Training engineers to meet the challenges of a changing world: how a competency framework improves teaching programs and team cohesion

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Abstract

The competency framework is a complex and time-consuming exercise seen by most teachers as an administrative process. When applied, however, it can be a powerful tool for adapting curricula for engineers to meet the emerging needs of society, including training in sustainable development. This paper looks at how to use the competency framework to generate a tool for bringing teachers together around shared objectives, helping students build their career paths and improving communication with the 'outside world'. This approach, largely inspired by the Tardif approach, is being used for the Bioengineering Masters Degree in Environmental Sciences and Technology at the Gembloux Agro-Bio Tech Faculty, University of Liège, Belgium. The approach has allowed the teaching staff to build a common educational project aimed at enabling bioengineers to meet the needs of society.

1 Introduction

The 'Commission des Titres d'Ingénieurs' (CTI 2006) defines engineers as individuals who are capable of resolving technical, practical, often complex and, usually, new problems. Throughout their careers, these engineers have to design, create and implement products, systems or services that take into account environmental, societal and financial issues (CTI and AEQES 2013b).

The work of an engineer differs from that of a scientist, particularly in terms of implementing his or her scientific and technical knowledge. An analysis of our courses by the Commission des Titres d'Ingénieurs and the Agence pour l'Evaluation de la Qualité de l'Enseignement Supérieur (Belgian authority), however, showed that most of our teaching staff remain very focused on academic subjects (CTI and AEQES 2013a). It is important to train our students to apply their knowledge in real situations, and therefore our transmissive teaching methods need to be turned into 'learning-based' teaching methods.

It also seems clear that engineers and bioengineers should bear some responsibility for the sustainable development of our societies. This should be taken into account from the very start of their training.

This paper describes the establishment of the method in the Bioengineering Masters Degree in Environmental Sciences and Technology, which led to a revision of the existing curriculum, creating a new one that was consistent with the competency-based approach, was approved by the whole teaching staff and met the needs of the future employers of these students and society in general.

The definition of competency is still under discussion and there are currently several definitions. This work was based on the definition of competence as: 'a complex knowing how to act supported by the effective mobilization and combination of a variety of internal and external resources within a family of situations' (Tardif 2006).

This approach should ultimately enable us to generate a tool which will help:

- Relevant teaching staff to work around a shared objective
- Students to build their career paths by more effectively identifying the modules that will give them specific skills
- Improve communication with both the professional world and the 'outside world' (e.g., other universities, professional bodies, accreditation organizations)

2 Construction of the competency framework

The creation of a competency framework cannot emerge solely from academic world. It is our duty to prepare young and enthusiastic candidates to fulfil new responsibilities and lead the society towards sustainable functioning. Building a bioengineering course that meets the expectations of the professional world involves using this framework in this process (Colaux-Castillo et al. 2013).

In order to build a competency framework, we:

- Conducted a survey among employers and new graduates. It showed that, overall, our students' scientific and technical training was recognized as being of high quality. Some concepts, however, seemed to be obsolete. This was the case with the geometronic course, which focuses on meters, which is now an independent curriculum. This survey helped us to refine the profile of our future bioengineers and to identify the skills needed for new jobs.
- Analysed 210 employment opportunities for bioengineers. This showed variations in expected skills, emphasizing the importance of soft skills such as team management, communication and leadership (Figure 1).
- Looked at various competency frameworks ([EUR-ACE] 2008; CTI and AEQES 2013b; CTI 2006; OECD 2011).
- Analysed our bioengineering courses

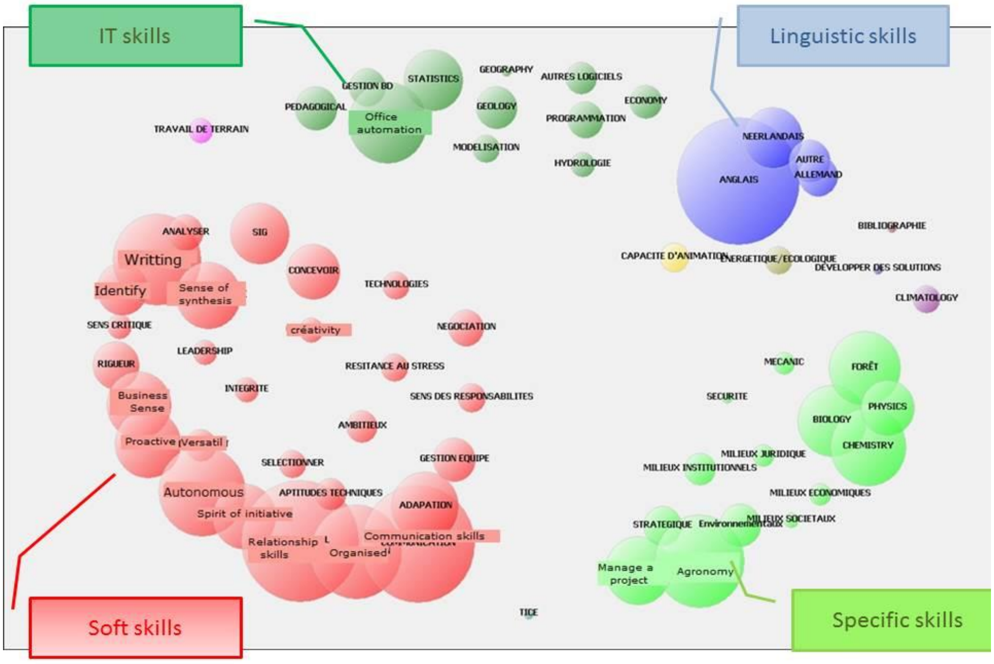

Figure 1: Lexical representation of the desired skills sought by employers

All these different sources of information allowed us to build a competency framework that was amended through iterative work. The draft framework was submitted to more than 219 employers. Their feedback (12%) was incorporated into the final version, which was based on skills (Figure 2) and was used as the starting point of the new teaching programme.

Figure 2: Final version of the competency framework for the Bioengineering Masters Degree in Environmental Sciences and Technology

3 Professional situations and Development trajectories

The competency framework is the keystone of the curriculum, but its constituent skills are general and complex (Tardif 2006). It is almost impossible for teachers to determine the learning activities directly from those general skills. In order to become more explicit, they were developed in real situations.

In order to help teachers integrate this guidance into course programmes, the skills are translated into professional situations. These professional situations take into account the extent and diversity of the area in which the said skill will be used (Tardif 2012). They describe what a student is able to do in the professional world when he is said to be ‘competent’ in those various skills. From these more clearly defined tasks, it is easier for teachers to determine the learning activities that will support students as they develop their skills.

For the skill described in Figure 2 as: ‘Designing technological solutions for the equipment, systems, infrastructures and services that meet new or established environment-related needs’, which is very general, we defined the following professional skill: ‘Design, size tracking and production of equipment in the agro-environmental field’, which is a contextualised skill, much more concrete and accessible not only to teaching staff but also to professionals.

Although the professional situations are clearer and more factual, they remain complex. They mobilise numerous resources, knowledge, abilities and attitudes. Developing a professional situation takes time and involves going through various stages of development. When children learn a language, they start by pronouncing a few isolated words before combining them into complex phrases. We learn to decipher words before we are able to read a book. These various stages constitute development trajectories. They involve progressively introducing complexity through the exercise of a skill. Development trajectories describe developmental processes and identify the levels to be achieved and the steps to be taken in moving towards professionalization (Tardif 2012).

In addition to the professional situation ‘Design, size tracking and production of equipment in the agro-environmental field’, we defined three levels of development: Novice, Beginner and Competent (Dreyfus & Dreyfus 1980; Hugonnet 2009). We expressed them entirely within the context of the professional situation (Figure 3). These different trajectories are connected to one another through the integration of increasing complexity in the path towards acquiring the full professional ability for this situation (Figure 3).

Design, size tracking and production of equipment in the agro-environmental field

Level of Development	Development Trajectories
Novice	To ***measure*** physical and chemical parameters and variables in the environment in order to monitor it
Beginner	To ***design*** simple equipment ***on the basis of a specification note*** and using existing techniques
Competent	To ***quantify the performances*** of a system using an operational monitoring system
Competent	To ***develop*** a technological monitoring system in a complex environment

Figure 3: Description of the development trajectories of a specific professional situation

Once these levels are clearly written, it becomes easier for teaching staff to identify the different courses and related learning activities that are involved in the training of those different development trajectories, but also the associated evaluations required to validate the acquisition of those levels.

Professional situation :

Design, size tracking and production of equipment in the agro-environmental field

		Physics / Mathematics	Vegetal	Chemistry	Hydrology	Environmental Physics	Environmental Metrology	Pedogenesis and Soil Hydrodynamics	Field Applications & Visits	Rural Engineering	Automation	Precision Agriculture	Indoor Crop Production	Soil Atmosphere Gaz Exchanges
		BA 1-3	BA1-3	BA1-3	BA3	BA3	BA3	MA1	MA1	MA1	MA2	MA2	MA2 (Optional: Binary choice)	MA2 (Optional: Binary choice)
	Optional	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
1	To measure physical and chemical parameters and variable in the environment in order to monitor it					EC								
2	To design a simple equipment on the basis of a specification note and using existing techniques						EC							
3	To quantify the performances of a system using an operational monitoring system							EC						
4	To develop a technological monitoring system in a complex environment												EC	

Figure 4 :
Matrix development trajectories versus courses implied in the learning or the evaluation (EC) of those different development trajectories

The process of developing the matrix as set out in Figure 3 enabled us to shed light on certain inconsistencies in the existing programme. Some courses were poorly integrated into the trajectories and others appeared to contribute to several trajectories. This observation encouraged reflection and collaboration among the teaching staff. In some cases, courses were merged into modules that tackled the development of an entire level. In other cases, teachers reviewed their learning objectives in order to avoid a duplication of activities in the course. This led to discussions, exchanges and arguments, but ultimately the work strengthened the team spirit.

The development trajectories force each teacher to rethink the learning activities in terms of the acquisition of the described level of development. The activities are more integrated, more practical. Figure 5 illustrates an activity organised for the Pedogenesis and Soil Hydrodynamics course, in which students monitor water and solute flows through soil columns using various sensors as part of the learning related to the development trajectory: ‘To quantify the performances of a system using an operational monitoring system’.

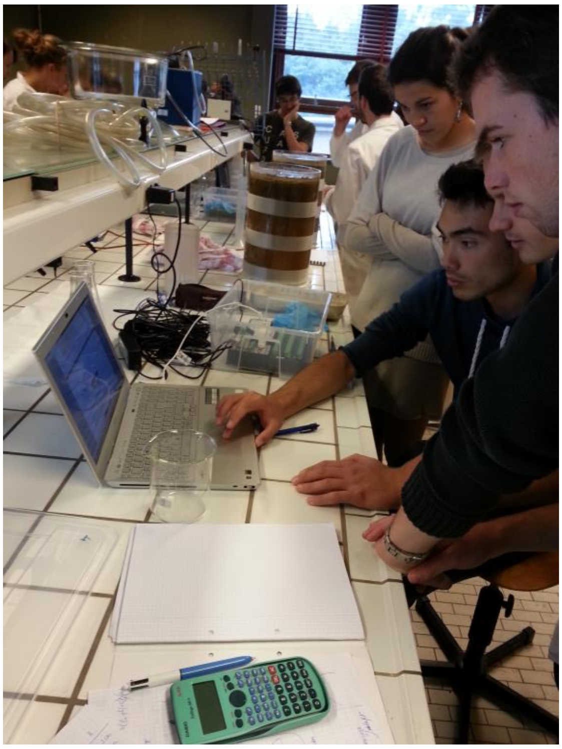

Figure 5: Learning activity associated with the third development trajectory illustrated in Figure 3

The entire process leads to the coherent and optimal development of the course. Some teachers are in charge of the certifying evaluation, which tests whether the students have acquired the right level of skills. All these certifications are shared among the members of staff.

4 Impact of the competency framework on various actors

Building a competency framework is often seen as a complex and time-consuming exercise that remains abstract for most teaching staff and professionals involved in its construction. By integrating this guidance into the curricula through the professional situations, the framework can become a powerful tool that can be used by three categories of users: academic staff, students and professionals.

4.1 Collaboration and cohesion of the academic staff

In contrast to past practice, where university professors designed their courses in a relatively independent way, this new type of teaching focuses on collaboration among teaching staff and transparency of content, with the shared objective of enabling students to master the skills required for their future career and for meeting the needs of society. Learning-based teaching requires teachers to concentrate on the acquisition of a developmental stage in the relevant professional situation. It induces better coherence in the curriculum.

This tool also helps to embed new teachers into a global project. There, they can identify the expectations of the team and the academic authorities with regard to their educational responsibilities.

This approach has provided an opportunity for our teachers to ask themselves how appropriate their course content is in terms of their teaching objectives. Better still, it has introduced new pedagogical content in response to new needs identified during the creation of the framework. A new dynamic has been established among those participating in developing this framework.

4.2 Tool to help students' choices of module

For students, this tool will enable them to be more involved in their own education. It will be specially adapted to choosing the optional modules. Depending on their career choices, students can make more informed choices about the modules that will meet the skills levels of the trajectories they wish to follow. The tool will also enable them to know exactly what is expected of them at various points in terms of achieving the levels in question. Students therefore become actors in the process and take the steps required for them to be ready for the qualifying evaluations. They build their professional project in coherence with the learning activities offered in the curricula.

This tool is also used as an evaluation grid for taking in new students from foreign institutions in order to check the relevance of some academic mobility.

4.3 Communication with the professionals

The use of the competency framework will enable the academic world to communicate more effectively with the professional world, setting out the tasks and levels of development that students should achieve in the various trajectories. Close collaboration with the 'Career Observatory' will ensure that learning responds as well as possible to the expectations of the professional world and to the new needs of society.

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