Design of competences based bachelor and master programs in Mechanical Engineering at the Ecole Polytechnique Fédérale de Lausanne

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Abstract - **This paper presents the process and the results of a project laid out to define the objectives of the Mechanical Engineering Bachelor-Master study plan in terms of competences and to set up a management process of the teaching activities that foster integrated and aligned learning outcomes.**

The first step consisted in collecting the societal and entrepreneurial needs expressed as knowledge, know-how and attitudes from a panel of 30 active professionals, mechanical engineers themselves or collaborating with them. The consecutive quantitative and qualitative analysis allows us to highlight expected competences for the mechanical engineer.

During the second step, realized with the participation of the teachers, the competences have been specified for the mechanical engineering domains succeeding in the definition of specific learning outcomes and in the specification of learning situations supporting the development and the assessment of those learning outcomes.

The project will culminate by the reorganization of the mechanical engineering study plan for the fall semester 2011.

The paper evaluates the enterprise and discusses its stakes especially in terms of the implication of the actors.

Index Terms – Mechanical engineering education, Competence based program, learning outcomes.

INTRODUCTION

Mechanical engineering education at EPFL has a long history. It has been for years one of the key providers of engineers for the national mechanical industry centered in machines, engines and watch industry. With the profound changes in the structure of the Swiss industry and the European education space that occurred at the end of the XXth century, the needs towards the mechanical engineering education has dramatically changed requiring more and different know-how and *savoir-faire*. Figure 1 presents the double loop mechanism necessary to align the study plan with the learning situations. Programs and teaching must follow, and in fact precede, the evolution of the necessary professional competencies.

The Bologna process has induced a restructuration of the old "4 year diploma" in a Bachelor-Master structure [1]. In the same time the expectation towards EPFL Dipl. Mech. Engineers has increased. Competences are expected from young engineers: wide and deep knowledge in engineering subject matters and methods as well as the bases of know how and human qualities in project management, teamwork, communication and management.

This was the ground for the project "Competences SGM" launched in 2007 that aims at (1) determining the key competences that define the objectives of the Bachelor-Master education study plan and (2) at setting up a management process of the teaching activities, which foster integrated and align learning outcomes as shown in Figure 2.

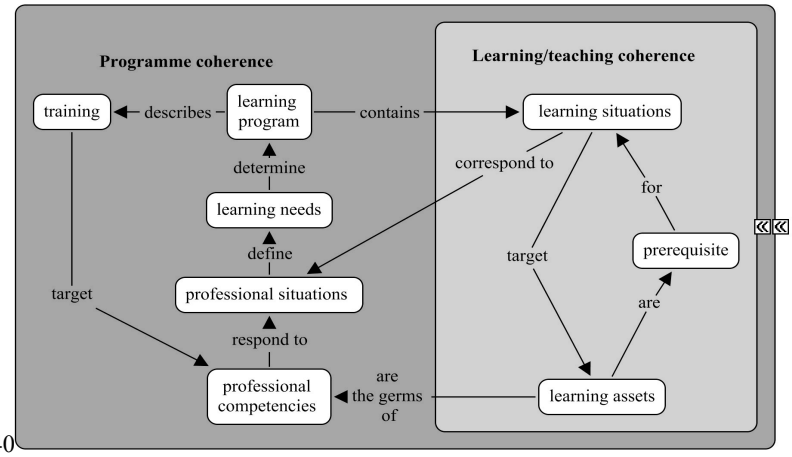

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FIGURE 1
THE MINDMAP OF THE PROGRAM AND LEARNING COHERENCES

THE QUESTIONNAIRE AND THE PANEL

The first step of the project consisted in collecting the societal and entrepreneurial needs expressed as knowledge, know-how and attitudes from a panel of 37 active professionals, mechanical engineers themselves or collaborating with them.

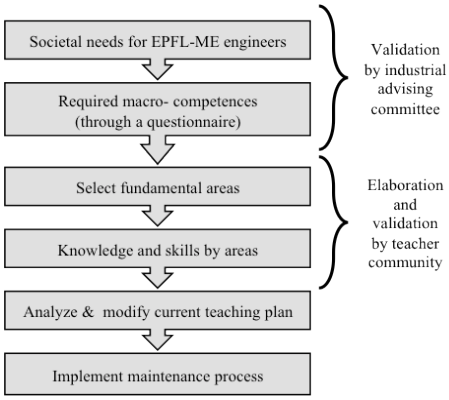

FIGURE 2
STRUCTURE OF THE COMPETENCE PROJECT

It has been asked to this panel to prioritize and quantify the importance of these knowledge, know-how and attitude for their profession, but also to indicate the corresponding ideal level of student's mastering for each of them [2]-[3]. Additionally it also has been systematically asked to them to justify their answers. The questions scan the 3D space presented in Figure 3.

The structure of the questionnaire is presented in Table 1. An argumentation was systematically asked to allow the members of the panel to explain their points of view and their rationales.

THE QUALITATIVE AND QUANTITATIVE ANALYSIS

The analysis of the questionnaire allows us to highlight the expectations towards the mechanical engineer graduated at EPFL in terms of knowledge, know how and attitude that have been synthesized in a competence reference list [4].

Here below some are given graphics are shown in order to give a glimpse of the quantitative information that has been collected.

The knowledge is a pillar of the engineer's competence. The panel has given a clear priority, not surprisingly, to scientific, engineering knowledge and technology. The two left upper histograms presented in Figure 4 are clearly queued at right, due to a part of the panel that gives an absolute priority to science and engineering when the majority has a more balanced opinion, keeping space for human science and enterprise related knowledge.

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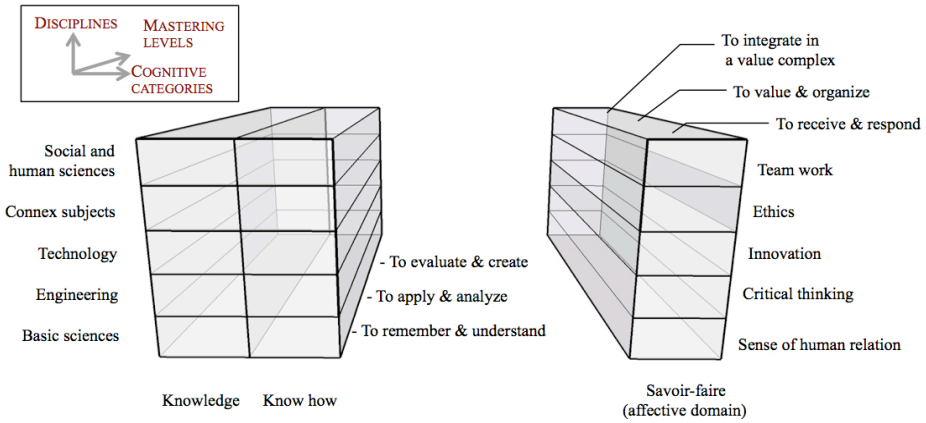

FIGURE 3
3D SPACE SCANED BY THE SURVEY

TABLE 1
STRUCTURE OF THE QUERY

Part A: Knowledge	Priority between disciplines Priority within each discipline Priority between theoretical, experimental and numerical approaches Company experience and internship
Part B: Know how	Priority between disciplines Priority within each discipline Specificity of EPF engineers Importance of multidisciplinarity
Part C: Social skills	Status of social skills in the engineer competence Priority between social skills categories Priority within each social skills categories

The analysis of the opinions of the panel reveals an interesting difference between the expectations about *basic sciences*, on one side, and engineering and technology on the other side. When 2/3 of votes require the maximum level of mastering for *engineering and technology* (to create and decide), ½ of them would be satisfied by a slightly lower mastering in basic sciences (to apply and analyze). The requirements on the other subject are minimal (to know and understand).

About the importance of social skills and other *savoir-faire*, the panel has been asked to vote for four propositions. Table 2 shows that the panel was strongly in favor of the two first proposals stressing the major importance of social skills and *savoir-faire* for the engineer from the very beginning of his professional career.

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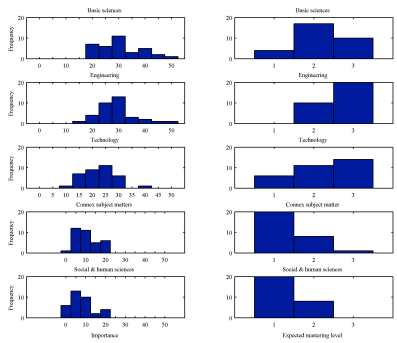

FIGURE 4
FREQUENCIES OF VOTES ON THE IMPORTANCE (LEFT) AND ON THE EXPECTED MASTERING LEVELS (RIGHT) FOR THE MAIN KNOWLEDGE CATEGORIES

In addition a qualitative analysis allows us to harvest what has been expressed in the argumentations. All the propositions have been ordered and classified to give a range of opinions and rationales about the expectations that awaits the young engineer. With that material, a first competence reference list has been settled,

TABLE 2
FREQUENCIES ABOUT THE OPINION OF THE PANEL ON THE STATUS OF THE ATTITUDE FOR THE YOUNG ENGINEER

PROPOSITIONS	VOTES
(a) The *savoir-faire* is absolutely necessary to guarantie the integration of the young engineer in his first job.	20
(b) The *savoir-faire* is necessary, but with dedication the young engineer can develop it during his first job.	14
(c) The *savoir-faire* is a must but it is less important for the young engineer than his technical knowledge.	1
(d) The young engineers should focus on scientific and technical aspects; the social skills can be acquired only with experience in a company.	1

influenced also by previous work such as the ULB competence list [5] and the BOK2 published by the ASCE [6] as well as previous work of some of the authors of that paper [7]. It is formed by four key competences that are completed each one with a list of components (Table 3)

TABLE 3
COMPETENCE REFERENCE LIST

Competence	Components
1. To understand, rapidly cope and communicate with his professional, technical, ecological and economical environment	• To learn new knowledge and develop new skills • To call up fundamental knowledge of mechanical engineering • **To call up specific knowledge of a mechanical engineering topic** • To communicate efficiently orally and by written in French, English and German
2. To identify, analyze and formulate complex problems by adopting a scientific, holistic and multidisciplinary approach	• To define the goal and the specification of the analysis • To choose the approach and the theoretical, numerical and/or experimental tools • **To conceive and realize a model, simulate and experimentally characterize a complex, dynamic and uncertain situation** • To synthesize the results of the analysis
3. To conceive innovative and efficient solutions	• To define the specification • **To create, – in relation with curiosity, find innovative solutions "out of the box"** • Evaluation – take risk • To choose solutions • To conceive with method
4. To act as a responsible professional	• To develop his own autonomy • To collaborate • To perform critical thinking • To act ethically • To develop himself professionally

The first comment that we usually receive when we have shared this result with the teachers within the university was that it was not specific to the mechanical engineering domain and it is true indeed. It brings a view on the profession that has a strong generic base constituting the "engineer" competences that is specific in its domain of application. The most specific part of the reference list has been highlighted in bold.

THE DOMAIN FILE AND THE COLLABORATION WITH THE TEACHERS

During the second step, which has involved the whole group of the program's teachers, the competences have been specified in relation with the mechanical engineering specific domains (mechanics, production and conception, control and mechatronics, energy).

This must end in the definition of learning outcomes (LO) by specific domain, by program (Bachelor and Master) and by the specification of situations supporting the development or the assessment of those learning outcomes. It is this work that roots the program in the competence reference list and this must be done in a very open collaboration between the program managers, the teachers and the pedagogical counselors. The main tool for that work is the *domain file*. This document is structured as shown in Table 5

It is planed to have files for the domains listed in Table 4

A first version of the domain file has been prepared with the different domain counselors (they are teachers in charge of counseling the students in establishing their personal study plan in a given domain). This was done by mind mapping the different domains in relation with the competence list [8]-[9].

TABLE 4
LIST OF PLANNED DOMAIN FILES

Basic sciences
Aero-hydrodynamics
Solids and structure mechanics
Biomechanics
Control and mechatronics
Design and production
Energy
Related subject maters and human sciences (for engineers)

TABLE 5
TEMPLATE OF THE DOMAIN FILE

Title	Content
Domain description	A short description of the domain and it border with neighbour domains
Learning income	A description in terms of knowledge, know how and savoir-faire necessary for the mastering of the domain but that are prerequisite to the courses of the domain
Professional situations	Examples of professional situations in which the competences proposed in the courses of the domain can be mobilized
Training situations	Examples of training situations in which the competences proposed in the courses of the domain can be developed
List of courses	The up-to-date list of courses belonging to the domain. A course can belong to several domains
Competence model within the domain	The structure of the competence in the domain showing the relations of precedence and synergy between them.
Table 'competences - learning outcomes – learning situations'	A table establishing the relation that roots the learning outcomes that can be specific to a domain or generic for engineering with the competences and linked it also with the learning situations fostering its development.

NEXT STEPS

The two fist steps of this Endeavour is now completed with the transmission to the teachers of a competence list and the setup of a process to root the study program for the mechanical engineers in this list of competences. This transmission was proactive in the sense that we have organized workshops with the teachers to "sell" the process and the results. The outcome of this collaboration is obvious as it allows the teachers to

- clarify how everyone positions oneself in relation with his colleagues in the domain,
- learn the process of program building,
- explicit what exists already and the possibility of integration between teachings and domains.

The next steps will consist in improving and completing the domain files and distributing the targeted learning outcomes within the set of the courses of the program. For this part, an innovative point of view has also been taken. Defining the content of the course file so that it indicates clearly the contribution of each course to the competence portfolio of the student. The structure of this course files is presented in Table 6.

An important step will then be the transmission to the students, since all these efforts will culminate by the re-engineering of the mechanical engineering study plan for the fall semester 2011.

CONCLUSIONS

This project is a pilot for the EPFL and the Swiss academy. It was then crucial to be attentive to the lessons to learn from this experience. In this perspective we have been helped by three favorable conditions (between other one obviously). The institutional leaders were rapidly convinced by the project and support us. Moreover the coordination team gathers a good knowledge in the subject matter, in pedagogy and in the competence approach. Another factor of success was that teachers are really concerned by the quality of their teaching.

We also have encountered difficulties. The level of information and pedagogical training was not even between teachers requiring an important effort of communication. It then requires time for every one to enter in the process.

TABLE 6
TEMPLATE OF THE COURSE FILE

Title	Content
Aims	A general description of the aim of the course in term of knowledge and competence
Content	A table of content of the course
Content Description by key-words	A list of keywords that must allow the selection of the course with a browser
Learning Incomes	A description of the knowledge and competence that a student must have to cope with the course
Learning outcomes	At the end of the course the student must be able to:
Teaching method	A description of the approach of the course in term of pedagogy and didactics
Expected work	The type of work expected from the student
Evaluation method	A description of the method used to evaluate the learning assets
Supervision	Information on the supervision offered in terms of assistance, office hours etc...
Bibliography and Material	A bibliography and a description of hand out
Links with other courses	A list of courses linked to this one
Credits	Amount of credits obtained in case of success

Nathalie
Kommentar [1]: Ne devrait-on pas ajouter ici l'étape importante des fiches de cours en donnant les différents elements de cette fiche qui sera réalisée par chaque enseignant?

The generic parts were discussed many times with different groups and it was difficult to keep it focused and coherent and in the same time to respect what has been talked with each group.

As well it was a constant effort to keep the balance between the generic and the specific when defining the learning outcome [10].

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