Compliance of student learning outcomes with industry needs in embedded systems engineering

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Aim and contributions

- **Aim of the paper:** To examine the effectiveness of our curriculum in embedded systems (ES) topics, in response to job market requirements, through the workplace learning (WPL) case studies of three DoEE/TEIoC students who were involved in the design, implementation, installation and operation of ES in real working environments.

- **Main contributions:**

✓ An overview of educational and professional issues that are related to students' readiness to enter the ES job market .

✓ The identification of some gaps between DoEE/TEIoC students' knowledge/skills and the competences demanded by the ES job market.

Current approaches for teaching and learning in ES (1/2)

- A stream of courses ranging **from** digital logic and system design, microprocessor systems and interfacing to hardware description languages, C/C++ and real-time programming and operating systems **to** specialized ES design courses (applied control theory for ES, real-time digital signal processing, real-time ES programming, wireless ES on a chip, validation and prototyping of ES, etc.).

- Emphasis is given to teaching practical aspects of the topics through lab assignments, project-based learning approaches and through carrying out capstone design projects.

- In many cases, there exists industry support from industry by providing C-compilers and microcontrollers to the students at no cost.

Current approaches for teaching and learning in ES (2/2)

- A blended learning way has been proposed by a consortium of EU HEIs and partners from Ukraine, Georgia and Armenia within the framework of an EU-funded Tempus project. Outcomes of this project include course material organized in modules to be used for physical, virtual and remote laboratories for education and training in ES.

- In general, for most of the current approaches, a software and hardware co-design approach is missing.

- The provision of a unified modular platform for skills practice is highly desirable.

- The E2LP platform, which is based on the results of the EU FP7 project “Embedded Engineering Learning Platform”, offers a flexible and extendable learning environment for new-coming technologies in ES and reduces the overhead in students’ learning.

ES education at DoEE/TEIoC

Course title	**Semester**	**Theory + Lab (hour/week)**
Computer Programming	2nd	3 + 2
Digital Circuits II	4th	3 + 2
Microprocessors	4th	2 + 2
Computer Architecture	5th	2 + 2
Digital Signal Processing	5th	2 + 2
Applications of Microprocessors and Fuzzy Logic	6th	2 + 2
Sensors and Industrial Automations	6th	3 + 2

Key attributes of the ES area from a professional point of view (1/2)

- **Workforce attribute:** It is highly affected by growing body of knowledge and tools (ES engineers should be well educated and trained a number of subareas along with problem-solving team working and creativity skills).

- **Hardware attributes:** Related to the physical (dimensions, weight, form factor) design, new communication interfaces, power management (such as the design considerations for power sensitive embedded devices), etc.

Key attributes of the ES area from a professional point of view

- **Software attributes:** The principal role of embedded software (i.e., the integration with physical world for monitoring and/or controlling external devices with real-time constraints) has implications to the programming language used, the adoption of code reuse practices, the teamwork effectiveness of the software development team, etc.

- **System attributes:** These refer to the hardware/software co-design approach that should be followed, as well as to reliability, safety and security attributes.

- **Commercial attributes** due to the rapidly changing market pressures.

WPL case studies in ES

- The six months' WPL duration of the DoEE/TEIoC students constitutes an integral part of our electronic engineering curriculum.

- In order to support the WPL of our students we exploit a Web 2.0 communications environment (http://practice-elec.chania.teicrete.gr). This communications environment **not only** facilitates the electronic collaboration of the learning triad of our internships (the student, the Host Entity (HE) supervisor, the academic supervisor), **but also** provides a cost effective way for the **formative assessment** for the WPL quality through the students' weblogs and the advice comments given by the academic supervisor of each student.

- At the end of the WPL period, a **summative assessment** that is based on three questionnaires completed, by the student (including, also, a final report), the HE supervisor, and the academic supervisor.

WPL case study 1: Design and implementation of a medium scale hydroponic nutrient control system (1/3)

WPL case study 1: Design and implementation of a medium scale hydroponic nutrient control system (2/3)

• pH, nutrient and electrical conductivity sensors were included in the system.

• Starting from the system modeling with a Finite State Machine approach, student A was confronted with TCL (Tool Command Language), C programming tasks.

• Student A had to program the appropriate control algorithm, the wireless communications with the microcontroller for parameter setting, as well as the graphical user interface.

• The PCB (Printed Circuit Board) design, fabrication and testing of individual components for driving the sensors with Arduino microprocessor, were carried out by the highly active participation of student A.

WPL case study 1: Design and implementation of a medium scale hydroponic nutrient control system (3/3)

• Student A (as included in his final report) states that "*During my WPL I had the opportunity to enhance my knowledge and upgrade my technical skills in electronic devices, in software programming, as well as in system modeling.* ***The help from the HE supervisor was great****, especially for TCL.* ***As it concerns PCB implementation, it was necessary to redesign and refabricate it for more than once****. Overall, my WPL was great, in terms of knowledge, skills and contacts, as I was involved with current technologies and* ***had the opportunity to develop a new way of thinking for technical and scientific issues***".

• According to the HE supervisor of the student A *"Students' A performance was admirable for all tasks assigned to him during his WPL period. He was prompt, diligent, hard-working and very bright individual.* ***He did not hesitate to think "outside of the box"****, and I can recommend him for any future undertaking of his career without any reservation*".

WPL case study 2: Design, programming, installation and commissioning for smart buildings (1/2)

• The HE is a company that offers integrated services across the whole range of building automation and control (lighting control, HVAC control, energy management, etc.). Furthermore, it develops and produces digital electronics and KNX devices that are sold in the global market.

•On June 2012 KNX Association accepted the company as a member.

• Konnex (simply KNX) is the leading home automation standard, which supports various communications media (twisted pairs, power lines, RF) and is evolving to be part of the IoT ecosystem.

• KNX devices fall into three categories: system devices (power supply, programming interface, etc.), sensors, and actuators. Every device has its own microprocessor.

WPL case study 2: Design, programming, installation and commissioning for smart buildings (2/2)

- **Tasks that were carried out by student B included:**

✓ Circuit design in company's laboratory
✓ Programming of ATMEGA 328 microprocessor, smart touch panels, etc.
✓ Installation of KNX devices (motion sensors, presence detectors, gas detectors, wind sensors for controlling blinds, blind actuators, etc.).
✓ Use of the ETS (Engineering Tool Software) for the design, commissioning and troubleshooting KNX systems.

- **According to the WPL supervisor of student B:**

"Student B showed a readiness for learning how to program alarm systems, how modern dimmers work, how to solve various technical problems, etc. H e, also, took part in all commissioning phases of a smart building. However, it was not possible to cover his deficiency in theoretical and practical topics during his six months WPL. We definitely include student B to be one of our future permanent staff, as being a person of nice character and due to his willingness for upgrading his knowledge and skills".

WPL case study 3: Mobile software management and troubleshooting of smart-phones

• The host entity for the WPL of student C was a multi-national company with service activities on behalf of various OEMs in communications technology.

•Student C was involved in tasks related to:

✓ Troubleshooting mechanical and electronic defects of smart-phones

✓ Mobile software management (i.e., the process of managing the software throughout its entire lifecycle due to software defects, upgrades, etc.) for the entire range of software on smart-phone devices (from Java, through add-on applications and down to the core built-in software components and middleware).

WPL assessment data of case studies

WPL quality issue	Student A	Student B	Student C	Mean for other 134 students
Efficiency of student’s prior theoretical knowledge (Students)	3	2	3	4.02
Efficiency of student’s prior technical skills (Students)	4	4	3	4.10
Overall rating of collaboration with HE (students)	5	4	4	4.76
Prospects for recruitment (Students)	4	4	4	4.48
Efficiency of student’s prior theoretical knowledge (HE Supervisor)	4	3	4	4.35
Efficiency of student’s prior technical skills (HE Supervisor)	4	2	4	4.60
Teamwork ability (HE Supervisor)	5	5	5	4.82
Qualitative efficiency of student (HE Supervisors)	4	3	5	4.53
Quantitative efficiency of student (HE Supervisors)	5	3	5	4.52
Prospects for recruitment (HE Supervisors)	5	3	5	4.52
Efficiency of student’s prior theoretical knowledge (Academic supervisors)	4	5	5	4.38
Efficiency of student’s prior technical skills (Academic supervisors)	4	5	5	4.36
Qualitative efficiency of student (Academic supervisors)	4	5	5	4.51
Quantitative efficiency of student (Academic supervisors)	5	5	5	4.62

Conclusions

- There seems to exist space for improving our educational approach as it relates to both the theoretical knowledge and technical skills of our students.

- As curriculum modifications or introduction of new courses involve considerable effort mainly due to bureaucratic reasons, a short term solution could be the redesign and the enhancement of existing courses through concrete decisions and actions.

- Adoption of the same embedded engineering learning platform for a series of courses in order to speed up the learning curve.

- An “Embedded Systems” course that is under development in the framework of the newly established graduate program of DoEE/TEIoC “Telecommunications and Automation Systems (TeleAutoS) may provide the experience and the feedback for a longer term introduction of a relevant course focused in ES in the undergraduate curriculum.