Embedding a Core Competence Curriculum In Computing Engineering

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Abstract - **This paper describes the processes that have started to reform the curriculum and learning landscape at Computer Engineering School of the Universidad Politécnica de Madrid (Spain) within the European Higher Education Area framework. In this context, competences and learning outcomes are emerging as a new teaching/learning paradigm, where approaches centered on the learner are increasingly important. In first place, it describes the process followed for the identification of its own core generic competences map explaining its connections between learning outcomes, levels, descriptors, credits, methodology, learning activities and assessment. Finally, it reports some of the results obtained in the implementation of this core competence curriculum realized in a pilot experience the first and second semester, analyzing the degree of institutional impact of the actions undertaken and perspectives for the future.**

Index Terms – European Higher Education Area, core competence, curricula reform, globalization, Computer Engineering.

INTRODUCTION

There exists a wide movement throughout Europe changing the actual university curricula in the context of the Adaptation to the European Higher Education Area (EHEA). Processes facing to the curricula reform and the design of new European degrees boosting people's mobility, their employability and the socioeconomic progress, i.e. entering the global workplace, must deal with two key concepts: Competences and learning outcomes. Both of them constitute a new teaching/learning paradigm, where approaches centered on the learner are increasingly important. In addition, the introduction of the European Credit Transfer System (ECTS) in a coherent way implies a clear definition of competences and learning outcomes [1]-[2].

As consequence of the review and definition of the academic-professionals profiles of the new Computing Engineering, generic and specific competences and skills are being proposed through competency-based curricula models. These approaches consider different references: reports developed by networks of the Computer Engineering Education institutions, the European Qualifications Framework for Lifelong Learning and the Dublin descriptors, among others, along with the official recommendations and documents approved by the corresponding European government, Ministries of Education, and the National Quality Assurance Agencies [3]-[7].

This paper explains the process designed and followed by the Computer Engineering School of the Universidad Politécnica de Madrid (Spain) whose objective has been the identification of its own core generic competences map integrating learning outcomes, levels, descriptors, credits, methodology, learning activities and assessment. In addition, it reports some of the results obtained in the implementation of this core competence curriculum realized in a pilot experience the first and second semester, analyzing the degree of institutional impact of the actions undertaken and the improvement possibilities in the future.

GENERIC COMPETENCES: A NEW SCOPE FOR THE SPANISH CURRICULAR REFORM

There are several initiatives around the world to change the Curriculum for Computer Engineering. For example, the Computer Society of the Institute for Electrical and Electronics Engineers (IEEE-CS) and the Association for Computing Machinery (ACM) already established the Joint Task Force on "Model Curricula for Computing" to undertake a major review of curriculum guidelines for undergraduate programs in computing [3]-[4]. In the majority of the European countries and within the movement to the European Higher Education Area (EHEA) competences and learning outcomes have acquiring renewed relevance for the curricular reform. They are considered a key aspect for answering to the fast technological change in the production and management knowledge and to the gap between the education and the labor market requirements [1]-[8]. Although competences and competency are concepts very used in the educative area in United States and some European countries (United Kingdom, Denmark, Finland, France), in the Spanish case they are in the early stages of developing and planning [9] .

In Spain employers affirm that some competences in certain non-technical areas such as communication ability, economics, leadership, teamwork and management are not practically being considered in their formation. Accreditation Boards, Engineering Associations, and governments in Spain are demanding the incorporation of

the called generic or transferable competences for the actual and the future engineering degrees.

In this context, one of the main goals is that students reach both generic competences (transferable skills) and subject-related ones, although it is broadly accepted that key outcomes of university programmes will be subject related competences. Generic competences constitute the basis for the ability to develop discipline-specific competencies, their interactions in an occupation-specific context are essential to be able to handle non-routine and unusual, complex working situation [8].

This approach supposed important changes in the current teaching-learning processes of many Institutions such as the Computer Engineering School of the Universidad Politécnica de Madrid. Principles of this new learning focus include active learning, ensuring links between new and previously learned knowledge, effective feedback, and scaffolding to help learners organize learning experiences.

Once the quality of an academic's teaching was the primary consideration, quality often measured in the quantity of content imparted. Now the shift in focus is to what the students are learning. The role of the teacher, when focused on student learning, is crucial but not in the traditional sense. The teaching activities that we now need to focus on are the creation of an engaging learning environment, providing the learning stimulus, supporting the learner, and providing effective feedback on the learner's progress.

The three important terms are significant, long-term, and changes. Significant can be considered as the learner having an appreciation and understanding of the content, not simply a rote-learned knowledge. This would entail the student having a working knowledge or the ability to apply and relate what is learned. The concept of long-term knowledge relates to the knowledge existing beyond the examination period: the knowledge is a working knowledge that provides the basis for further learning and application. Finally, changes mean not only the taking on board of the information but the integration of that knowledge with other knowledge. Integration of knowledge learned is critical to it effective use.

In the document of the Spanish Education Ministry in 2003 [10] it is said that the official degrees will have to provide a university formation in which the generic competences are integrated harmonically with basic ones; transversal competences related to the integral formation of the people and specific competences than make possible a professional profile that allows the graduates integration in the work market.

CORE COMPETENCES AND CURRICULAR DEVELOPMENT MODELS

Instructional design represents the planning process for designing instructional events. It is the systematic approach to course development and involves an iterative process which requires ongoing evaluation and feedback. Instructional design models attempt to make explicit the relationships between the internal and external components of the learning environment. In this sense, a model of curriculum design can be useful for supporting the development of both generic and specific competences. It can be adapted and accommodated into a teaching framework to actively enhance the development of these competences by recognising and responding to students' perceptions of learning [11]-[13].

Compared to traditional instructional systems approaches of designing instruction, constructivism makes a different set of assumptions about learning and suggests new instructional principles. However, design practices do not merely accommodate constructivist perspectives. The implications of constructivism for instructional design are revolutionary as they replace rather than add to our current understanding of learning. Instructional designers are thus challenged to translate the philosophy of constructivism into actual practice. But until the present there are several problems and very few examples of models used to develop generic competences (or transferable skills) are available from the literature [14]-[17].

Chadha [11] considers three different approaches related to competences development: 'embedding', 'bolting on' and 'integrating' competences components. Although it makes reference to skills, the model can be applied to generic competences, in which:

- **Embedding** – no direct reference is made to developing transferable competences and the emphasis is on promoting the development of technical 'know-how'.
- **Bolting-on** – competences are developed independently of the core discipline, enabling the explicit development of students' transferable competences.
- **Integrating** – competences are developed and taught explicitly within the core discipline and the same amount of emphasis is placed on the development of transferable competences as technical abilities.

According to Chadha, established models of good practice suggest that effective skills development depends on opportunities to practice skills with support and guidance, encouraging reflection and subsequently development. Consequently, those programmes which are structured and coherent and which run throughout the curriculum would prove far more beneficial in terms of providing opportunity to reflect and develop.

On the other hand, the idea of a core competence draws attention not only the different approaches but to the contextual basis of competence, considering all the links within the instructional design (Figure 1).
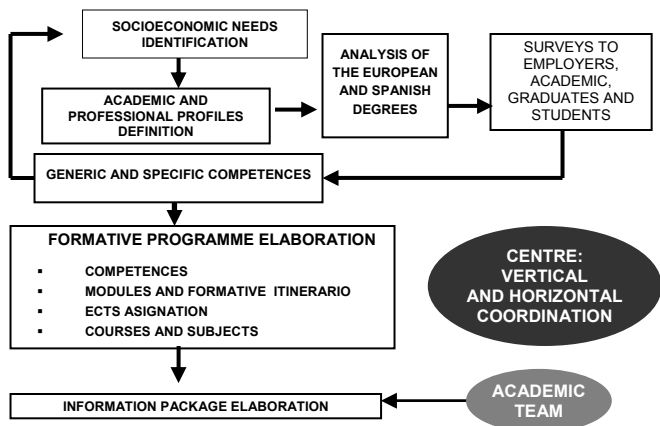
FIGURE 1
SCHEME FOR PLANNING THE CURRICULAR REFORM WITHIN THE EUROPEAN
CONVERGENCE PROCESS

For implementing this scheme, we can use different methodologies, focusing on developing instruction for: (a) a classroom, (b) a product (c) a system [18]-[19]. It can be orientated to the outcomes, or centered in the program contents (see examples of Figure 2 and 3).
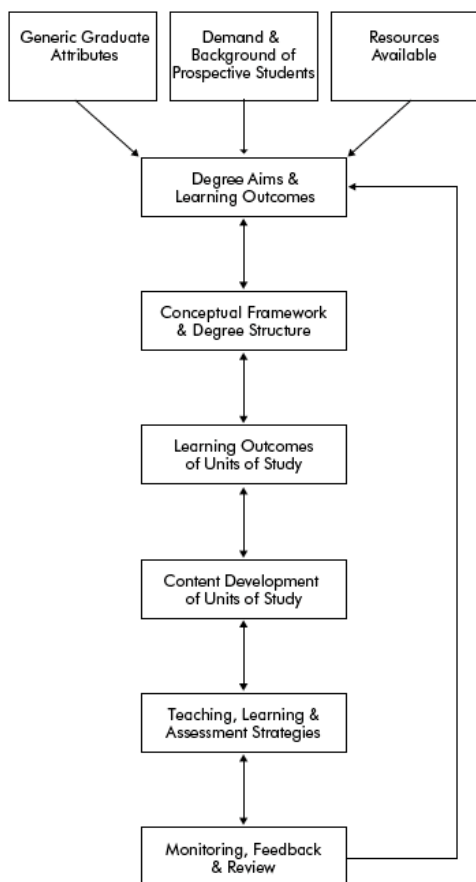

FIGURE 2
LEARNING-OUTCOMES MODEL (LOM) FOR CURRICULUM DESIGN IN THE UNIVERSITY OF GLOUCESTERSHIRE AND THE UNIVERSITY OF WESTERN AUSTRALIA (2004)
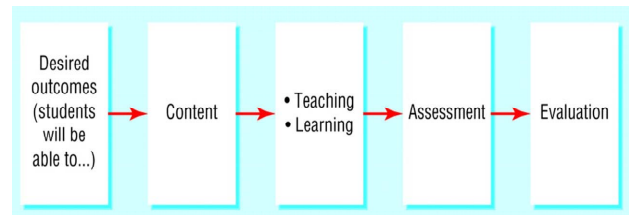

FIGURE 3
DESIGN "BACKWARD", BASED ON DESIRED LEARNING OUTCOMES
(PRIDEAUX , 2003)

We consider an adaptation of the ILOS (Intended Learning Outcomes) model, integrating generic and specific competences according a feed-back methodology: design "backward" with deliver and active participation of the academic staff (Figure 4). Intended Learning outcomes are statements describing what students know, understand, and can do with their knowledge, as well as what they feel, value, and believe, as a result of their learning experiences.
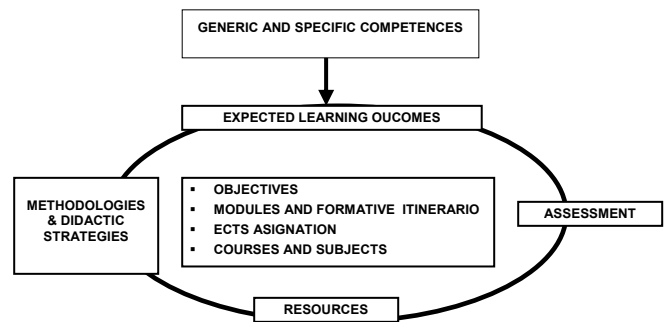

FIGURE 4
CURRICULAR DESIGN MODEL AT COMPUTER ENGINEERING SCHOOL OF THE
UNIVERSIDAD POLITÉCNICA DE MADRID

In practice two types of learning outcomes can be distinguished: general or generic competences (transferable skills) and subject specific competences (theoretical, practical and/or experimental knowledge and subject related skills), all developed considering the National Agency for Quality Assessment and Accreditation (ANECA) descriptors, the Dublin descriptors and the Framework for Qualifications of EHEA [7], [20].

A CORE COMPETENCES MAPPING PROCESS

We define competency mapping as the process of identifying key competences for a particular degree. In our institution, it was begun supporting and enabling staff to fully reflect upon potential competences, conducting formal research to identify the most important competences, and reaching consensus. Although the principal advantage of core competences is that they facilitate communication within disciplines among the state's faculty. Also it constitutes an instrument for the academic cultural change. At present,

faculty and staff are developing and articulating these important linkages to create strong curricula plans.

In this section we explain, in the first place, the context of the pilot experience and methodology used. After, we define the approach taken to gather the information needed in this process, and finally, we sum up the results obtained.

A pilot experience at the Computer Engineering School.

We have developed a pilot experience to define a map of core competences in a controlled environment of teaching in the first and second semester of Computer Engineering curricula of the Universidad Politécnica de Madrid. There are, in this context, 31 teachers, plus other 6 teachers playing an additional role as coordinators of subjects.

Besides the curricula description, every department has a certain amount of autonomy to determine the way in which the subjects are taught. Even some departments give the teachers the choice to orientate and evaluate the competences they find adequate. That way we have to face a heterogeneous situation where there was not any record of the competences worked or the teaching methodologies used.

To embed a core competences curriculum in Computer Engineering we needed first to know the actual situation of the core competences developed by the experiment teachers. We realized that a 'plan from above' could only succeed if we approached teachers to explore their different circumstances and ways of dealing with core competences. So we decided to gather information from them in order to determine our own map of core competences.

As we have pointed out before, there are several lists of competences generated by different studies in the European context. The separate competences were determined based on generally standard taxonomies [8]. There is not yet a common agreed ensemble of core competences in the Universidad Politécnica de Madrid, so we decided that it would be better to present the whole information to the teachers and let them choose the ones from the entire list that were really being worked by them and to what extent. In this way we could establish our own set of core competences based in previous and authorized works.

Gathering information about the experience

We followed a 'multi-step' approach to gather the information we needed to complete in our competences mapping. Here we present these steps:

- **Establishing an extensive catalog of core competences**, according to the main curricula model references in Computer Engineering and corporative studies for computer engineering professionals in our geographical context.
- **Meetings with teacher coordinators**: We held a series of meetings with teacher coordinators to know the overall situation of the teaching of core competences in the first and second semester of Computer Engineering. These allowed us to ascertain the plurality of existing approaches to teach the same subject.

- **Coordinators' survey**: Considering the different and varied situations that were taking place, we needed a certain degree of harmonization of the different existing situations. We considered that the best way to standardize the information was to collect it throw a standard method: the survey. We prepared a brief questionnaire to be answered by the teacher coordinators. In general we asked several issues concerning the organization of the subject they were going to teach and to what extent the department had a control over the teachers in those tasks. The answers revealed a high level of autonomy in some subjects, whereas other kept quite normalized.
- **Teachers' survey**: the coordinators' survey pointing out a big degree of autonomy for some teachers, so we decided to ask the teachers to be more precise. We prepared a new questionnaire. First we tried to obtain the responses through a 'self-applied' questionnaire with a 45% response rate. As we wanted to get nearer to a census than a sample, then we used personal interviewers to complete a nearly 90% of the whole population of teachers. This time we asked more specific issues. There were organizational questions as well as questions regarding competences. The organizational questions referred to the way in which they taught their subjects: use of new technologies, coordination with teachers from other subjects, methodologies of evaluation and teaching. The questions referred to work of core competences: what competences they taught, to what extent, the knowledge of mechanisms to evaluate them.

Main results

An initial target of 37 competences was established and requested in a survey to professors (N = 31). Table I shows the list competences such us were asked to the teachers.

TABLE 1
LIST OF GENERIC COMPETENCES PROPOSED

Competences
1. Applying knowledge of mathematics, science and engineering
2. Analysis and synthesis
3. Logical and mathematical reasoning
4. Professional basic knowledge
5. Creating and using models that describe real situations
6. Designing and interpreting experiments
7. Problem solving
8. Decision making
9. Ability for argumentation opinions and decisions
10. Organizing and Planning
11. Oral and written communication in its native language and in graphical, formal and symbolic languages
12. Communicating in foreign language
13. Writing and interpreting technical documentation
14. Using ICT
15. Information management
16. Critical and self-critical ability
17. Ability for interpersonal relations
18. Ability for communicating with non experts or experts of other domains

19. Work in multidisciplinary teams
20. Ability to work in multicultural teams
21. Working in international context
22. Appreciation of the multiculturalism and diversity
23. Understanding of professional and ethical responsibility
24. Applying knowledge to the practice
25. Designing and managing projects
26. Autonomous learning and updating knowledge
27. Recognition of the continuous training importance
28. Researching
29. Adaptability (to new situations, different contexts …)
30. Working under pression
31. Negotiation and solving conflicts
32. Leadership
33. Outsourcing management
34. Enterprising
35. Creativity and innovation
36. Motivation for quality and continuous improvement
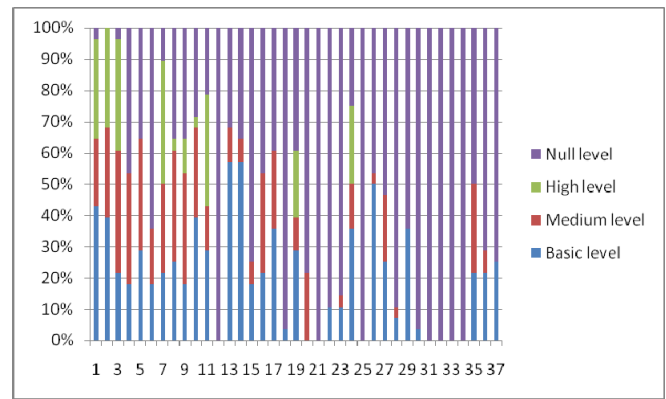37. Commitment with environment and sustainability

The survey provided us a ranking of the 'worked in class' core competences and the best known to be taught and evaluated. Those are shown in the following Table II.

TABLE II
TOP TEN CORE COMPETENCES WORKED IN COMPUTER ENGINEERING

Place	Core competence	%
1	Analysis and synthesis	96,55
2	Applying knowledge of mathematics, science and engineering	93,10
3	Logical and mathematical reasoning	93,10
4	Problem solving	86,21
5	Oral and written communication in its native language and in graphical, formal and symbolic languages.	75,86
6	Applying knowledge in practice	72,41
7	Planning, coordinating and organizing	68,97
8	Writing and interpreting technical documentation	65,52
9	Creating and using models that describe real situations	
10	Decision making	62,07

We could notice that the main core competences outlined by the teachers were related to Science subjects, like the competence in Mathematics and Engineering, logic and mathematic reasoning or abstraction, analysis and synthesis. But there were also important 'non-Science' competence, like the competence of written and oral expression in their mother language.

Besides of the competences that were being worked in class, we could also establish to what extent or level (high, medium, basic or null) those competences were worked. The results, presented in figure 5, were very similar to those shown previously (every column represents the level of teaching by every competence listed in the table I). This fact allowed us to state a consistent list with both criteria.

FIGURE 5
LEVEL OF TEACHING OF COMPETENCES.

As we can see in Figure 5, competences in Mathematics, Science and Engineering are again the competences that are taught in the highest level. For an explanation of the figure, in the annex you can found the whole list of competences as shown form left to right in the figure.

The coincidence of both criteria, the most used criterion and the high levels that they are worked criterion, lead us to restrict the initial list of forty competences to the following 5 core competences:

- Analysis and synthesis.
- Applying knowledge of mathematics, science and engineering.
- Logical and mathematical reasoning.
- Oral and written communication in its native language.
- Writing and interpreting technical documentation.

These five competences constitute our core generic competences. About of them we are working in topics as resources for their teaching and evaluation.

CONCLUSIONS

Competences and learning outcomes play a key role in the teaching and learning process within the European Higher Education Area framework. Generic competences and their corresponding learning outcomes should not only be defined on the level of formal qualifications such as degrees but also on the level of modules or courses. Their inclusion in the pieces and the total of a curriculum stimulate its consistency and comparability.

In Spain still there is a gap between "theory" and "practice" between competences, learning outcomes and curricular development. It is important that faculty staff can explore and validate reliable ways to design and evaluate competence based curriculum.

We are working to answer appropriately the following questions:

- Where in the curriculum can students learn and practice skills such as writing, critical thinking, speaking, and teamwork?

- What teaching strategies and assignments are useful to help the students develop these skills?
- What assessments would be selected to determine if students are mastering the generic competences?
- How competences are to be worked, realized and assessed and the impact of this change, both at individual and European university structure level, needs further research and debate.

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