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DEVELOPPING A PRODUCT DESIGN ENGINEERING PROGRAM: EXPERIENCE OF A FRENCH SCHOOL TRANSFORMATION

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ABSTRACT
The launch of the Bologna process is significantly modifying the European Higher Education landscape since 1999 and is a way of reinforcing the European Council ambition to become "the most competitive and dynamic knowledge-based economy in the world"[1]. The degree evolution into a three-cycle system as well as students, teachers and researchers mobility within Europe are priorities. For engineering schools this institutional reform is an opportunity to review their organisation and programs. It needs to take into consideration other substantial changes one can find within industries, whether they are of economical, technological, material, social or organisational nature.
We worked on the educational transformation of the product and engineering design Master of Science degree proposed by INPG (Institut Polytechnique de Grenoble) in France. After a reflection about the change process the objective of this paper is twofold: to present the new curriculum and to propose a methodological approach which could be implemented in another educational context. Besides the use of a holistic approach, a first overview of the global context and a diagnostic of the institution as-is situation, we investigate the skills, knowledge and proficiency areas a product design engineer should develop or acquire at school. Based on industry needs and researchers' interviews, we propose then tools and methods to help envisioning the future curriculum structure that a new engineering department would offer.

Keywords: engineering education, curriculum design and development, engineer skills and knowledge, Bologna process

1 INTRODUCTION

In this era of knowledge economy, the role and social position of the product and engineering design within industrialised countries has evolved due to multiple reasons. This professional identity transformation is not initiated within companies; it gets prepared in engineering schools where teaching methods and organisation sometimes differ.

This paper describes how a French engineering institution has changed its organisation and programs to better cope with the context evolutions that industries and higher education have to face to, whether in France, in Europe or at a global level.

The subject of our research is, within the context of the Bologna process launch, to find out which product and engineering design program to put in place and how. Based on our experience, our observations led at INPG (Grenoble Institute of Technology) in France for five months and integration of international experiences and methods (CDIO[2] conference, international researchers' interviews), we propose to present the new curriculum as well as the approach and tools that, although specific to the French educational system, could inspire other institutions.

Sharing this experience cannot start without explaining firstly the global and dynamic context. As a second point this paper explains INPG challenges. Then it presents our research approach and ends up with two kinds of results: the training curriculum structure for design engineering Master of Science and a methodology for implementing such a program.

[1] European Council of Lisbon – March 2000
[2] http://www.cdio.org

2 MOTIVATION

At a global level and in an industrial context, recent evolutions that have affected product design engineering activities are mainly of technical, organisational, social and educational nature. The context analysis is based on recent technological studies [1] [2], design engineering researches [3], sociological and social studies about Human Resource changes within industries [4].

2.1 Recent evolutions

From a technical point of view, industrial products become nowadays more and more complex. The mechanical part is obviously not the only characteristic of an industry-designed product; the introduction of electronics, electricity and other technology-related elements leading to what we call mechatronics, coupled with a need for miniaturisation, customisation and eco-oriented design, contribute to this complexity. From a process perspective, design engineering goes beyond product design and product manufacturing activity; it encompasses the product service and therefore forces engineers to think from now on in terms of product life cycle.

As far as industrial organisation is concerned, flexibility, agility as well as the need for innovation and sustainability have recently forced the most competitive companies to rationalise their activities, especially in the strategic field of product and system design. The globalization wave and international competition encourage many companies to delocalize their production, maintenance or R&D functions and to develop remote activities. “Virtual enterprises” work more and more in networks and through projects where collaborative design in a multicultural environment becomes a strategic activity.

Socially speaking, employability and skills have been recently introduced within companies. Whereas “employability” refers to an ability to get a job and take an active part within ones professional life, “skills” is the English generic term for competences. The trend to work in projects requires adaptability, project management and communication skills. The knowledge economy model emphasizes on knowledge capitalisation, which becomes crucial for a design engineer.

Lastly, the European High Education has launched the Bologna process to foster students’ teachers’ and researchers’ mobility within Europe. By introducing a common three-cycle system and degree level for undergraduates and graduates, it aims at enhancing the European attractiveness and competitiveness but requires institutions to adapt to the ECTS system of credits and get open to international exchanges.

2.2 Conclusion and first hypotheses

This section shows how the global context surrounding the design engineer professional has gone through evolution and thus explains the reason why change is required for an engineering school. On the one hand, the design engineer must adapt to many changes and constraints: race for innovation, globalization and knowledge economy, product complexity, environmental rules, international regulations, labour market, company culture, ethics and activity sectors…. On the other hand, the Bologna reform reinforces the need for engineering schools to review and adapt their organisation so that future design engineers are better prepared for their career. First hypotheses are that the design engineer needs to broaden its skills and knowledge, whether linked to science and technology (mechatronics, collaborative design…) or project situations (project and team management, international environment…). Thinking in terms of competences (or skills) would be of help for the engineer employability as well as for the school visibility at a national and international level but would lead to substantial changes.

The challenge is therefore to think about a training organisation and content that would attract students and help them to acquire knowledge and developing skills thanks to an active pedagogy (i.e. highly involving students). Our research method takes into account the global context and other constraints such as the national specificities and Bologna requirements, industry needs, teachers’ and researchers’ ethics and vision as well as the school strategy.

3 THE GRENOBLE CASE

3.1 The French specificities

One can see three impacts the Bologna process has onto the French institution. First, the French education cycle has to follow the format 3+2 years and no longer 2+3 (where the first 2 years, for engineering studies are dedicated to preparatory classes). Within universities, degrees obtained after 2 years (undergraduate) and 4 years (postgraduate) would be no longer delivered. A Bachelor of Science is then delivered after the first 3 years, followed by a Master of Science after 2 more years. Second, the French education makes the distinction between the MSc degree proposed by universities and engineering degree that is delivered by Engineering schools called "Grandes Ecoles" and is recognized by the French Engineer Council (CTI - Commission des Titres de l'Ingénieur). With the Bologna process, engineers get a Master of Science grade and keep their engineer title, which distinguishes them on the French labour market. Finally, the emphasis on skill development within engineering schools is a new concept that needs to be accepted by teachers and researchers. In this respect, the CTI Committee insists on introducing more human and social sciences within the French Engineering schools and on keeping a certain volume of non-scientific disciplines (sport, foreign languages…)

3.2 INPG reform and objectives

Grenoble Institute of Technology (INPG) has been involved since 2006 in the process of regrouping its 9 engineering schools for creating 21 labour-oriented departments. Among them, the school of Industrial Engineering (ENSGI) is maintained and faces the challenge of managing two departments - Supply Chain engineering and Product Design engineering – to be chosen by students after one common year leading to Bachelor. Whereas the first department already exists, the second one lives a profound transformation. Our research focuses on the organisation, school strategy and actors involved in the change: students and teachers/researchers closely interlinked with industries. The new curriculum to propose must nonetheless meet the CTI requirements, mainly expressed in terms of ECTS spent per modules (30 ECTS per semester).

4 RESEARCH OBJECTIVES

Our research objectives were twofold and pointed up the school need for change. After a global context analysis, it consisted in assessing the as-is situation and the school strategy before envisioning the future training organisation.

4.1 Objectives, scope and means

Our research had the following objectives:

- to create a new curriculum which fosters the future design engineers employability and which lays the foundations for the school and INPG institution national and international visibility
- to make the most of this research for proposing a method applicable to other institutions also in the process of reviewing their educational organisation

The research was based on a holistic approach which advantage is to take into account as many elements as possible.

The research scope had five main interrelated dimensions:

- The institutional organisation (change process initiated by Bologna, teaching resources, INPG and school strategy)
- The technical and scientific elements related to product design engineering (product and design engineering characteristics, tools and technologies evolution)
- Socioergonomics (design engineer profession, skills and knowledge)
- Sociological aspects (school culture and identity definition, tensions)
- Issues related to didactics and cognition (teaching and learning)

To reach our objectives, the method was to compare the product design engineer activity as a professional and as a student so that the main critical elements are identified as gaps. To do so, we first studied the as-is situation study before tackling the envisioning process. The hypothesis is that the new curriculum and the engineering school strategy act as means of filling in these potential gaps. The approach was to think in terms of systems and sub-systems. An engineering school can be considered as a system with functions, history and culture, which transforms itself when committed in a change project. The research and industry interrelations with the school appear as key elements as an engineering school cannot live today without the support of research lab and industry networks.

4.2 The as-is situation

The global context analysis and the pre-analysis we made ended up in identifying the causes for change, the school assets and drawbacks, and in confirming the education project. The SWOT analysis

(Strengths, Weaknesses, Opportunities, and Threats) helped us better understanding the two current schools identity. The main located weakness was the need to reinforce the school international reputation. One outstanding strength was the presence of the Design engineering network of Excellence VRL-KCiP. It has been completed by multiple parallel analyses mostly focused on the future design engineer skills and knowledge a high school can train.

Three elements were assessed during this phase, all in relation with product design engineering:

- The key knowledge and capabilities of an engineer as professional
- The existing engineer student curriculum and disciplines
- The national and international reputation of the schools and associated laboratory

A first step has been to establish the generic job description of the product design engineer in terms of skills (i.e. competences) and abilities; this was carried out on the basis of official sources such as the French National Employment Agency (ANPE), the Management Employment Agency (APEC), and the French National Engineers and Scientists Council (CNISF). It led to the conclusion that a product engineer has got many facets, depending on the company activity sector, its business, culture (French, English, multicultural environment) and products to design.

The existing curriculum is based on disciplines provided by teachers from both the Mechanical Engineering and Supply Chain path. The first one proposes two options, Design and Production Systems engineering, based on an active pedagogy and multidisciplinary projects. The second one puts emphasis on human and social aspects beside the "typical" disciplines.

As far as school recognition is concerned, a domestic benchmark on Higher Education (cf. 5.5) has led to the conclusion that international reputation has to be reinforced in order to intensify the students' mobility and the school competitiveness.

4.3 The envisioning process

The envisioning process aimed at defining a new curriculum adapted to the envisioned product design engineer identity and employability with regard to industry needs, and adapted to the future school organisation, culture, strategy and identity. The major change for the curriculum is a shift from mechanical engineering based on technology and systems optimisation to engineering design processes. It strove to take into account the global context evolution (at economical, scientific, social and educational level) as well as the local and micro economical constraints:

- Adaptation of the curriculum content to the design engineering technical and scientific evolutions (product-process couple, product lifecycle, new technologies and regulations, etc.)
- Thinking henceforth in terms of skills and not only knowledge
- Bologna and CTI constraints (e.g. ECTS proportion per discipline)
- Adaptability of the new curriculum to the new school culture, resource and organisation, and complementarity with the Supply Chain path
- Industry needs and other economic pressure (globalization)
- Enhancement of a national and international reputation

It was therefore based on different activities:

- A job analysis focused on expertise and key skills required to a product design engineer in a professional environment
- The opinion of local industries (R&D, HR) about design engineering needs and prospects
- The high-level vision of European researchers about technology, products, and design engineering
- The feedback of teachers about disciplines, learning methods, teaching priorities and internationalization means

By a series of interviews, we confronted the views of industrial actors with the vision of teachers and researchers about future design engineers. Whereas the first ones think in terms of skills the others tend to insist on the knowledge base students should acquire.

Once the to-be situation was specified, the means could be confirmed through the school strategy.

5 RESULTS: THE NEW CURRICULUM AS A STRATEGIC ELEMENT

The curriculum design is the outcome of a merge between several analyses about: global context, profession, student knowledge and skills, and school strategy with regard to internationalisation. It derives from the key abilities of the product design engineer.

5.1 Key abilities of the future product design engineer

The research led us to analyse in details the product design profession. The product design engineer activity was broken down into four dimensions:

- Knowledge
  - Basic knowledge (scientific basis, methodologies, programming, foreign languages)
  - General knowledge (enterprise functions understanding, international regulations, global supply chain process)
  - Specific knowledge (scientific concepts from other disciplines, industry sectors)
- Know-how
  - General abilities (design problem solving methods, design-to-cost approach, product life-cycle management)
  - Distinction if generalist or specialist (technical expertise vs high level vision)
  - Skills required in project mode (people and budget management, communication)
- Capabilities
  - Adaptation and integration ability (autonomy, team work)
  - Organisation ability (planning management)
  - Innovation ability (observation, creativity, challenge)
  - Acquisition, capitalization and knowledge transfer within collaborative context
  - Personal knowledge updating capabilities (employability increase)
- Personal and interpersonal skills
  - Personal skills (sense of motivation and initiative)
  - Collective or interpersonal skills (negotiation, listening, facilitating skills)

In a professional environment, several key points relate to the design engineer new skills. First of all, the technical and scientific knowledge is no longer a differentiation between engineers. In a context of complexity, performance and productivity, his/her skills have to broaden so that he/she knows how to identify structure, analyse and solve a technical and complex problem in socio-technical approach. –

This trend has been recently highlighted by some international researches in the US and Australia upon engineering education and the need for "sustainability education" and a broader education "to understand the impact of engineering solutions in a global and societal context"[5].

Secondly, the integration of the product and its realization process require simulating, anticipating, and organising the design project from its planning, development, industrialization through to maintenance, recycling. It has to take into account the client needs, technical regulations, and the constraints of any actor involved in the product lifecycle.

Moreover, human interaction whether of relational, communicational or technical nature, has more and more importance in collaborative projects. To communicate, to cooperate with other stakeholders, to facilitate and manage multidisciplinary teams, to manage constraints, to coordinate activities, to negotiate and decide, to pilot the project are additional design and innovation activities. As a strategic activity, innovation requires knowing how to acquire, capitalize and transfer knowledge and know-how inside a company; it also requires developing collective skills, having a technological watch, contributing to the improvement of information systems, databases and supplying chain process.

To sum up, the design engineer becomes an absolute change agent as he/she contributes to the company strategic business success and its organisational and social evolution. He/she can evolve as a generalist (project manager) and/or expert (specialist).

5.2 Detailed definition of the Product Design Engineer

The product design engineer activity was defined according to the French official job description function analysis (ANPE "ROME" codes). It is a mix of seven different profiles: Technical research and development engineer in industries, Method and industrialization engineer, Mechanical engineer, Quality engineer, Maintenance engineer, Organisation & consultancy engineer, Product engineer.

It was completed by the global definition of an engineer that CTI and CNISF provide.

Lastly, three types of profiles were identified, based on the product lifecycle:

- Technological innovation engineer
- Systems and simulations engineer
- Methods and industrialization engineer

5.3 Consequences for the curriculum design

In a learning situation, the following cognitive elements were identified as critical for the engineering school:

- Innovation and scientific and technological watch (R&D, knowledge about materials and new technologies, innovation methods…)
- resolution of technical and complex problems: by applying scientific and technical knowledge, and by mobilizing know-how (functional and technical analysis, abstraction, conceptualization, planning, modelling, simulation, prototyping, testing, industrialisation…)
- knowledge management and technical data management (data handling and information systems, communication tools, information sharing and knowledge capitalization methods…)
- collaborative design engineering project management (methodologies, socio-technical approach, complexity management through multiple professions/culture and languages, product/process integration, lifecycle management, international regulations…)
- team management (communication, motivation, listening, conflict resolution, collective skills management…)

Based on this assessment, the teaching strategy puts emphasis on:

- a progressive learning: Year 1 tackles the supply chain and mechanical basis, Year 2 aims at developing project and team work, Year 3 allows for specialization
- an active pedagogy : through individual and collective projects, internships throughout the three years
- a comprehensive view : mixing the Product Design Engineering students with students from other tracks (e.g. Supply Chain during Bachelor degree, Electrical engineering) allows them to get a better overview of the Supply Chain process complexity
- a multidisciplinary orientation: the value the school adds lies in the fact that social and human disciplines are mixed and analysed together with other disciplines (project management, scientific aspects, communication in English…)

The idea was then:

- to develop the necessary skills requested in industries through a reconstruction of similar professional situations or through professional experience
- to broaden the students view in order to make sure they get a good overview about design engineering activities

The first point was achieved by implementing design engineering projects, if possible through collaborative and cross-disciplinary projects involving other schools. This is what is called “Plateau Projet”. The second point was to reinforce general design knowledge dissemination, problem solving methods, and product diversity knowledge. The main focus was to thus to encourage collaborative design engineering, work on the whole product lifecycle and present three types of products: eco products, user-centred products, smart products.

Academically speaking, these topics cannot be followed by all students for workload and planning reason; optional modules have then the advantage of allowing students to make choice in their professional project orientation and specialize during the two last semesters.

5.4 The product design curriculum

The following training curriculum was developed and submitted to the CTI Committee for validation:

Table1. Product Design Engineering Curriculum

Semester 1 – Year 1 (Lest year of Bachelor degree)		
Modules	ECTS Credits	Hours
Breakthrough seminar	5	63
Modelling and stochastic simulation	4	54
Industrial sciences: Mechanics	4	54
Industrial sciences: control/command	4	54
Algorithms & Computer Science	4	54
Decision economy and enterprise sociology	4	54
English - 2nd foreign language - Sport	4	72
TOTAL	29	405

Semester 2 – Year 1 (Bachelor)		
Modules	ECTS Credits	Hours
Industrial design	4	54
Industry management	4	54
Industrial sciences: computer for production systems	4	54
Applied mathematics	4	54
Accounting techniques	4	54
Project management	4	54
Professional experience	3	21
English - 2nd foreign language - Sport	4	72
TOTAL	31	405
Semester 1 – Year 1 (Master of Science) – Product Design Engineering track		
Modules	ECTS Credits	Hours
Product behaviour: structural analysis	5	63
Product information systems	5	63
Product-Process integration	5	63
Design technology	5	63
Products and Markets	6	76
English - 2nd foreign language - Sport	4	72
TOTAL	30	400
Semester 2 – Year 1 (Master of Science) – Product Design Engineering track		
Modules	ECTS Credits	Hours
Collaborative project	10	126
Industrial process (1 choice out of 3) - Conceptual design and innovation - Engineering development - Industrialization (common with Supply Chain track)	5	63
Industrial products (1 choice out of 3) - Eco-products - Products and consumers - Smart products	5	63
Design management and methods	6	76
English - 2nd foreign language - Sport	4	72
TOTAL	30	400
Semester 1 – Year 2 (Master of Science) – Product Design Engineering track		
Modules	ECTS Credits	Hours
Design engineering: Further development(2 out of 4) - Optimisation and mechanical problem modelling - Machine design - Design and integration methods - Virtual reality and reverse engineering	2*5	126
3 modules out of *n* among: -GI school offer (collaborative design, company internationalisation, project evaluation and control, client/supplier relationship management, activity creation, industry information systems, sustainable production, micro-nano production - INPG offer (connected technology) - Research offer	3*5	189
English Ethics and society Science history and philosophy	5	85
TOTAL	30	400
Semester 2 – Year 2 (Master of Science) – Product Design Engineering track		
Final project	30	400

At a higher level, the success of this new curriculum organisation is closely dependent on the school strategy. As said before, such a strategy has to integrate four interrelated systems: the students, the industrial world, the school environment, and the research laboratories.

5.5 The school strategy analysis results

The domestic benchmark highlighted four key success factors that the engineering school has to put forward in order to influence its local and international position:

- A realistic size and structure of the school made of two complementary tracks
- A large scope of targeted industrial areas and professions (all functions of the global product design are represented)
- The quality of partnerships with international institutions and student exchange plans
- The relevance and credibility of research laboratories associated with the school

6 METHODOLOGY AND TOOLS SUPPORTING THE RESEARCH PROCESS

6.1 State-of-the-art

The state-of-the-art related to methods for building engineering curricula has been analysed all along the project. As all higher education engineering schools have their own specificities and national regulation constraints we could not find adequate methods for designing our curriculum. However we were able to lead a critical analysis of our work founded on methods proposed by the CDIO.

6.2 Method for designing the curriculum

As said before, our global method was a system-oriented approach using a holistic view. This means considering the students, the institution, the research and industries as systems interacting between each others, and interdependent in various points, for instance at pedagogical, political, technical levels. Practically speaking, the research was led in a participative observation manner: we led interviews, participated in the school reform meetings and facilitated the change by sharing our analysis results throughout the project. Moreover, one of the key success factors throughout this project is the commitment of the education.

The project phases

Considering the project phases (Analysis, envision, design, construction, implementation and support), the main phases we focused on were the first two ones (see below). This led to the curriculum design.

Table 2. Curriculum design phases tracks and outcomes

Analysis phase	Envisioning phase details
***Global context analysis:** -Science, technol, products - Design engineering - Enterprise sociology - Education	- Increase of product complexity, development of mechatronics - User-centred, smart and eco-products, design-to-cost, life-cycle mgt - Project- and network-oriented work, virtual enterprise - Bologna Process requirements, Competitors benchmark (French schools and foreign departments)
***Design engineer profile:** - Engineer skills - Engineer knowledge	- Skills broadening: collaborative project management, knowledge capitalisation, communication (Human and social sciences), English… - Scientific knowledge (Mechanics, electricity, electronics, physics, electromagnetism, chemistry, heat science, biology, optics, acoustics…), enterprise knowledge (IS, Finance, HR), programming, international quality/ISO/security regulations, project methodologies, ethics…
*** Engineering school:** - Strategy - Curriculum organisation, pedagogy and disciplines - Stakeholders (resources)	- National differentiation, need for partnership increase with research labs and industries, importance of international attractiveness and recognition towards students, industries and research community - Progressive learning (scientific basis, “plateau-projet”, specialisation); need for new disciplines and concepts (Human and social science, cost management), active and international collaborative project-oriented pedagogy; skill development increase - Researchers and teachers vision, culture, knowledge and skills;

	industry needs -Comparative analysis of French and foreign schools curriculum content

The curriculum detail design process

The curriculum design process is the result of a didactical transposition [6] which starts from a combination of three parallel analyses related to:

- The global context analysis at different level (technology & science, socio-economical situation, HR & management context, product and design engineering evolution, educational reform …)
- The product design engineer profile (job function, responsibilities…)
- The engineering school organisation and structure (curriculum, strategy with regard to its national and international reputation, culture, ethics…)

All of them lead to a better understanding of the environment surrounding the product design engineer.

6.3 Tools used to support the research process

We present hereafter the main tools and methods that were used during this research for designing the curriculum together with the school strategy definition.

Change causes analysis

Four main causes have been used to confirm the project viability and have been linked to constraints: Finale cause, efficient cause, material cause and formal cause.

The SWOT analysis

It highlights the main strengths, weaknesses, opportunities and threats of both existing schools.

Questionnaires

The questionnaires we used during our interviews were addressed to local and international teachers/researchers and industries. They focused on the design engineer process evolution, product design engineer skills and knowledge needs, and the school internationalisation means.

Functional analysis of the envisioned training

The functional analysis was a convenient tool which allowed us to define:

- the product design engineer functions (e.g. to mobilise resources for designing or improving a product/system or service and to fulfill customers' requirements)
- the various elements this engineer has to adapt to (techniques, materials, processes, company culture and needs, globalisation constraints, labour market, ethics…)

Used for designing the curriculum, it gives an overview of its various functions, as pointed out below:

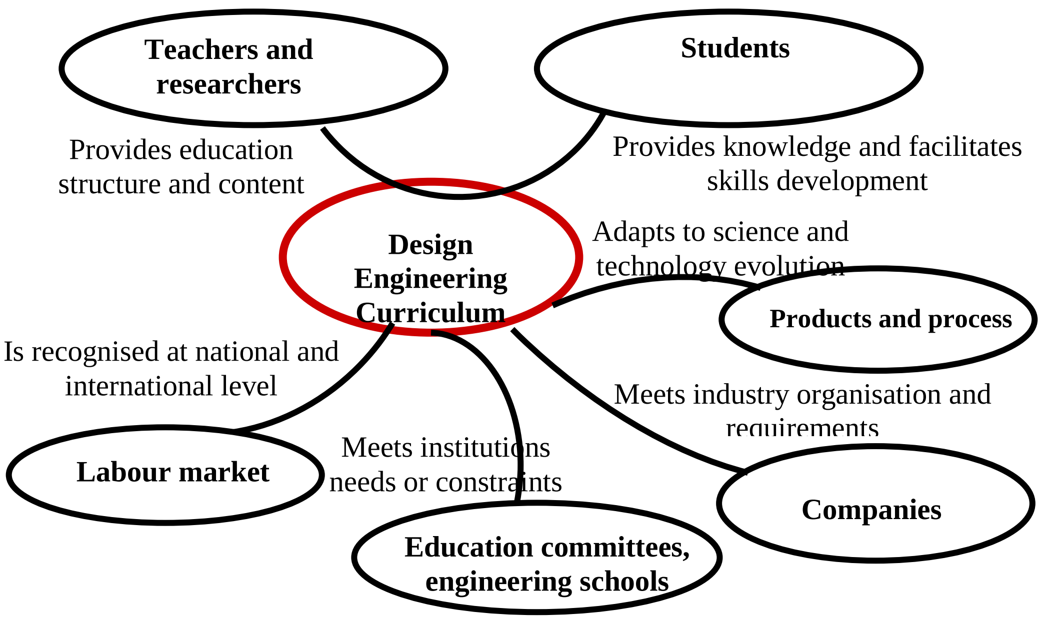

Figure 1. Functional Analysis of the Design Engineering Curriculum

The didactical transposition

The didactical transposition we made was based on three inputs:

- the industry practices and needs
- the job profile analysis
- the researchers' and teachers' visions

It compares the current and future skills and knowledge needed in a professional situation with the ones developed in a learning situation. Then it points out the gaps as far as the future skills, knowledge and learning situation are concerned. In parallel, it takes into consideration the school strategy defined in terms of pedagogy, resources, reputation.

The main output is consequently a new curriculum in line with the school strategy.

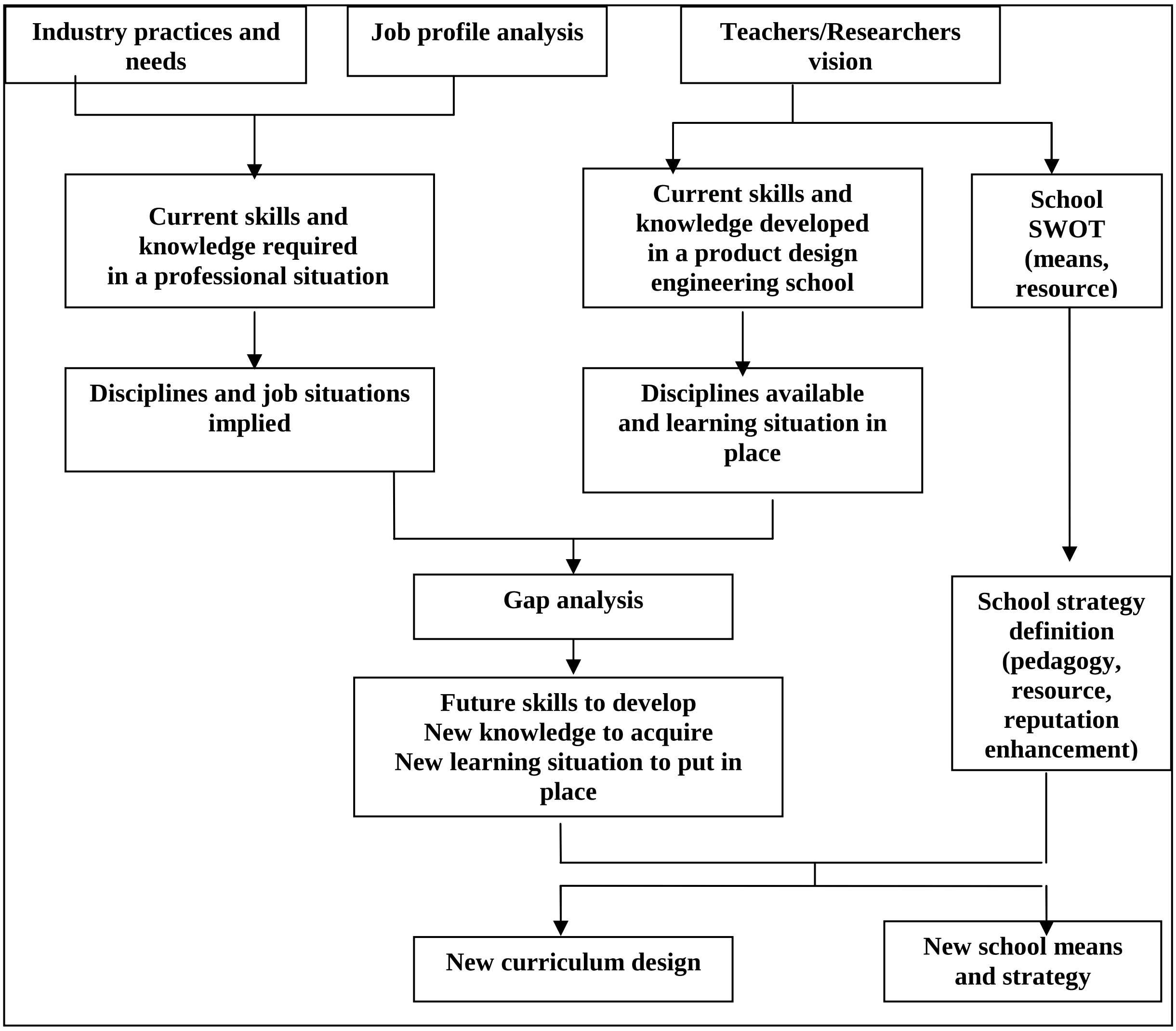

Figure 3. Didactical transposition

The benchmark or comparative analysis

The benchmark of French engineering institutions we conducted helped us identify the future school strength and weakness and clarify the school strategy towards its reputation. To do so, the following criteria and indicators have been identified:

- Curriculum structure originality
    - number of students specialized in design or innovation
    - ratio between students specialized in a department and students in the school
    - pertinence of the Design department or option (volume of hours)
    - originality of projects or internships
    - access conditions

- teaching originality (types of disciplines offered, e.g. human and social science)
- Work integration easiness and scope of occupied jobs
    - specificity of sectors of activity (industry vs consulting orientation)
    - suitability of functions with product design
    - wage at school leave
    - school age
    - school reputation
- Quality of the reputation at international level
    - scale of networking with other universities
    - originality of international exchanges (double diplomas, Erasmus programs...)
    - percentage of students received
    - importance of student stay abroad (internship, laboratories, industries, courses...)
- Importance of research associated with the school or department
    - size and reputation of research labs specialized in integrated design
    - pertinence of the specialisation of the design laboratories
    - scope of other training programs in integrated design (e.g. master of science with a research orientation)
    - importance of research at international level (membership of a network of excellence)

7 CONCLUSION AND PERSPECTIVES

In an industrial world, the current societal context is characterised by uncertainty and complexity. Our global study confirms the recent evolutions and influence of embedded elements: introduction of new technologies, economical globalisation trend, international company competitiveness increase, global cost reduction pressure (outsourcing and partnership development), need for flexibility and agility, etc. As far as design engineering function is concerned, our study confirmed the strategic role of the product designer within any industrial company and the need for widening its knowledge and abilities. The context analysis, the researchers' vision, the professional requirement studies, as well as the education benchmark confirm the need for reviewing the school organisation and integrating new elements within the future curriculum. The most important transformation was to widen the mechanical engineering disciplines to industrial and design engineering processes. The use of pertinent skills that enable a design engineer to solve quickly a complex problem is the primary requirement of industrial employees. For an engineering school, this key concern cannot nonetheless be envisaged without the dissemination of scientific knowledge, complementary and interdependent to skills.

The didactical transposition we followed led us to design a curriculum that offers design activities and methods enabling them to work on international and collaborative product design projects and to act in terms of product-process integration and product life cycle. Since the design engineer skills and knowledge have to include new domains (mechatronics knowledge, project and team management skills, collective knowledge capitalisation, international and cultural aspects…), students have to get used to collaborate with experts of other domains interrelated with their core functions. Consequently, the mix with students from other tracks (supply chain, electronic, etc) should encourage design student openness to multidisciplinary and multicultural design activities.

7.1 Lessons learned

The wider the research, the better. In such a study, it is indeed important to include as many different points of view as possible (points of view of industries, students, teachers, researchers…). One of the key elements of this research is the holistic and the system-oriented approach which avoids thinking in terms of separate disciplines, as multidisciplinary knowledge is one of the product designer characteristics. However the introduction of the concept of skills within an engineering school is not always well accepted as not all teachers are prepared to this substantial change of mind. The commitment and participation of most teachers and researchers is a tremendous success factor.

7.2 Limits and perspectives

The methodology we propose is only applicable for the beginning of the phases of an educational reform project. Trying to develop the product design skills of a student within a school

cannot be achieved without implementing an evaluation system which would contribute to confirming the skills and knowledge acquisition process. The learning assessment activity was out of the scope of our research but should be a critical process to think about.
International education practices such as CDIO (Conceive, Design, Implement, Operate) methodology have been launched within more than 20 renowned universities specialized in Design engineering. Through a focus on the skill development they aim at making the students aware of their learning outcomes. Design courses have for instance such learning objectives: “Develop innovative design concepts [...] using a systematic approach, Develop a good understanding of real life consumer product design processes[…], Become familiar with some modern design tools and techniques, Understand customer perceptions regarding designed products, Develop creativity skills, Learn the importance of sharing responsibility through teamwork […], develop good professional dissemination skills in terms of communicating ideas and concepts through presentations [...]”[7].
On that basis, a hypothesis would be that using learning criteria and indicators could make the students more active in their learning and more confident in their professional orientation. This research did not explore the impact of this new curriculum and learning styles onto the engineer’s employability and the professional skills as the implementation stage has not yet started. The use of self-assessment, peer or teaching assessment could be examples of evaluation means provided learning objectives and criteria have been communicated [8]. Last but not least, the diversity of teaching approaches (uncertain situations, constructed environment, professional projects…) and team composition (multidisciplinary teams, heterogeneous social groups…) and pedagogical supports and styles would be potential investigation and research topics within higher education.

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