change";
- "Technology in Health".

An elaboration of these debates can be found in Poboroniuc et al. (2013).

The second stage of the workpackage was to survey existing programmes that had direct relevance to the identified challenges. To this end a survey comprising 39 questions was developed. The main objective of the survey was to identify technical content currently included in relevant programmes, their associated learning outcomes, and methods and levels of student achievement. All SALEIE Project partners were invited to respond to the questionnaire for all relevant existing academic programmes within their own institutions. Responses were collected using the Survey Monkey questionnaire software.

Data obtained by the survey, led to the following conclusions, identified by Poboroniuc et al. (2013):

A. The generic programme structure of the Bologna Process should be used for all proposed programmes. As a result, Bachelor level programmes should have between 180 and 240 ECTS of study for 3 and 4 year programmes respectively; Masters level programmes should have between 90 and 120 ECTS of technical content and should build on the learning achieved in First Cycle Degree curricula, Poboroniuc et al. (2015, 2016).

B. The most common titles for programmes that most closely align with the identified technical challenges are those in:

- "Systems Engineering, Systems and Control, Computer and Systems Engineering";
- "Biomedical Engineering" and
- "Power Engineering, Renewable Energy Systems Technology".

C. The programmes identified as being relevant to the technical challenges are founded on research work being undertaken in the host academic unit and are hence research led. A very useful consequence of this is that they provide a solid foundation for future work and a potential source of future research students.

D. Only a limited number of the programmes identified in the survey returns were truly focussed on the challenge areas. Many only contained individual courses or modules in the challenge area so only partially fulfil the overall project workpackage objective.

Based on the survey findings, the project expert group focused their attention on the design of model curricula in "Renewable Energies" and "ICT Security".

3. The ICT Security curriculum

Due to present concerns in ICT security, new strategies are clearly needed to fight advanced cyber-attacks. Governments all over the world are stepping up their efforts, both for offensive and defensive purposes.

On the 3rd March 2010, as a follow up to the 2000 to 2010 Lisbon Strategy, the European Commission set out a "vision for Europe's social market economy for the 21st Century in its "Europe 2020 – A strategy for smart, sustainable and inclusive growth" document. The strategy lays down targets to be achieved by 2020 in employment, research and innovation, energy and climate change, education and combating poverty. In "Europe 2020" (European Commission, 2010) three "mutually reinforcing priorities" are laid down, one of which is "smart growth" which it defines as "developing an economy based on knowledge and innovation". A consequence of this is the projected increase in the use of ICT and the need to increase consideration of aspects such as ICT security. Europe starts this process from a less than optimum position. The EC recognised in 2010 that we are falling behind when it reported that, in respect of ICT, it is: "A market worth € 2,000 billion, but only one quarter of this comes from European firms. Europe is also falling behind on high-speed internet, which affects its ability to innovate, including in rural areas, as well as on the on-line dissemination of knowledge and on-line distribution of goods and services" (European Commission, 2010). Clearly ICT is a critical platform technology that underpins Europe's technological and economic strengths. A priority for the European Union is to ensure "ICT systems and networks are resilient and secure against all possible disruptions, whether accidental or intentional, to develop across the EU a high level of preparedness, security and resilience capabilities, to upgrade technical competences to allow Europe to meet the challenge of network and information infrastructure protection, and to foster cooperation between the Member States by developing incident cooperation mechanisms between the Member States" (European Commission, 2013).

The above stated need further supports the choice made by the workpackage team to develop curricula in ICT Security.

Whilst there are common definitions of terminology at the European level for characteristics of academic programmes the workpackage focus groups revealed they are not being consistently followed across Europe. As a consequence, it was decided to define the terminology to be used for curricula developed in the workpackage to ensure a common understanding. Any institution wishing

to adopt one of the developed curricula should be able to map their terminology to the project terminology using the following project definitions:

- Curriculum: The aggregate of modules of study given in a learning environment. The modules are arranged in a sequence;
- Syllabus: Is an outline and summary of topics to be covered in an education or training programme;
- Programme: A plan of modules to be covered to achieve a specific degree and/or qualification;
- Module: Lectures, labs and other activities related to one topic.

A full workpackage terminology dictionary can be found in Poboroniuc et al. (2015).

The Bachelor structure has to embed some fundamental, widely adopted modules (e.g. fundamentals in Mathematics, Physics, Electronics, etc.), accounting for 180 ECTS over six semesters. However, during the final studies the Bachelor's graduates will already get an insight within ICT security topics (e.g. Network security, Web application security, Security management).

Figure 1 shows the Bachelor level proposed ICT Security curriculum structure in its finalized version. The first four semesters account for 120 ECTS and contain compulsory and optional modules, the fifth one accounts for 30 ECTS and contains the graduate's specialized modules for ICT security issues and challenges, and the sixth one deals with the internship and/or bachelor project. Within the Bachelor structure, all the modules received a code and those related to ICT Security, a proper description according to a template which will be presented within the following section.

The Master structure has to embed specialized compulsory and optional modules, accounting for 120 ECTS over four semesters. The curriculum was developed for three different specializing pathways: Bioelectronics security & safety, Cyber-physical Systems Security & Safety and IT Security. The first semester is common for all the specializing pathways, the second and third semester differ and contain specific subjects. The last semester is dedicated for master thesis.

Figure 2a presents the proposed structure of the IT Security branch of ICT Security curriculum. The study subjects related to other two specializing pathways for semester 3 and 4 are presented in Figure 2b. Each of the modules has been coded in a convenient sequence, they account for 6 ECTS each and have been described on a template basis.

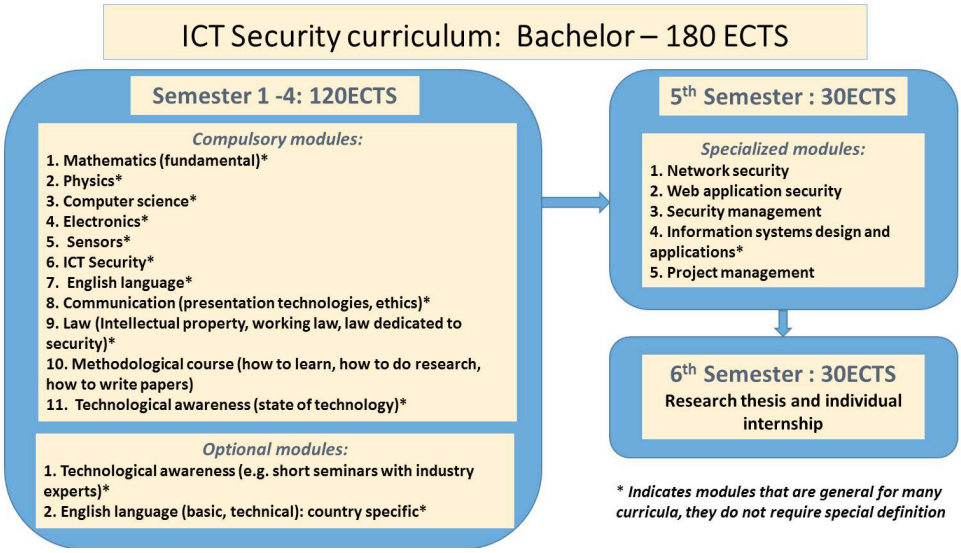

Figure 1. Bachelor level (180 ECTS) ICT Security curriculum

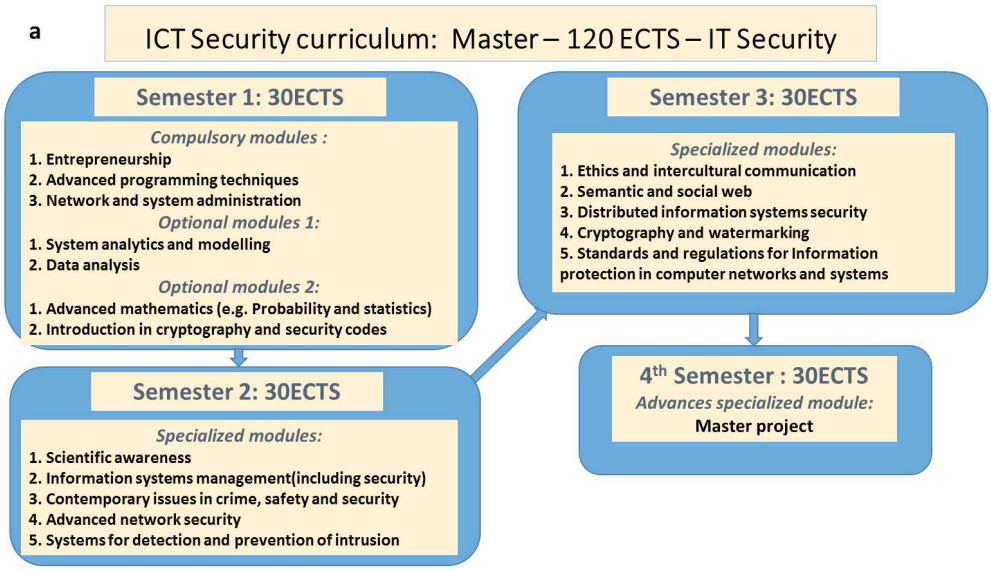

Figure 2. (a) Masters level (180 ECTS) ICT Security curriculum – IT Security specializing pathway (Semesters 2 and 3)

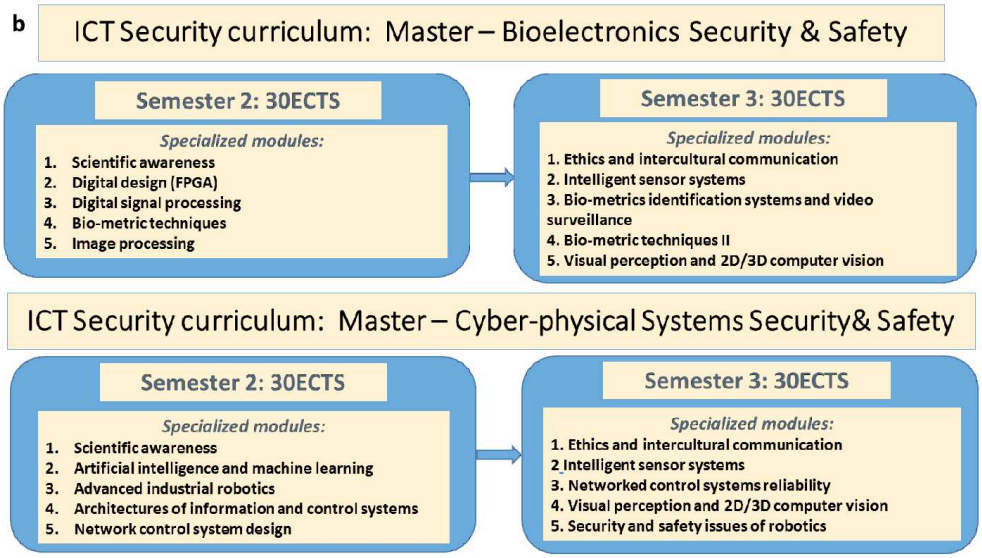

Figure 2. (b) Masters level (180 ECTS) ICT Security curriculum – Bioelectronics security & safety and Cyber-Physical Systems Security & Safety specializing pathways (semester 2 and 3)

3.1. The template describing the ICT Security curriculum modules

Following the WP3 workshops a template aiming to present each of the ICT Security curriculum modules has been created and then used to describe these modules. This will help students to have an overview on the required knowledge in order to face future global technical challenges related to this topic. Being aware of a paradigm shift that took place during the last decade, the learning objectives are now learner-centred being oriented towards knowledge, skills and competences rather than content, a fact which has been reflected within each module description.

A module description form proposed by Poboroniuc et al. (2015), contains the following points:

- Module name;
- Programme (e.g. Energy or ICT);
- ECTS (European Credit Transfer and Accumulation System) number;
- Type: Bachelor or Master;
- Scope and form;
- Duration (e.g. weeks, hours/week leading to a proper counting of hours of student workload);
- Type of assessment;
- Qualified prerequisites;
- General module objectives;
- Topics and short description;
- Learning outcomes (embed knowledge, skills and competences);
- Module recommended literature;
- Other comments.

3.2. Example of module description form for "Network and System Administration" (ICT03M1)

The ICT03M1 – *Network and System Administration* module is part of the ICT Security programme, accounts for 6 ECTS (with the example delivery model given of 2 lecture hours and 2 laboratory hours per week over 15 weeks, the remainder of the hours made up of self-study time and assessment). The module provides students with the basic knowledge of the administration and management of networks and the common tasks of network management systems, defined in the standards X.700/ISO 7598-4.

The subject is based on the knowledge acquired by the students from previous classes included in the bachelor degree on: Communication systems and processes, Routing and Commutation, Global network and internet communications, Networking security.

The "*Topics and short description"* subchapter enlists: Network administration and management systems, Standards for Network administration and management systems, peculiarities and types of network operating systems (NOS), NOS Services, Network protocols and their peculiarities in NOS, Configuration of NOS as a DNCP server, Common principals of the management of networks, Remote access to the network, Network address translation, Network security – Kerberos protocol, Monitoring Tools, management and troubleshooting.

Learning outcomes are visualized in 3 dimensions: knowledge, skills and competences as shown in Table 1 for *Network and System Administration* module.

Table 1. Learning outcomes for ICT Security curriculum - Network and System Administration module

Knowledge	Skills	Competences
Most frequently used high level protocols and services	Operating systems and associated hardware: Installation, configuration, security and fault finding	Operating systems and associated hardware: Fault diagnosis and resolution
Network administration and management systems	Networking and Network Infrastructure skills: Installation, Configuration, Security, Fault Finding, including installing, configuring, securing and troubleshooting	Network problem diagnosis and resolution.
Standards used in network administration and management systems	Server operating systems administration skills; System and network service administration skills; Directory service administration skills.	Maintain current knowledge and expertise in technology and new tools through research into technology problems, provision of technology support, and personal development
Of core infrastructure services (DNS, TCP/IP, DHCP, Routing, Remote Access, Network Protection, Patch Management, Firewall Configuration, IPSec as examples) including their implementation, management and fault finding		Written and oral communication skills as demonstrated through the presentation of new theories and solutions to existing problems.
Of research and development in network and system administration		Aware of innovation and innovation processes
Able to update and extend the knowledge and skills in network and system administration		

3.3. Quality evaluation of module description

Once the first drafts of ICT Security curriculum modules have been drawn a quality check process has been initiated in order to ensure the feedback that will improve the curriculum modules' description. The first step has been to allocate these module descriptions to different reviewers, and the second to gather the required feedback from employers, academics and students. Both processes ran in parallel.

A. Quality check of the first draft modules description

The procedure of quality assessment was based on a checking-points questionnaire, *Module Reviewer Form,* developed by the WP3 experts. The form was filed by reviewers after analysing the assigned modules description. Once finished, the coded questionnaire, along with the corrected module description, was returned to the WP3 leader as task manager.

The *Module Reviewer Form* enlists the used definitions (e.g. curriculum, syllabus, programme, module), some reviewer's details which are for internal use only, and questions regarding the completeness of the module sections, number of hours/subject, allocated ECTS, student workload, learning outcomes, content, assessments, references, etc., which have been answered with *Yes* or *No.*

Poboroniuc et al. (2015) proposed that if is necessary, additional comments could be inserted at the end of the reviewer form.

B. Quality check based from the feedback from employers, academics and students

The quality check and improvements of the *ICT Security* modules description addressing the feedback from employers, academics and students have been based on two questionnaires regarding the content of the modules. In order to gather the questionnaire answers the SALEIE partners have been asked to provide at least three filled-in questionnaires by contacting and discussing ICT Security curriculum modules with academics, employers and students.

4. Results and conclusions

The objective of workpackage 3 of the project was to design and develop model curricula for identified relevant technical challenges in the Electrical and Information Engineering subject area. The model curricula were defined by overall programme specifications; modules specifications for all technically specific modules, technical pre-requisites and learning outcomes. Through this level of specification, it should be relatively straightforward for any institution to adopt the curricula in their institution. A benefit of this approach is that it makes the task of content comparison between partnering institutions simpler which in turn should facilitate student mobility through programme such as ERASMUS Plus.

The first phase accomplished by the WP3 group of experts in EIE field was to analyse the "15 Global challenges facing humanity" established through Millennium Project (2009) which connects futurists around the world to improve global foresight.

The WP3 project members have discussed, during workshops and project meetings, the EIE situation in global challenges perspectives, as mentioned by Poboroniuc et al. (2013) and Poboroniuc et al. (2014a), in particular with respect to the incidence on the number of the students committed in EIE fields. A number of five global challenges (ICT, Energy, Science and Technology challenges, Environment, Health) have been selected and analysed. It was decided that curricula for *"ICT Security"* and *"Renewable Energy"* would be developed. Our paper presents the overall process in the creation of the ICT Security curriculum.

The second stage, the survey of existing curricula provided a foundation for the development of the high-level specification for relevant curricula. A template aiming to present each of the ICT Security curriculum modules has been created and then used to describe these modules. This will help students to have an overview on the required knowledge in order to face future global technical challenges related to this topic. Beside topics and short description, each module contains the learning objectives, skills, competences and other elements giving the learners an orientation towards knowledge rather than content.

The first structure of the ICT Security curriculum has been refined by means of a feedback process which comprised the reviewing of each module and gathering the academics' and industry feedback. The final form of the ICT Security curriculum together with its module description can be accessed on the SALEIE project website. A consent form has been released and provided to the employers and academics in order to be able to process their answers or data internally within the project or in any paper if agreed. In the future, attention will be paid to student and teacher feedback of the content of our proposed curricula so they can be continuously improved.

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