INTERNATIONAL ENGINEERING AND PRODUCT DESIGN EDUCATION CONFERENCE
2-3 SEPTEMBER 2004 DELFT THE NETHERLANDS

VALUE CREATION AND MANAGEMENT IN A GRADUATE ENGINEERING SCHOOL

M. Bigand, B. Yannou and C. A. Davy

ABSTRACT

Due to today fierce international competition, innovation and value creation within the product design process have become compulsory for occidental companies. Hence, being industrial engineering teachers and researchers in two sister French engineering graduate schools, the authors are convinced that the processes of value creation and management are essential in the education of tomorrow's industrial engineering and project managers.

Our students actually acquire value and innovation spirit, reflexes, and professional skills in several stages: first, a traditional training is provided through Value Management and Innovation Management courses; second, a more active and practical training consists in a team project activity. These educational practices get along with a *skills map* which constitutes a repository of skills we believe an engineering and project manager should possess. Further, within the last ten years, we have experienced a progressive approach in the project management of student teams. We came up with global guidelines that the teaching staff now asks the students to follow. For several reasons, an alternative project management approach has recently been experienced thanks to the creation of a new *Engineer Manager Entrepreneur* curriculum. Student teams are given large autonomy: they are only accompanied by an adviser from the teaching staff; marketing or scientific methodologies are introduced whenever their need is detected along the course of the project.

Keywords: Value creation, innovation, project management, learning by doing

1 INTRODUCTION

In the context of a global and highly competitive market place, companies of our industrialized countries are ever compelled to transfer their production to developing countries. Their situation of relatively low wages and their increasing competitiveness in technical skills inevitably competes with the limited gains in productivity of our countries. In addition, certain developing countries, e.g. China, currently invest in high-level engineering schools, and will be able in a few years not only to industrialize, but also to design products with a high level of technology.

For our countries' firms, within the framework of product design, at least three points are essential to survive: *technological monitoring, innovation and pro-activity*. *Technological monitoring* is the need for a company to collect regular information about its rivals, about new patents related to its activity, and generally speaking all relevant information on design evolutions (new components, technical press articles, etc.) [1][2]. The Internet is a convenient medium to access to this information. *Innovation* means the ability of the company Design Department to generate new products or product

alternatives in a continuous creation process. It is indeed essential for a company to propose a significantly different offer from its rivals on a market place where customers are more and more demanding [2]. *Pro-activity* is the ability of a company to anticipate or to originate a change, and not only to react to market and technology events. The firm size may hinder its capacity to be reactive and pro-active, so Fayolle [3] underlines the need for huge business corporations to turn their management organizations into confederations of entrepreneurs ("*Small is Powerful*").

In this context, Value Management is a recent standardized methodology, see [4], which can be defined as a new way of management as well as a problem solving technique for high-level company concerns. It is a natural evolution of Value Analysis and Value Engineering techniques developed in the 1940's and 1950's [5]. A general definition of value, which highlights its central position in industrial problem solving, is provided as the relation between, on the one hand, the satisfaction stakeholders have for a given solution with regards to their initial needs and, on the other hand, the amount of resources consumed to reach it.

Training programs in engineering graduate schools must take these evolutions into account and develop appropriate skills among their students. The authors are teachers in industrial engineering in two engineering graduate schools (*Ecole Centrale* in Paris and *Ecole Centrale* in Lille), renowned in France to be among the top "Grandes Écoles" (wiz. engineering graduate schools). A significant part of the curriculum traditionally consists in wide scientific and technical insights into various disciplines such as Materials Science, Mechanics, Electronics, Signal Processing, etc. Besides, our students must know how to put this knowledge into action when confronted to an actual scientific issue or industrial project. They have to adopt a trans-disciplinary policy of action, which we have chosen to teach them through practicing the processes of Value Creation and Value Management during a long lasting project activity. Project activity exists since a tenth year at *Ecole Centrale* (in Paris and Lille) and a general project management methodology is now regularly followed by the students and the teaching staff. The effectiveness of this curriculum is improved by the use of a *skills map* [6] detailing the elements each future engineering and project manager should acquire. A new curriculum of *Engineer Manager Entrepreneur*, relating to *Iteem - European Technological Institute of Entrepreneurship and Management,* has been initiated in September 2003 by both *Ecole Centrale* in Lille and Lille business school (*ESC Lille*) [7]. Within this framework, we had the opportunity to experiment alternative project management teaching methods compared to *Ecole Centrale*, which we present hereafter.

Our paper is organized as follows. Firstly, we describe our main and rather traditional training methods in Value Creation and Management at *Ecole Centrale* (in Paris and Lille) Section 2 summarizes introductory courses on Value Management and Innovation whereas Section 3 describes the *skills map* used to elaborate or improve the training curriculum. Secondly, Section 4 describes and compares two educational approaches in the management of students project activity, one at *Ecole Centrale*, and the other one at *Iteem*.

2 VALUE MANAGEMENT AND INNOVATION

Value Management (VM) [4][8] usually consists in a number of successive actions as follows:

- listing the different needs of the stakeholders, scrutinizing potential existing solutions and gathering potentially interesting information through appropriate surveys,
- expressing needs into more detailed functional requirements (that will constitute a reference framework for future assessments),
- identifying sources of added values on which the innovation efforts will be targeted and innovating at different promising locations,
- proposing a short-list of aggregated and consistent solutions or scenarios and assessing these solutions in terms of costs and values,
- making a final choice, making recommendations and supervising the detail design or implementation,
- capitalizing the knowledge of the VM operation.

More generally, VM can be considered built on four main concepts: functional approaches, value approaches, innovation processes and convergence processes. Whereas functional approaches, value approaches and convergence processes have been thoroughly dealt with in [9], we wish to insist here on innovation processes as they involve several original notions and tools our students are being taught. When declaring that "*creativity is the process of generating something new that has value*", Higgins [10] means that innovation efforts should be focused on the best potential sources of added value, which have been identified through the VM process. Innovation processes consist of innovation management as well as innovation techniques. Innovation management addresses various issues such as coordination and processes for the use of innovative tools [11], technological and economic surveys, patent policy, employee involvement policy, project team composition policy, skills management, economic intelligence, company strategy, partnership policy, etc. Innovation techniques are of two types:

- *Creativity tools*. These can be classified in two categories [12]: intuitive tools coming from studies on group psychology (such as brainstorming, nominal groups, analogical methods), and rational tools coming from more systematic procedures (such as discovery matrices, morphological analysis, Functional Analysis).
- The *TRIZ methodology* [13] for product reengineering. It is based on a set of tools such as contradiction matrices, ARIZ systematic invention algorithm, technical systems evolution laws, etc. These tools are based on the analysis of recurrent innovation mechanisms in patents and also on the analysis of recurrent innovation trajectories in families of physical systems.

Our training was designed to allow students to master the theoretical and also the practical sides of innovation processes. It is therefore composed of traditional courses for theoretical knowledge acquisition, and of a team project activity for practical knowledge acquisition. The courses are in two parts, see [9], the first relating to *Functions and Values* and the second to *Innovation Management and Techniques;* each part is composed of ten 3-hour sessions. The courses occur before the students project activity. This educational approach is improved by using a *skills map* [6] summarizing the elements we ask the students to acquire within their training as future engineering and project managers.

3 A *SKILLS MAP* TO IMPROVE VALUE CREATION AND MANAGEMENT TEACHING

Before developing a curriculum dedicated to training *engineers* aimed at becoming value creators and managers, the term "*engineer*" needs being properly defined. Based on the ten managerial roles depicted by Mintzberg [14], a *skills map* was therefore elaborated [6]. It details the eight main skills an industrial project manager should possess (see Table 1), and helps the teaching staff supervise and check that the training fosters the development and use of these skills. More precisely, the *skills map* is used as a spreadsheet to describe each educational action as a contributor to the eight skills improvement. Compared to the contribution of other parts of the training, the project activity is essential since no other activity covers such a large number of expected skills. As a consequence, the students are aware of the importance of the project activity assessment.

Table 1. Expected skills (skills map) for an industrial project manager.

Competency	Item
To design	To formulate a problem, To formalize, To model, To imagine solutions from the model, To choose satisfactory solutions
To produce	To transform a realistic model and ensure its feasibility, To experiment, To produce
To innovate	To mobilize and stimulate personal or team creativity, To be open-minded to outer ideas and environment, To target creativity toward an objective
To drive	To structure and valorize a project, To egg on dynamics in a project, To ensure the project management
To organize	To make use of appropriate means and methods to ensure information or instructions exchange and to ensure coordination between the actors of a system; To regulate and control the evolution of an organizational system
To communicate	To exchange clear and precise information, To be open-minded to outer ideas and environment, To develop an ease-to-contact feeling, To organize information flow using adapted methods and tools, To argue orientations
To train	To select people who will receive a training, To elaborate a training plan, To supervise all or a part of a training, To assess people's progress
To undertake	To manage, To market, To create value, To negotiate, To evaluate risks, To be autonomous

4 COMMITTING STUDENTS IN VALUE CREATION AND MANAGEMENT THROUGH PROJECT ACTIVITY

We present here two sister educational methods and a quite different third one aimed at training industrial project managers. The first one was implemented 10 years ago at *Ecole Centrale* in Lille [6]: it is a well structured and supervised project activity. The second project activity, at *Ecole Centrale in* Paris, follows a similar framework. The third one is new and was initiated in September 2003 in the *Iteem* institution for the *Engineer Manager Entrepreneur* curriculum. This latter training program is essentially based on creativity, spontaneity, search and self-apprenticeship.

4.1 Project activity at Ecole Centrale in Lille

In this educational activity, each student team has to carry out a *design and manufacturing* project during two school years (about 300 hours per student), in cooperation with external industrial partners and under the guidance of a team of teachers. The subject must respect several given criteria: it should have a scientific and technological dimension while considering all other possible dimensions into account, such as society, environment, economy, etc. Moreover, several scientific fields must be involved in the project: e.g., a subject limited to the sole computer science would not be accepted. Indeed, a large project is, by definition, both complex and multidisciplinary, and our aim is to train multidisciplinary engineers. An example of a successful project is that of the design of a meteorological weather station for hang gliding. The end-users wished to know the weather conditions at the take-off site situated on top of given mountains or hills. They would therefore avoid climbing up to the take-off site uselessly. The design has involved the combination of several sensors (anemometer, thermometer, etc.) which measurements have been processed and delivered to the end-users *via* an artificial voice. The system had to be placed inside a waterproof box on a 5-meters-high pole to protect it from vandalism.

More generally, the team of 4 to 6 students is voluntarily built around a goal chosen by its members during the *project exchange period.* This takes place during the first six weeks of schooling. The team size is mandatory because a too small team encounters too few organizational problems, and a too large team becomes hard to deal with for inexperienced managers. It was decided that students would choose their project theme in order to best ensure their motivation throughout its two-year duration. This also gives them the opportunity to express their own creativity, which may take the form of developing a personal passion with a team support; whatever the case, efforts are made so that each student becomes a genuine actor in his/her own training and gets to work harmoniously with others. Students have to formulate a design problem by themselves and also specify its boundaries. The subject has to respect given criteria (see above), which are validated by a teachers team at a sufficiently early stage to avoid possible drifts. Moreover, each team is suupported by a whole set of experts. A *Scientific Manager* is chosen within the teaching staff: his/her role is to validate the main project orientations (goals, scientific approach, specific training plan for the team members, etc.) and to help compose the *Advisory Team*. Relationships with external partners (other Advisors, industry, etc.) are generally undertaken by the students team. Advisors intervene only when requested by the students. A *Pilot* is designated: he/she is a lecturer who brings help in project management and risk assessment. At the project beginning, a *communication expert* meets the project team in order to underline the complex nature of the project activity. The team performs several pre-studies in order to tackle this complexity. They have to identify all the subject and project activity dimensions: social, economical, ethical, etc., as well as scientific and technological.

The first task of the team is to determine accurate boundaries for their project. The recommended method consists in reformulating the subject without any solution in mind. Brainstorming, Value Analysis and bibliography search are the main tools used at this stage. A document aimed at expressing the need is written by the team and presented to the teachers and partners three months after the project start. Once this document is validated, potential solutions are explored using above mentioned design techniques and innovation methods (see Section 2). A choice is made for adopting a product solution. Then the project team must estimate a project planning (including WBS, OBS, CBS, financial arrangement, Pert or Gantt). Another written document is presented by the students (about 6-8 months after the beginning of the project) and the realization stage may begin. During the realization stage, the team manages its project

on its own; on the teachers side, the aim is to prevent rather than to heal: a real-time "monitoring" is preferred to an *a posteriori* evaluation. Regularly, a meeting is organized by the students with the main project actors so as to monitor its progress. At the two-year project end, an oral presentation is organized, and the students provide a final written report. A part of this final report sums up the intermediary ones. Fig. 1 recalls the main elements the students must deliver all along the project.

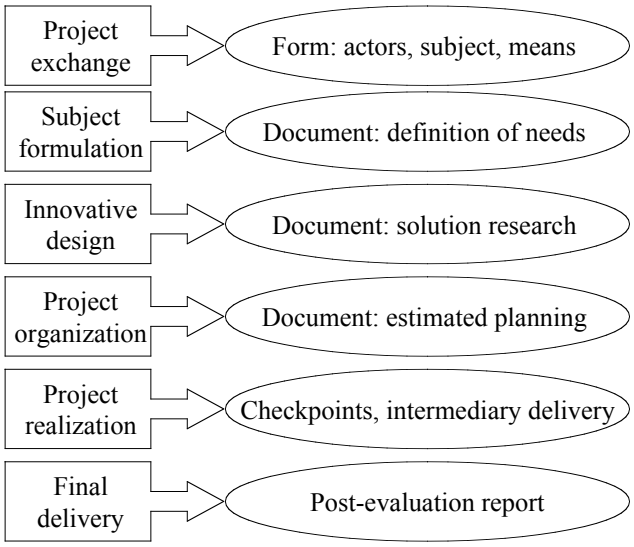

Figure 1. Main deliverables during the project activity

This project activity is ideal for students to acquire know-how, academic knowledge, as well as personalising their curriculum; it also allows each student to confront and make real use of several disciplinary courses, whereas a conventional academic training often remains at the level of the assimilation of mono-disciplinary scientific contents. However, some design problems may require complex theoretical notions that cannot be acquired within a project activity, and which would rather correspond to research issues: this is where the teaching staff is fully required to put proper limits to the project subject. Besides, the project activity may be the first time when a student faces an ill-defined problem where he/she is asked to formulate, to specify, to design, to experiment several possible solutions, and to produce. Project activity has proven qualitatively that it is an appropriate exercise to develop many of the items described in the *skills map*. It allows an actual value creation within the project, which is taken into account in the teachers project assessment. For the industrial partner, the produced value can take several forms, e.g. innovation (in this case, the firm can generally recover the intellectual property and take out a patent), market research (performed through the association with business school students if need be), a prototype or associated documentations.

After a few years of breaking-in period, a general methodology has been formalized, and several required and common project landmarks have been established. This methodology was needed because all teachers were not skilled in project management. As most of the lecturers and students involved have a scientific Cartesian-type profile (typical of France), this methodology is a reassuring framework. However the overall idea is to remain non-directive: e.g. lots of questions may be asked and answered, best practices are promoted rather than unique recipes, adaptation is preferred to rigid

structures and solutions. Nevertheless, we noticed that the methodological framework is sometimes automatically applied instead of carrying out a genuine thought. This is the reason why a new approach is currently tested within the context of our new *Engineer Manager Entrepreneur* curriculum.

4.2 Project activity in the *Engineer Manager Entrepreneur* curriculum

At *Iteem*, a series of three projects is proposed each during one of the first three years (on a curriculum of five years): (1) analysis of an existing product or service; (2) design and realization of an innovative product/service, and (3) simulation of a company start-up. 120 hours per year are dedicated to each of these projects. Student teams are composed of 5 students similarly to *Ecole Centrale* project activity. The aim is to put into practice notions learnt during a few preliminary courses (1st year), and to acquire managerial skills. The following only deals with the second year project (design and realization of an innovative product/service).

Based on the experience acquired during 10 years of *Ecole Centrale* project activity, the choice has been made to withdraw the main formal responsibilities of the teaching staff. There is neither any *Scientific Manager* nor any *Pilot*, but only an *Advisor* coming from the teaching staff. Neither method nor tool (except those learnt during their first year) is given beforehand to the students. But when a student team faces a difficulty and/or reclaims help on a particular point for its project, the Advisor may bring the appropriate method, process or tool. E.g., after several meetings poorly organized by the students, the Advisor may identify the organizational problem and discuss with the students a more efficient method. This behavior is adopted not only for managerial aspects (costs, time, communication, etc.) but also for scientific and/or marketing approaches. An advantage is that a minimal amount of methodologies is introduced before the start of the project. New knowledge is brought only when needed and it is then based on an actual experiment. Minimal mandatory methodologies include Value Management and Innovation courses, which the Advisor may help to put into practice. At the end of the project activity, a course is given in order to synthesize the main project management concepts that have been experienced. This educational approach requires the Advisor to be very flexible, available and constantly open to student difficulties. It is only possible when the Advisor is able to stand back from educational practices in project management, which is the case for our new *Engineer Manager Entrepreneur* curriculum thanks to 10 years experience at *Ecole Centrale*.

5 CONCLUDING REMARKS

Project activity coupled to traditional courses offers lots of advantages when training future industrial project managers who will have to help their company constantly innovate and add new values to its products and services. Firstly, students are trained to effective and useful techniques: creativity tools, product or process Value Analysis, Value Management, actual decision making, etc. Secondly, students acquire a good practical knowledge of Value and Innovation in the industry. Finally, the training lets them experiment and refine sound managerial reflexes and skills.

In terms of educational methods, we believe it more effective to alternate directive traditional courses to structure the reasoning, and periods of autonomy in order to develop managerial and solving problem skills. Our experience at *Ecole Centrale* and now at *Iteem* is that the educational challenge is to find the right balance between imposing methods or solutions and letting students totally alone when facing a scientific or an organisational issue. At present, we believe that our choice of minimal

methodology courses before the project activity, coupled to regular teaching whenever students need it, is a rather good compromise. Further work will consist in analysing the skills actually acquired by our first *Iteem* students using the *skills map* described herein, in order to keep improving our training choices.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge all the students who participated in the project activity at *Ecole Centrale* in Lille and in Paris, and at *Iteem*.

REFERENCES

[1] Pahl G. and Beitz W., *Engineering Design: a Systematic Approach*, 2nd Edition, Springer-Verlag, London, 1996.

[2] Ozer M., A survey of a New product Evaluation Models, *The Journal of Product Innovation Management*, Vol. 1, 1999, pp. 77-94.

[3] Fayolle A., *Entrepreneuriat – Apprendre à entreprendre*, Dunod, ISBN 2 10 008189 6, 2004.

[4] EN-12973, Value Management. European standard, 2000.

[5] Miles, L. D., 1947, *Techniques of Value Analysis and Engineering*, available free at http://www.valuefoundation.org/bkmiles2.htm.

[6] Bigand M., Craye E. and Deshayes P., Project monitoring in a graduate engineering school, *IEEE/SMC Transactions, Part C: Applications and reviews*, 30(2), 2000, pp. 183-188.

[7] For information on the *Engineer Manager Entrepreneur* curriculum at *Iteem*, see http://iteem.ec-lille.fr ; on *Ecole Centrale* in Paris, see http://www.ecp.fr; on *Ecole Centrale* in Lille, see http://www.ec-lille.fr; and for informations on Lille business school (*ESC Lille*), see http://www.esc-lille.fr.

[8] Ben Ahmed W. and Yannou B., Speaking of Interests Rather Than Values Would be Less Confusing: the Example of Product Design, *International Journal of Value-Based Management*, 16(2), 2003.

[9] Yannou B., Bigand M., A curriculum of value creation and management in engineering, *European Journal of Engineering Education*, vol. 29(3), 2004.

[10] Higgins J. M., *101 creative problem solving technique: The handbook of new ideas for business*, New Management Publishing Company, 1994.

[11] Ngassa A., Bigand M. and Yim P., A new approach for the generation of innovative concept for product design, In: Proceedings of the International Conference on Engineering Design: ICED'03, Stockholm, Sweden, 2003.

[12] Lambin J. J., *Le Marketing Stratégique*, New-York: Mc Graw Hill, 1991.

[13] Savransky S. D., *Engineering of creativity - Introduction to TRIZ Methodology of Inventive Problem Solving*, Boca Raton, Fla: CRC Press, 2000.

[14] Mintzberg H., *The Nature of Managerial Work*, New-York: Harper & Row, 1973.

Contact Information:
Catherine Davy,
Ecole Centrale de Lille
Équipe de Recherche en Génie Industriel (ERGI), BP 48
F 59651 VILLENEUVE D'ASCQ CEDEX, FRANCE
Email: Catherine.Davy@ec-lille.fr

Co-authors Information:
• Professor Bernard Yannou
Ecole Centrale de Paris
Laboratoire de Génie Industriel
F 92295 CHATENAY-MALABRY, FRANCE
• Michel Bigand
Ecole Centrale de Lille, ERGI, BP 48
F 59651 VILLENEUVE D'ASCQ CEDEX, FRANCE