A method to elaborate a qualifications framework for innovative design – Application to a master degree in innovation.

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Abstract:
We describe the construction of a skill standard for a master degree education in innovation and products engineering. Our final goal is to check and assess pedagogy result for accreditation, to explain the purpose of each training unit and to facilitate the employability of trainees by the definition of new skills for these emergent jobs. Our method is inspired from the one used to elaborate occupational standard, a framework to evaluate qualifications in vocational training. From the occupational analysis, an occupational profile describes the missions, activities and skills. An activity is observable and requires multiple skills with various levels. Each skill is assessed by clustering a set of capabilities. Two adaptations of the initial method have been done; they concern the acquisition of information for understanding the activity, and a definition of skill levels that relates to roles taken in design teams (from a simple participation to the ability to manage a design session).

The application is part of the curriculum of the second year of Master Innov-acteur in UTBM. It contains five core units (innovation strategic management, business intelligence, innovative design, emotional perception, and marketing). The method is applied to "innovative design" which aims to search and to validate solutions. This activity uses methodological tools like functional analysis, brainstorming, Triz ... but differs from classical problem solving in many aspects: problem and solution co-evolution, use of representations, reasoning modes for creativity, a process constantly refined by designers, its collective character, and the use of reflexive practice necessary to conduct it. Four core skills are identified and linked to sixty one capabilities. This study shows the possibility to apply this method to high level cognitive activities. Another result is the necessary combination of communication capabilities to technical ones in order to assess technical skills.

Key words: Design, Innovation, Reflective Practice, Accreditation, Qualifications framework for lifelong learning.

1. INTRODUCTION

In this article, we describe the elaboration of part of a reference skill standard for a master degree in product engineering innovation. It concerns innovative design. Our objectives are multiple. First, as teachers, our goals are to control the "results" of our teaching and to communicate on it. Second, defining the detailed objectives of each teaching unit will allow trainees to access (with the teaching team) individual requirements, to concentrate acquisitions on new or missing knowledge and know-how, and ideally to make self evaluation. Especially, for these emerging carriers a detailed reference skills standard can help for skill appraisal, supporting individual integration and development. Last, it could facilitate the management of collective and individual skills.

Innovative design is involved in any innovation, or simply design, project. Its objectives are to search new and technically viable concepts for corresponding requirements, and to prepare decisions concerning the product development. Argumentations are fundamental and require both technical and communicative skills As this activity is not easy to perceive, we will begin with a presentation of some of its features in section 2.

Then, the method we used will be exposed in section 3. A presentation of our reference skill standard will follow in section 4, and its use in section 5.

2. INNOVATIVE DESIGN

Discourses on (innovative) design activity are multiple, but we can consider that none of them can form a complete model able to describe the complexity of the activity. Moreover, a direct observation is not sufficient to understand the diversity of design situations. Nether the less, we will give here some of its important features, founded on literature survey, on our research based on the observations of design sessions, and on our experience in teaching and practising. It is important to underline that the skills we will consider concern the handling and management of the design process; most of them are based on techniques, methods, and methodological tools. These skills complement more classical technical ones in physics, mechanics (including the knowledge of components of current products), manufacturing, production organisation, product behaviour assessment … or even CAD modelling, which we will consider previously acquired.

2.1 Co-evolution

Design problems are "ill defined", especially in innovative design [1]. These problems do not have enumerable potential solutions; it is not possible to set a succession of operations leading from a problem formulation to a solution; and, most of all, it is not possible to have a correct formulation of the problem(s) without engaging in some sorts of solution hypothesis [2]. During the design process, "unexpected discoveries" are common [3], typically new criteria: they will complete, modify, or even erase the current formulation of the problem. Also, new (sub) problems emerge. Design research recognizes that solution(s) and problem(s) co-evolve during the design process [4]. A consequence is that the formulation of needs, functions, and requirements… must be considered as final results of the activity rather than as given data or intermediate deliverables. Innovative design deliverables are made descriptions of both the proposed product (its structure) and the needs it corresponds to. These two descriptions are linked by the analysis of the product behaviour and by functional analysis.

2.2 Importance of creativity

Different reasoning modes are required from innovative design. Determining the product behaviour requires classical engineering knowledge, essentially based on deduction. But the ability to propose and build solutions also depends on other reasoning modes like teleological, abductive, and analogical reasoning. These modes are difficult to learn and assist: Creativity techniques (brainstorming…), some methods like TRIZ [5], catalogues of technical solutions, or information systems, can help. Specific capabilities must be associated to these non conventional reasoning modes.

2.3 Importance of representations

Designing is also thinking on a product still not existing, and not defined. Part of the activity consists in the construction of relevant representations describing different and complementary aspects of a product, all evolving. Among them, structural representations in the form of drawings (schematic or technical), CAD or physical models are naturally present. But other representations support the expression of behaviours, functions or product use (need): simulation results, functional or flows models … The first function of all those texts, graphs, mock-up or tables are to support the reflection on the product [6]. In collective situations, additional functions appear such as information sharing, communication of ideas, or personal involvements … Building and using relevant representations requires specific skills, including technical and communicative components.

2.4 Design process

The evolution of problem and solution, and the use of multiple reasoning modes, give the design process an opportunistic character; more exactly, its definition has to be constantly refined by designers. Project piloting (rather than management) requires the designer to determine objectives, intermediate milestones, and to permanently evaluate the current situation in order to transform it. From a technical point of view, this is first an analysis of the current definition of the product aspects, and the extent to which they are complete and coherent. Actions are then programmed (among them sub problems identification and resolution), and the product definition is transformed. This is an iterative procedure, where each action depends on the others (path dependency, but also teleological one). We chose to group these possible actions in three categories: product analysis, interpretation and focalisation, and transformation; each one requires specific skills.

2.5 A collective activity

In engineering design, technical creativity is both individual and collective work, with interactions between these two working modes: individuals have to report on their work, which can be specified in meetings. A multidisciplinary design team processes a greater quantity of information than individuals, and this information comes from diverse technical domains. Moreover, group dynamics is known to favour creativity.

Each participant must therefore have elementary relationship know-how (express an idea, listen to others …) and the animation of meetings must be supported by animation techniques (be attentive to each participant, allow each one to act, reformulate ideas …); this social part of the activity relies on communication know-how for both participants and animator.

2.6 Reflexive practice

In a previous paper [7], we defined reflexive practice as "the attitude adopted by an individual in order to take an external and critical look at his/her activity (in progress or completed). It allows him to analyse the contextual and generic elements of a situation, to gain a critical distance in relationship to the schemas being used, to capitalize". This reflection is necessary to consciously program future actions. We consider that it must be mobilized for all the aspects of the design situation. These can be technical (co evolution), relative to the use of methodological tools and product representations, to the piloting of the project and to social communication. This reflection is not of the same nature for the piloting of the activity or for the realization of elementary actions.

2.7 Occupational profile

The innovative design activity as described above is involved in several occupational profiles, like product designers or design engineers. The core jobs we focus on are in R&D or design departments.
The corresponding missions essentially aim to build and develop new product solutions; they often include the animation of work groups, and sometimes the diffusion of new methods.

3. METHODOLOGY

The method used is inspired from the one used to elaborate an occupational standard [8], a framework to evaluate qualifications, in vocational training.

3.1 Vocational training methodology and definitions

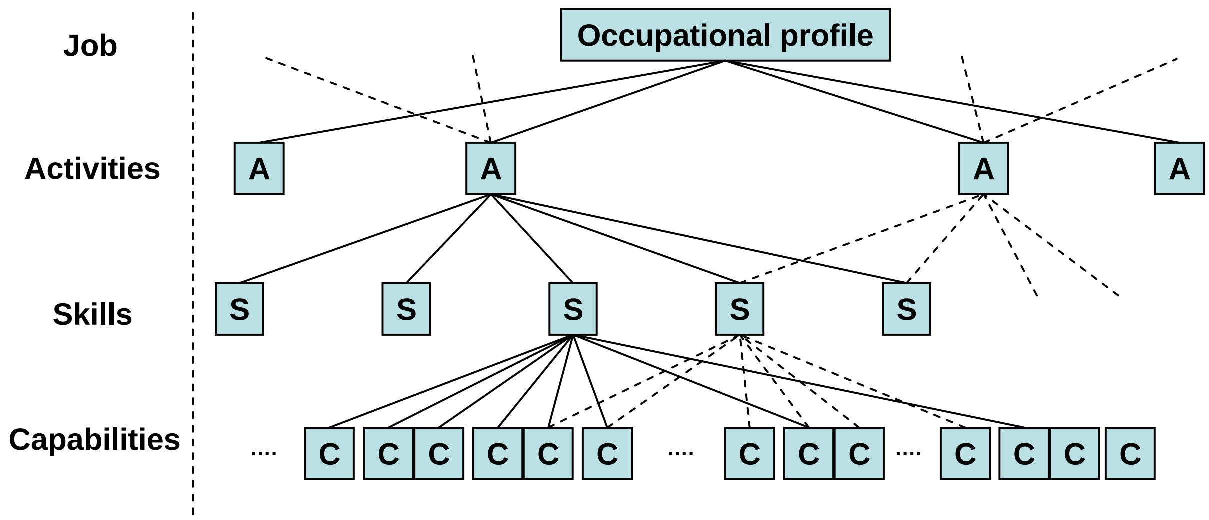

FIGURE 1: Four concepts of an occupational standard reference.

This method [9], [10] is organized around four concepts structured in a hierarchic manner (cf figure 1), depicted according to a top-down progression:

- The first step is the occupational analysis to define an occupational profile.
- The second step is the activities writing. An activity is a set of final, identifiable tasks organised by a logical process. It is observable and requires multiple skills with various degrees.
- The third step is the skills identification. The skill is defined as the ability to act successfully in a professional situation [11].
- The last step is the definition of capabilities (elementary level) which are: theoretical knowledge, technical, behavioural, operational know-how. Each skill is assessed by clustering a set of capabilities required in an occupational situation.

All information about occupational profile, activities, skills and capabilities are brought together in an occupational standard. This framework provides objective data necessary in human resource management: writing the job description, selecting personnel to fill positions, training them on specific tasks, identifying training courses and evaluating their efficiency and efficacy, needs assessment, vocational assessment, and job communication.

Analysis methods to elaborate this framework are the one used in Social sciences: occupational practice analyses, surveys, individual and group interviews, observation, work diaries. All those methods are usually used to describe technical employment.

The specificities of the activity we studied (high level, cognitive, communicative …) involve adapting it. A first change concerns the acquisition of information, made from literature survey, research and design sessions observation, teaching, and personal practice and the second change concerns the definition of the level of skills.

3.2 Skills

The usual levels are:

- novice,
- intermediate: common practice,
- advanced: mastery (great skillfullness) and ability to teach,
- expert: expertise level or ability to improve the area knowledge.

In this study we prefer to define the level of skills relatively to the activities in collaborative teams. The required levels of skills are different, depending on the roles taken. Our skills levels (SLi) are:

- **SL1**: I only have theoretical knowledge and I don't know how to practise.
- **SL2**: I can act, with the help of the team. This level corresponds to an active and constructive participation in a meeting.
- **SL3**: I act in autonomy, interactions with my colleagues happen for reporting.
- **SL4**: I manage a meeting partly or entirely

This scale is increasing: capabilities to act alone are required for conducting a meeting.

3.3 Capabilities

According to their definition, capabilities are assessable. Each capability can be written in the form “be able to”, and without any conjunction (specially “and”). As innovative design activity is largely instrumented, many capabilities are related to choose, use, and modify techniques and methodological tools. This activity is reflexive, self evaluation can be possible. Capabilities level definition range from “no action” to “act automatically”, based on cognitive scheme. “The cognitive scheme (…) has the advantage to make easier action by automating it (…) [12].

The levels are:

- **CL1**: I'm not able to act.
- **CL2**: I'm able to act in common situation.
- **CL3**: I'm able to act in 80% of situations, even unusual.
- **CL4**: I'm able to act automatically.

Only practical experience enables to gain the level 4 and we cannot require it in academic training. But the repetition of situations can help to gain this level.

3.4 Capabilities-skills connection

Capabilities contribute to skills. Each skill of defined level is linked with certain capabilities of given level.
In the following section we transpose this method to the innovative design activity.

4. APPLICATION

This section presents the main two steps of the application to a master degree course. Identifying the capabilities is the first step; each one is deduced from one skill. The second one aimed at determining the dependences between capabilities levels and skills levels; we then saw that a capability level is often required for two or more skills: Innovative design activity skills are not independent.

4.1 "Innov-acteur" : a master degree in innovative design

We applied the method to a master degree in innovative design, called "Innov-acteur". The curriculum contains five mains poles: innovation strategic management and patent right, business intelligence and knowledge management, innovative design (on which we focus here), emotional perception and design, and innovation marketing. Transverse modules on foreign languages, communication, and of course an application project complete the curriculum. [13]

Selected trainees enter with skills in several disciplines according to their previous curriculum (economics, patent right, management, engineering …). During the curriculum, they get the specific skills required to participate to innovative products or services development projects, or to manage some, Those skills systematically include the ability to built and manage the design process, to use (or make use of) methodological tools, and to improve the cooperation between the project actors. For their first job, trainees must be able to take responsibilities in products or services creation activities, at first as assistants, then as managers.

4.2 Identification of the required skills for innovative design

At the first step, we identified four main skills (Si): three correspond to the three categories of actions mentioned in 2.4, plus the design process management. We propose to define them as follows:

- **S1**: to analyze and understand why a product has been designed in the way it has, and to criticize it. It consists in having a static "designer's look" on an object already existing or being designed, to answer the following questions: "what?" (What is this object, what it is made of?), "what for?" (What are the needs it is designed for, and the functions it has to complete?), "how?" (How does it work and match the required performances?). This needs using some tools of functional and technical analysis in order to describe several products aspects (needs, functions, behaviour, structure).
- **S2**: to build and decide one's aim and action map. From the previous analyses (on the current reality), the work to be done consists in defining the future reality to be built, i.e. in detecting the main performances to be improved or problems to be solved (framing, prioritizing, defining goals and focusing on them).
- **S3**: to imagine and build some solutions, then evaluate them, and decide to keep or modify it.
- **S4**: to manage the design process and the project. Aside the operational level of the tasks previously described, the designer's sight must include the possible consequences of the current activity in order to anticipate them, and to take in account the "good" and "bad" unexpected events.

Each skill can exist at the different levels described in 3.2. (Skill S4 at the level SL2 is the exception: managing the process cannot be done by someone only able to act with the help of the team).

4.3 Identification of the capabilities required for each skill

Determining the capabilities required for each of the skills described above is the second step. This is fundamentally a top down process: capabilities are obtained by breaking down one skill. But we also identified some capabilities from a reflection about the functions that each step of methodological tools completes in the design process. (see example in "group 1" hereunder).

We remind here that our scope doesn't include all the capabilities relatives to specific domain skills: for instance, we don't mention the ability to use CAD tools or to assess product behaviour.

We present hereunder the five groups of capabilities we identified (one per "technical" skill, plus one for the relational capabilities).

- **Group 1**: 16 capabilities were derived from skill S1 (product analysis), for instance :
  - basic: recognize or state the system perimeter;
  - using analysis methods (for instance functional analysis): identify the main lifecycle phases, express the needs and the functions of the system, identify the main flows of matter energy or information.
- **Group 2**:11 more capabilities were derived from skill S2 (problem framing and focusing), for instance :
  - describe the product to be designed and build its specification, as just accurately as necessary (qualification criteria, validation tests …);
  - decide and describe a goal (using TRIZ concepts and tools like ideally, evolution laws or multi-screen representation, for instance).
- **Group 3**: 6 more capabilities were derived from skill S3 (imaging and building solutions), for instance :
  - choose the most adapted creativity tool or animation technique;
  - propose original and pertinent concepts.
- **Group 4**: 5 more capabilities were defined from the skills S4 (design process managing), for instance :
  - take into account the unexpected events;
  - evaluate the situation and prioritise actions to be done.
- **Group 5**:we added here 23 more capabilities in communication, animation and relational abilities, like :
  - incite and valorise project actors participation;
  - evaluate the current situation and decide actions to be done.

4.4 Capabilities-skills matrix

			Skills											
			S1 Product analysis			**S2** Framing and focusing			**S3** Building solutions			**S4** Process piloting		
			Levels			Levels			Levels			Levels		
			SL2	SL3	SL4	SL2	SL3	SL4	SL2	SL3	SL4	SL2	SL3	SL4
Capabilities	Group #1	Level CL2	11	4			9	8			9		10	9
		Level CL3		12	16		2	3			1			2
	Group #2	Level CL2		6	9	8	3			6	5		8	7
		Level CL3					8	11			3			2
	Group #3	Level CL2			4		3	4	3	3			4	3
		Level CL3						1		3	6			1
	Group #4	Level CL2		1	5		1	5		1	5			
		Level CL3											5	5
	Group #5	Level CL2	22	11		21	7		23	4				
		Level CL3		8	23		11	23		14	23		20	23

Table 1: Number of capabilities for each skill - extracted from the capabilities-skills matrix

The following step aims to determine which level of each capability is required to get every level of each skill.

A same capability can be involved in many different skills, sometimes with different levels. The situation is the same at the upper level, since a same skill can be required by many different activities.

All these crossings and overlaps show that the activity is complex. It is obvious that the three first skills are not independent and that they overlap: you cannot frame and focus your action (skill S2) without understanding the initial situation analysis (skill S1); modifying a product (Skill S3) requires to have detected first the characteristics to be improved and to have understood the problems they hide. Last, managing the process (Skill S4) requires understanding all the concepts.

We built a complete capabilities-skills matrix, elaborated from our industrial and academic experiences in the field. Table 1 is extracted from this matrix and shows all the crossings. Its cells contain the number of capabilities of each level from each group required for a given level of a given skill. For instance, the number "3" in the grey cell means that, among the capabilities of the third group, 3 are required with a level CL2 to get the skill S2 at a level SL3. The columns relative to skills levels SL1 and lines relative to capabilities levels CL1 are obviously not considered. As we said in 3.3, we estimate that the capability level 4 (acquisition of cognitive scheme) cannot be required at the end of an academic curriculum - see above.

The table shows that an increase in the skill level requires higher levels of both technical and communicative capabilities; it requires as well a higher number of different capabilities (qualitative and quantitative changes). It also confirms that piloting the design process requires almost the whole set of capabilities, but not necessarily at the highest level.

Finally, a synthetic ratio can be calculated from the complete capabilities-skills matrix, in order to digest each student's level in every skill from his elementary capabilities evaluation.

5. RESULTS AND DISCUSSION

This matrix was tested on the ongoing master, at the end of the theoretical semester of training (i.e. in February 2008).

5.1 First experimentation

The capabilities list was distributed to 6 subjects involved in Innov-acteur Master. For each capability we asked them to self-assess their level (between CL1, CL2, CL3, CL4) at the end of the academic semester, before going to placement. Five subjects came from initial training and one is in an adult vocational cursus.

Capabilities titles seem to be clear enough, making it possible for each student to estimate his own level.

Nether the less, we noticed three kinds of shifts (since we know these students well). The first one is linked to self esteem. The second comes from possible confusions between management capabilities and meeting animation ones. The third one concerns communication capabilities, and is due to an under rating of the gap between theoretical knowledge and its application in professional situation. The synthetic ratios calculated confirmed the pedagogic team opinions and evaluations during training work.

5.2 Possible applications of the evaluation device

The first application naturally concerns training. In order to pilot the training process, it is useful to assess skills at different times of the curriculum: at its beginning, at the end of the academic semester just before the placement begins, and at its end. It could even help to determine ECTS grades, as a complement to other ways of evaluation, especially for greater populations where an individual monitoring is not easy.

A detailed skills assessment is also very useful for the students, to better know themselves. It helps them to compose their *curriculum vitae* and to prepare future job interviews.

The proposed device can also be used in human resources management, to support someone's skills assessment, or to describe the required skills in order to define a job. Indeed, it allows completing the currently observed occupational profiles, by describing some new or emerging skills: for instance, the ability to choose the right methodological tool at the right moment, or to pilot a work group, is poorly recognized yet as a required skill for designers, and almost never mentioned in companies' skills standards.

6. CONCLUSIONS AND PERSPECTIVES.

Innovation design is cognitive and complex. It uses instruments (methodological tools …), it is largely communicative (multiple actors and social concerns), and reflexive.

In this article, we show that it is possible to define a reference skill standard for this professional activity. Such a standard can give each student an indication of his own skills and their evolutions relatively to explicit requirements. In this aspect, this tool can help in a remark on learning. This tool can also be useful for professional insertion in emergent activities.

We took inspiration from a method classically used for professional skills. We made two modifications to adapt it to our purpose.

The first modification concerns the comprehension of the activity. The impossibility to understand it by simple observations involves considering some of its main features from literature survey and from our own activity (research, practice and teaching).

The second modification concerns the different skills levels definition. Instead of defining them as increasing degrees (novice, intermediate, advanced, expert), we defined abilities to act in different situations as participant, autonomous worker and animator.

Two actions are programmed in the future. First, we intend to test this reference standard on larger panels of engineering designers, including professionals. Second, an extension to the whole of innovation skills has to be done. In our master degree, innovative design is one activity among five, and its skills consider the interactions inside this activity and with communication. The objective is to define a complete skills reference standard with all the possible interactions before certifying it with industrial professionals.

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