Int. J. Engng Ed. Vol. 25, No. 1, pp. 102–111, 2009
Printed in Great Britain.

0949-149X/91 $3.00+0.00

Application of Process Re-Engineering Methods to Enhance the Teaching–Learning Process in a Mechanical Engineering Department*

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This paper aims to demonstrate the feasibility of using systematic process re-engineering methods, which are in general use in the industrial and service sectors, in the university environment. By using these methods it is possible to make an in-depth analysis of the processes used, compare the results with those that are required for the organisation where the processes are run to achieve its goals and, depending on this comparison, set up a series of proposals for improvement, so that activities that do not lead to achieving the goals can be eliminated and thus make more effective those that do lead to success. In order to demonstrate the feasibility of this, a process to improve operations has been completed at the Mechanical Engineering Department at Madrid Technical University. The aim is to optimise performance regarding the achievement of the goals, which are to maximise the learning of its students, both with regard to learning and attitude—curiosity, entrepreneurship and a firmness of character oriented towards continuous improvement and individual responsibility. In particular, the methodologies of KJ, Ishikawa were used as well as those of Relevant Actions, and concepts from the Toyota Production System. Improving the teaching–learning processes is extremely necessary today, taking into account the paradigm change involved due to the Bologna declaration and the European Higher Education Area. Given the reduced scale of the work, the results are very encouraging and show the potential for improvement that may be obtained on a large scale. Above all, this paper aims to provide a list of the causes of typical problems that arise in the university that will be of use to the reader and puts forward ideas for possible ways to improve the everyday running of the university.

Keywords: process re-engineering; KJ method; Toyota Production System; teaching; learning

INTRODUCTION

MADRID TECHNICAL UNIVERSITY has been teaching the mechanical engineering degree for 175 years. The students obtain knowledge and skills that enable them to find a job quickly in leading companies and reach management posts. Employers' opinions of the students' training are usually positive. The generalised view is that the knowledge acquired, even though it is not necessarily needed for the job, is useful in that it trains students to analyse and solve problems. Recent changes to the curricula in line with the Bologna agreements in European Education mean, among other things, reducing the time needed to complete a degree. Considerable effort has been made to condense study plans without any noticeable loss in the knowledge and skills learned. However, students take longer than the time programmed to finish a degree, which prevents the goal set from being achieved. Therefore, this time needs to be reduced but without any significant loss of training quality. This means improving the learning process, which in turn means improving the teaching process. To this end, and following the general structure of the different process re-engineering methodologies in existence, the School's mission was drawn up and transferred to the dimensions that make up the 'set of operations', from which an 'ideal situation' was derived. Afterwards, an analysis was made of the real situation, through the 'complaints' of alumni, and relevant actions were obtained in order to approach the ideal situation, (total fulfilment of the mission). From this discussion 23 'problems' were extracted regarding the teaching process. It was attempted to select the most representative sample possible from alumni, that is, one that would encompass the greatest number of engineering tasks that a mechanical engineering student with at least five years' experience can develop in their professional career. The work was done by eight people with middle management positions in engineering project management, in research and development work,

* Accepted 4 July 2008.

production and technical sales, in water treatment, aerospace, automobile industry and electrical sectors. Applying the KJ technique these problems were grouped into six large families. The two most important were decided by a vote. Using the Ishikawa method, a series of possible causes were obtained from these two large families of problems. Then, a list of 50 actions was drawn up to improve the fulfilment of the mission, using the relevant actions methodology. These tools are explained in more detail in later sections.

It should be pointed out that the wording of the mission is not as generic as it should actually be: the school must not only train professionals for the private sector, but also prepare future researchers and teachers. This has not been taken into account in this paper.

PROCESS RE-ENGINEERING TOOLS USED

There are numerous works published dealing with the application of systematic process re-engineering methodologies in the service sector (for example, [1–6]). The general structure is similar in many of them: once the organisation's goals have been set, a systematic study is conducted of each and every process that is run, from the point of view of its contribution to the achievement of those goals, thus detecting any failures and possibilities for improvement. Then, these ideas for improvement are prioritised according to how relevant they are in best achieving the goals.

In order to perform these studies, innumerable tools are available (for example, [7]). Table 1 shows some commonly used ones. Below, is a brief explanation of those used in this work.

The dimensions of the mission

Every organisation has a particular mission that attempts to define what 'customer satisfaction' is in its own specific situation. In order to check that the mission is being fulfilled, that is, if the 'customers' are being satisfied, some kind of system is required that will allow one to quantify or at least to measure the key dimensions on which the organisation must focus its strategy and operations. In this way, and depending on how these variables are assessed, the way to adapt these strategies can be calculated and, if need be, proceed to improve them. In this work the dimensions specified by Riverola and Muñoz-Seca ([8]) are used: three of them refer to basic aspects of service cost, time, extent of range, and two others to the speed of change of these three: innovation and the capacity to control the variability of the first three; that is how to produce results in line with the organisation's mission throughout time-consistency. To be competitive, an organisation cannot be the best in all variables at the same time, but only in *some* that generate satisfaction for the 'customer', with 'healthy' levels of performance being achieved in the rest.

The organisation's operations as a whole

Once the dimensions of the mission have been defined together with the key dimension (or the key dimensions), one proceeds to embody this in the different operations of the organisation. Different authors (for example [9–11]) have systematised the value chain of a generic organisation called, *Business Activities Sequence (BAS)*, which in general can be divided into the following activities:

- Design Chain: encompasses the activities: R&D, Quality Assurance, Process Design.
- Value Added Chain: Purchases, Entry Logistics, Production, Exit Logistics.
- Service Chain: Made-to-measure Integration, Fulfilling the Mission, Continuity of Interaction.

Each of these activities may be defined, in turn, through a set of variables. In process re-engineering, one aims to operate on each of these, with different analysis, diagnosis and improvement methodologies:

- Processes: these allow the materialisation of knowledge. They are the indications that allow the processors to run the operations properly, via a definition of the operations needed and the resources to be used.
- Capacity: the maximum production speed that can be attained by the system. Problems of lack of capacity usually become waiting problems.
- Flows: the way items flow within the system. There are five types of flows: materials, customers, orders, information and money. The structure of each type of flow must be (re)defined as well as the way the different items share the system.

Table 1. Examples of tools to facilitate the systematic study of processes

Processes' contribution to the mission	Toyota Production System, Technique W^4H (Why, Why, Why, Why, How), Quality Function Deployment, Change Management tools
Study of processes	Material, information and knowledge flow diagrams
Detection of failures in processes	Complaints of the least satisfied customers, histograms, correlation diagrams
Search for ideas for improvement	Brainstorming, forward steps method, back steps method, systematic variations, similitude methods, lateral thinking methods
Classifying non-quantifiable concepts	KJ method, Affinity Diagram, Prioritisation Matrices
Causal search	Ishikawa method, Causal relationship diagrams, Decision Matrices

- Human resources: there is a particular type of processor, person, with special characteristics who requires an individual analysis, as they are resources capable of making decisions. From an operational point of view, three characteristics are of interest, which need to be maximised: their freedom, their ability to generate knowledge and learn and their ability to use the knowledge they possess (their intelligence).
- Information System (IS): on the one hand, this allows decision making errors to be minimised, and on the other all decisions to be co-ordinated in time—that is, have the right information available at the right time.
- Conflict Solving System (CSS): a set of rules as a basis for decision making. These rules are the organisation's materialisation of knowledge, its 'culture'.

Depending on the worth of each dimension of the mission, each variable must be defined in a different way. For instance, if the mission involves prioritising the dimension of *time*, the processes need to be well-defined, without leaving any possible variability uncovered. On the other hand, if the dimension of *innovation* is prioritised, the processes will need to give the processors greater freedom.

The Toyota Production System (TPS)

Some of the guidelines contributed by the TPS will enable the ideas for improvement to be better defined, as well as providing a starting-point for the work to be set: the definition of an *ideal situation*, where the mission would be perfectly accomplished, and from which a description of the ideal states of the variables of each of the activities of the BAS could be obtained. Basically, ([12]), the tacit knowledge housed in the TPS can be captured in four basic rules, that guide all the activities of the BAS, the links between them and their improvement for all the organisation's products and services:

1. Every job should be specified in detail, content, sequence, development in time and results.
2. All customer–supplier links should be direct, and in a yes/no system free of ambiguities, for sending orders and receiving a reply.
3. The path a product/service follows until it reaches the customer should be as simple and direct as possible.
4. Any improvement should be made according to scientific method under the guidelines of an expert, at the lowest possible level of the organisation.

The KJ ideas grouping methodology [8, 13, 14]

As will be seen later, one of the activities to be performed in process re-engineering is *prioritising* ideas for improvement. Prioritising is simple when it is a question of classifying quantifiable concepts, but the difficulty increases when they are not quantifiable. There are different tools for classifying non-quantifiable concepts. The KJ methodology is used in this work; this basically consists of classifying concepts according to the affinity of the images these invoke in the mind of the classifier. Different authors have shown that certain aspects of language inhibit creativity in human beings. Therefore, operating with images implies a conscientious effort to break with syntactic dependency and liberate the true meaning of the qualitative data. The KJ method is conceived to take advantage of the creative potential of a group, the maximum output being achieved with around ten members. As will be seen later, the method proposes making an initial group of ideas and then a second and a third group from the groups obtained in order to finally be able to study the causal relationships between the groups obtained at the last level of grouping. The grouping must be done by mutual consent. Then the most important groups are prioritised, also by vote.

The Ishikawa method

This well-known method (in [7] a more thorough explanation than the one here, and how it works, can be found) consists in listing the four or five major causes of a problem, and putting them into a fishbone formation to then go on to analyse and examine them until a sufficient level of description is reached to allow direct action on the *ultimate* causes. It means getting the people involved who are directly connected with the problem. To get to the ultimate causes of a problem means eliminating the root of the problem during the solving process and not its consequences, in order to ensure there will be no repetition.

The 'golden triad'

This concept, used by Riverola and Muñoz-Seca [8], encompasses the three characteristics that any organisation must aspire to if it is to maximise the achievement of its mission: one linked to the performance of the BAS *efficiency*, one linked to extrinsic motivation *attractivity*: salary, social recognition of one's job, training received to keep oneself in the labour market, etc., and *unity*, linked to people's vital motivation: being conscious of the importance of their work for the welfare of a group of people, both inside and outside the organisation. If attractiveness and unity are to be achieved in organisations that work with *brain power* instead of *muscle power*, this author deems it essential to constantly challenge those brains to make them continuously creative. To this end, the best tool is *continuous improvement*, consisting of institutionalised process re-engineering within the organisation.

Relevant actions methodology

Having studied the possible causes of the *important* problems (since they have already been prioritised by the participants who are presumably familiar with the processes, the ideal situation and the real situation), we go on to study the

possible *relevant* actions (those that have some repercussion on the greatest fulfilment of the mission, and, therefore, will lead to a smaller difference between what is promised and what is offered, all of which will have a positive repercussion on customer satisfaction). It is possible to quantify the relevance of each action: to the list of actions arising out of the study is added a calculation of their repercussion in each of the dimensions of the mission that have already been considered for their importance in achieving the mission (see above). The relevance of each action is justified by specifying the dimensions of the mission that it is helping to achieve and the way to quantify it is specified (to check the progress of its implementation). We also attempted to make the actions have an effect on the other elements of the 'golden triad' (attractiveness, unity), given that the university is the paradigm of an organisation made up of 'brain power'.

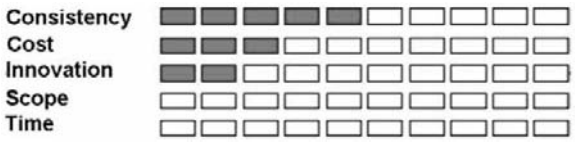


Fig. 1. Deploying the mission to operations.

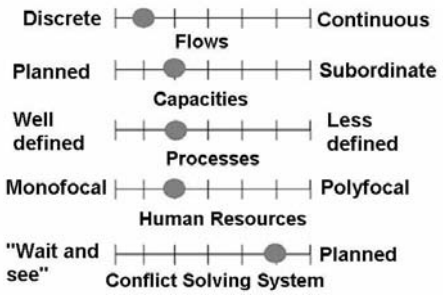


Fig. 2. Implications of the mission on the operations set.

EFFICIENCY: DESCRIPTION OF THE MISSION. ITS DEPLOYMENT TO OPERATIONS. IDEAL SITUATION

The university's mission could be described as *'getting students to learn to analyse in order to confront problems and solve them'*. This definition describes the basic skills and knowledge that an engineer needs to posses in their professional career:

- The ability to analyse and solve: this implies having the necessary technical knowledge that encompasses the different engineering problem solving tools, in addition to a knowledge of different standard solutions, (commercial products, product families . . .), and also sufficient knowledge to face up to solving exploratory problems.
- An ability to confront problems: on the one hand this indicates sufficient self-confidence to begin to analyse a complex problem and also the proactive nature and spirit of curiosity that leads to the analysis of further problems. Possession of the other two abilities may possibly lead to the acquisition of the latter.

To deploy this definition of the mission to the five dimensions of the operations set, these dimensions are prioritised by giving ten points among them as shown in Fig. 1. This gives an idea of how each of the elements of the operations box should be designed in each of the activities of the business activities sequence. In the case of the university, this would be made up of:

- Design chain: R&D and consultancy activities, Quality assurance, Process design.
- Value added chain: Purchases (in research and teaching innovation projects and in consultancy activities), 'production' (teaching)
- Service chain: Made-to-measure integration (for example, in-company courses), continuity of interaction (for example, alumni associations)

In a highly schematic form, prioritising the dimensions of the mission would lead to the following characteristics of the elements in the operations box, which are shown in Fig. 2.

This 'ideal situation' could be described (in the way of the Toyota Production System) by features such as the following:

- Discrete flows: individualised teaching as far as possible taking account of the restrictions imposed by cost: tutorials play an important role by adapting teaching style to each student's learning style, etc.
- Planned abilities: the needs of teachers and administrative and services staff are planned, as well as course objectives and content according to the predictions that could easily be obtained from close contact between the university and employers through research and consultancy projects, etc., and from the feedback supplied by universities about the performance of students who have completed their degrees.
- Very defined processes: the teaching process is defined by using different tools, such as 'teaching notes' for all the subjects taught, assessment files on learning profiles, etc.
- Monofocal human resources: for example, the teachers become specialised in one area of knowledge and do not need to carry out bureaucratic activities that take time away from the main ones (teaching, research, consultancy, management).
- CSS: prediction is needed since errors committed in the teaching process are difficult to correct.
- IS: transactional, since the teacher and student carry out different activities in parallel.

Fig. 3. Result of compiling observations.

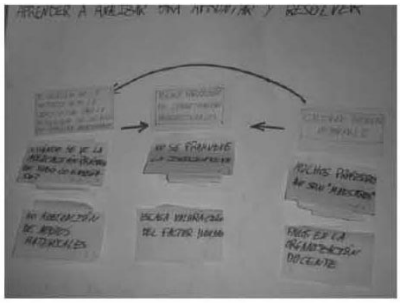


Fig. 4. Display of the first and second level groups and the causal relationships between the high level ones.

EFFICIENCY: ANALYSIS OF THE REAL SITUATION. GROUPING USING THE KJ METHODOLOGY

Each of the participants in the discussion jotted down on post-it papers different aspects connected with the teaching process in the school that they thought could be improved. After discarding those that were repeated, 23 observations were obtained (Fig. 3), which described deviations from the real situation with respect to the ideal one. Since the observations are not numerically quantifiable, which meant it was difficult to classify them, the KJ technique was used to classify them and a vote, giving out 3, 2 and 1 points to three groups (Fig. 4). Figure 5 shows the end result of the KJ process.

The two high level observations most voted for by participants were:

- When will we see the practical application of what is taught?
- Personal initiative is not encouraged: linked to the skills of 'confronting' and 'solving' indicated above.

As can be seen from the observations made and the observations of the groups, the real situation differs considerably from that defined as ideal.

EFFICIENCY: CAUSAL ANALYSIS AND RELEVANT ACTIONS METHODOLOGY

We then went on to analyse the causes that may have led to the situations described by the two most voted for observations in the KJ. To do this, fishbone or 'Ishikawa' diagrams were drawn.

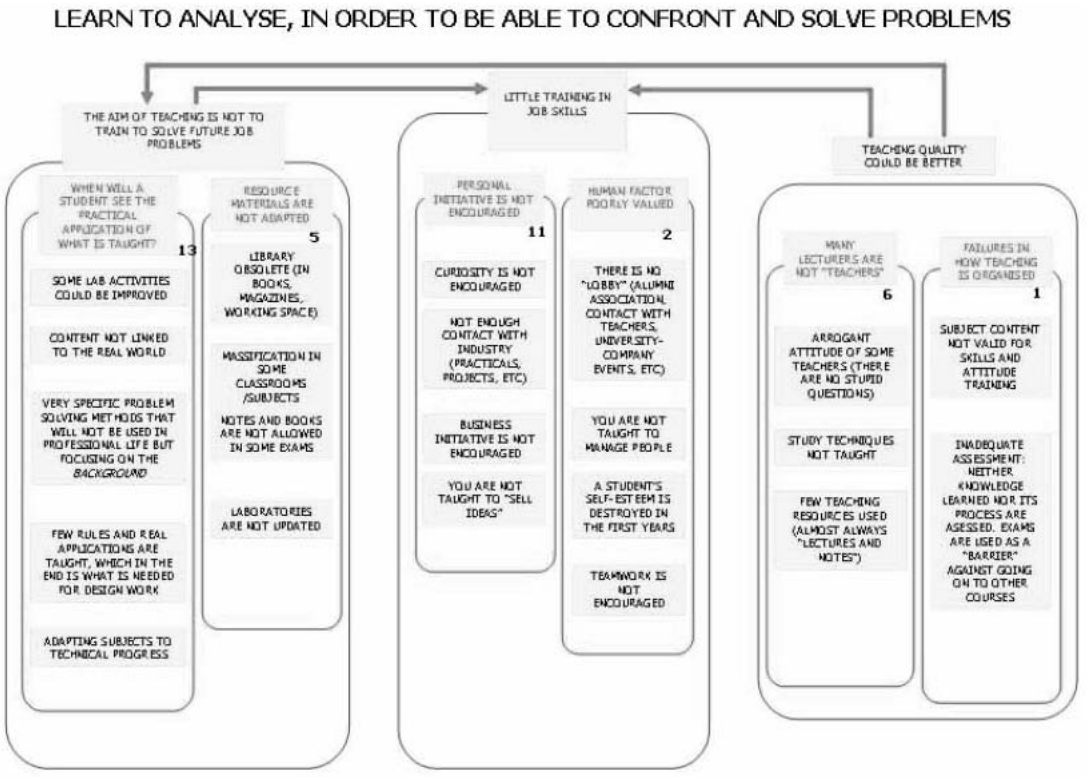


Fig. 5. KJ end result.

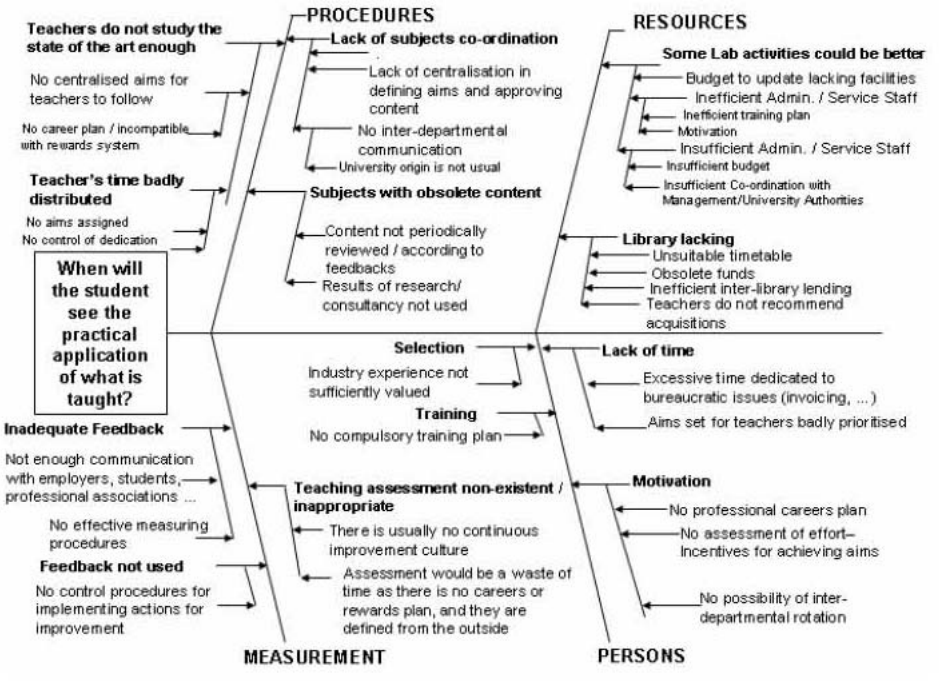


Fig. 6. Result of the causal analysis group 'When will the student see the practical application of what is taught?'

Figure 6 shows the result of analysing the group observation, 'When will we see the practical application of what is taught? Figure 7 shows the group observation, 'personal initiative is not encouraged'.

Figure 8 shows the list of proposed actions in accordance with relevant actions methodology for each cause obtained. Figure 9 shows the justification of the relevance of each action. The actions to be considered in the first place will be those that get the highest total score, since if they are successfully implemented, they will have a greater impact on the fulfilment of the mission and therefore, on customer satisfaction.

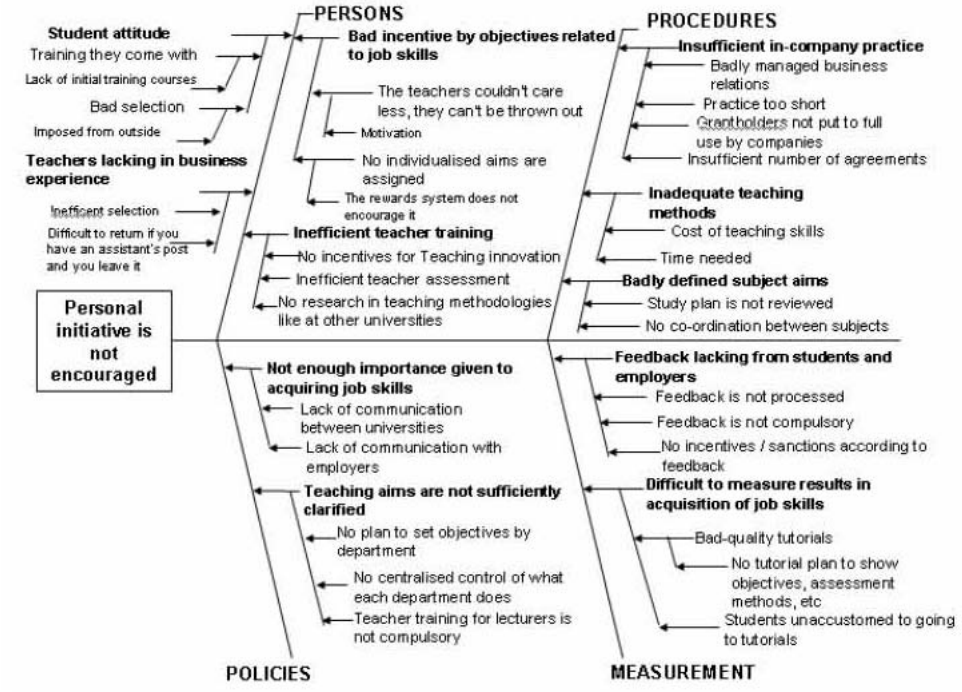
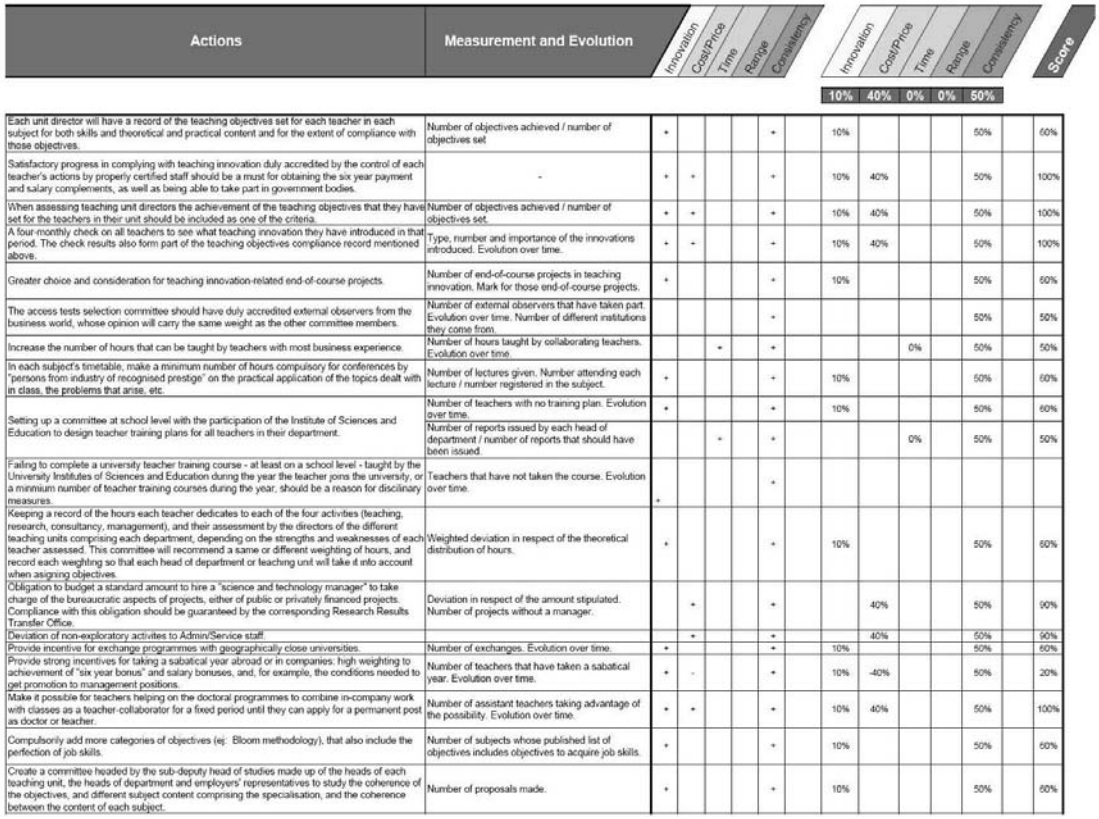


Fig. 7. Result of the causal analysis group 'Personal initiative is not encouraged'.

Point of action	Actions	Measurement and Evolution
No centralised objectives set for teachers	Each unit director will have a record of the teaching objectives set for each teacher in each subject for both skills and theoretical and practical content and for the extent of compliance with those objectives.	Number of objectives achieved / number of objectives set
	Satisfactory progress in complying with teaching innovation duly accredited by the control of each teacher's actions by properly certified staff should be a must for obtaining the six year payment and salary complements, as well as being able to take part in government bodies.	-
	When assessing teaching unit directors the achievement of the teaching objectives that they have set for the teachers in their unit should be included as one of the criteria.	Number of objectives achieved / number of objectives set.
No control of teacher dedication to teacher innovation	A four-monthly check on all teachers to see what teaching innovation they have introduced in that period. The check results also form part of the teaching objectives compliance record mentioned above.	Type, number and importance of the innovations introduced. Evolution over time.
	Greater choice and consideration for teaching innovation-related end-of-course projects.	Number of end-of-course projects in teaching innovation. Mark for those end-of-course projects.
Business experience not sufficiently taken into account when choosing teachers	The access tests selection committee should have duly accredited external observers from the business world, whose opinion will carry the same weight as the other committee members.	Number of external observers that have taken part. Evolution over time. Number of different institutions they come from.
	Increase the number of hours that can be taught by teachers with most business experience.	Number of hours taught by collaborating teachers. Evolution over time.
	In each subject's timetable, make a minimum number of hours compulsory for conferences by "persons from industry of recognised prestige" on the practical application of the topics dealt with in class, the problems that arise, etc.	Number of lectures given. Number attending each lecture / number registered in the subject.
No compulsory training plan	Setting up a committee at school level with the participation of the Institute of Sciences and Education to design teacher training plans for all teachers in their department.	Number of teachers with no training plan. Evolution over time
		Number of reports issued by each head of department / number of reports that should have been issued.
	Failing to complete a university teacher training course - at least on a school level - taught by the University Institutes of Sciences and Education during the year the teacher joins the university, or a minimum number of teacher training courses during the year, should be a reason for disciplinary measures.	Teachers that have not taken the course. Evolution over time
Objectives set for teachers badly prioritised	Keeping a record of the hours each teacher dedicates to each of the four activities (teaching, research, consultancy, management), and their assessment by the directors of the different teaching units comprising each department, depending on the strengths and weaknesses of each teacher assessed. This committee will recommend a same or different weighting of hours, and record each weighting so that each head of department or teaching unit will take it into account when assigning objectives.	Weighted deviation in respect of the theoretical distribution of hours.
Excess time devoted to bureaucratic activities (invoicing,...)	Obligation to budget a standard amount to hire a "science and technology manager" to take charge of the bureaucratic aspects of projects, either of public or privately financed projects. Compliance with this obligation should be guaranteed by the corresponding Research Results Transfer Office.	Deviation in respect of the amount stipulated. Number of projects without a manager.
	Deviation of non-exploratory activites to Admin/Service staff.	
No possibility of inter departmental rotation	Provide incentive for exchange programmes with geographically close universities.	Number of exchanges. Evolution over time.
	Provide strong incentives for taking a sabatical year abroad or in companies; high weighting to achievement of "six year bonus" and salary bonuses, and, for example, the conditions needed to get promotion to management positions.	Number of teachers that have taken a sabatical year. Evolution over time.
Difficult to return if you have an assistant's post and you leave it	Make it possible for teachers helping on the doctoral programmes to combine in-company work with classes as a teacher-collaborator for a fixed period until they can apply for a permanent post as doctor or teacher.	Number of assistant teachers taking advantage of the possibility. Evolution over time.
Defined objectives lacking for each subject	Compulsorily add more categories of objectives (ej: Bloom methodology), that also include the perfection of job skills.	Number of subjects whose published list of objectives includes objectives to acquire job skills.
Lack of centralisation in defining objectives and approving content	Create a committee headed by the sub-deputy head of studies made up of the heads of each teaching unit, the heads of department and employers' representatives to study the coherence of the objectives, and different subject content comprising the specialisation, and the coherence between the content of each subject.	Number of proposals made
Study plans are not reviewed	Set up records under the deputy-head of studies, of the changes desirable to the study plan in the light of experiences obtained from -students, employers, teachers- over time, with views to introducing them into the next study plan.	WACC of the number of proposals for change.
Insufficient communication with employers, students and professional bodies...	Set up a committee made up of employers, teachers and Admin./Service Staff, whose job would be to periodically make proposals for updating subject content and objectives. The committee would be chosen from teachers at the university in question and also members of the National Assessment Agency serving on national project and teacher assessment committees.	Number of proposals for change.
	To request feedback from the heads of the grantholders doing in-company practices on objectives, content, teaching resources, etc, and a proposal for improvement.	Number of proposals implemented from feedback
Content not periodically reviewed /according to feedback	Set up a procedure to control content and teaching practice actions for improvement and appoint somebody in each teaching unit to put it into practice. As stated in other proposals for action, introducing actions for improvement should form part of the teacher's assessment.	Teacher assessment.
Research/consultancy results are not incorporated into teaching	Periodic checks on the results of introducing research and consultancy into subjects and the publications for teaching it. Record of these checks and their use in assessment.	Number of changes and publications produced by each teaching unit. Evolution over time.
There are no adequate measurement procedures	Share measurement methods with other universities.	
There is no tutorial plan to indicate objectives, student asessment methods in tutorials, etc	Set up a tutorial plan to make teachers responsible for a certain number of students (no more than 10), and design an assessment record card to measure students' knowledge and skills acquisition. Reserve two days per four month period for asessing the 10 students and send the record card to the teachers of the subjects in which they are registered. Given that the School has 3122 students and 306 teachers, the proposal of 10 students per teacher would seem viable.	Random sampling to check compliance. Number of non-compliances. Evolution over time.
	Set up a plan for first course students to be mentored by those of the last courses, with volunteer teachers responsible for a certain number of student mentors.	Student mentor reports.
Sudents are not used to going to tutorials	Make tutorials compulsory (2 tutorials every four months, rest voluntary)	Tutorial attendance lists (with repercussion on the final mark).
	Encourage teachers of tutored students to be proactive (for instance, emphasising the importance of teacher assessment and the subjects taken by students)	Random interviews with teachers
There is no inter-departmental communication	Assign an amount for inter-departmental research and educational innovation projects.	Amount assigned. Number of projects. Teacher questionnaires.
Inefficient training plan for Admin. And Service Staff	Periodic assessment of the involvement of Admin./Service Staff in the research / consultancy activities teachers undertake, with an effect on their pay.	Teacher assessment.
	Each teaching unit director should design and register an annual training plan for Admin./Service Staff as well as assessing compliance with the plan and recording any deviations.	Number of deviations recorded. Evolution over time.
	Provide incentive for exchanging the Admin./Service Staff of similar departments in geographically close universities.	Number of exchanges. Evolution over time.
Inconvenient library timetable	Extended opening times when each exam period approaches.	Student questionnaires.
	Set aside additional library space for study during extended hours when each exam period is approaching.	Student questionnaires.
Obsolete library material	Assign each teaching unit a set of numbers for universal decimal classification together with bibliographical recommendations to supplement those obtained by inter-library lending. To be done twice-yearly.	Number of proposals for adding to / removing from collection.
	In public or private requests for financing, the compulsory inclusion of a budget for book purchases or magazine subscriptions. Control by the corresponding Research Results Transfer Office of compliance with compulsory purchasing.	Amount assigned.
	Unification of library data bases in the different departments and the university library (different loan conditions from libraries).	Number of departments with data bases not yet unified.
Insufficient budget for updating facilities	Promote the purchase and sale of second hand equipment in excellent condition but unused as the project for which it was bought ended with no continuity (there is a very wide specialised market).	-
	Compare the material requirements for laboratory practice with the facilities available, and prioritise the budget for those with the greatest difference and which are not eligible for financing by research / consultancy projects.	-
Lack of initial training courses for new students	Make initial training courses compulsory and count as credits.	Course attendance lists.
	Exams to know the level of new students so as to be able to decide the content of initial training course subjects -also including job skills.	Average performance rating (=average exam mark). Evolution over time.
Grantholders not put to full use by companies	Obligation to have a document signed by the company describing the grantholder's job description. No agreement will be signed with the company until the document is available.	-
	Obligation for the company to carry out and record an assessment of the grantholder's dedication.	-
	Company ranking according to deviation between what the grantholder is offered and the real situation.	Ranking.
Insufficient number of agreements	To make the most of the old students' association.	Number of new agreements signed through the association.
	To make the most of teachers with positions in professional bodies and standardisation organisations.	Number of new agreements signed through such organisations.
	Control by management of how the external relations department is run.	-

Fig. 8. Proposed actions.



Actions	Measurement and Evolution	Innovation	Cost/Price	Time	Range	Consistency	Innovation	Cost/Price	Time	Range	Consistency	Score
							10%	40%	0%	0%	50%	
Each unit director will have a record of the teaching objectives set for each teacher in each subject for both skills and theoretical and practical content and for the extent of compliance with those objectives.	Number of objectives achieved / number of objectives set	+			+		10%				50%	60%
Satisfactory progress in complying with teaching innovation duly accredited by the control of each teacher's actions by properly certified staff should be a must for obtaining the six year payment and salary complements, as well as being able to take part in government bodies.	-	+	+		+		10%	40%			50%	100%
When assessing teaching unit directors the achievement of the teaching objectives that they have set for the teachers in their unit should be included as one of the criteria.	Number of objectives achieved / number of objectives set.	+	+		+		10%	40%			50%	100%
A four-monthly check on all teachers to see what teaching innovation they have introduced in that period. The check results also form part of the teaching objectives compliance record mentioned above.	Type, number and importance of the innovations introduced. Evolution over time.	+	+		+		10%	40%			50%	100%
Greater choice and consideration for teaching innovation-related end-of-course projects.	Number of end-of-course projects in teaching innovation. Mark for those end-of-course projects.	+			+		10%				50%	60%
The access tests selection committee should have duly accredited external observers from the business world, whose opinion will carry the same weight as the other committee members.	Number of external observers that have taken part. Evolution over time. Number of different institutions they come from.				+						50%	50%
Increase the number of hours that can be taught by teachers with most business experience.	Number of hours taught by collaborating teachers. Evolution over time.			+	+				0%		50%	50%
In each subject's timetable, make a minimum number of hours compulsory for conferences by "persons from industry of recognised prestige" on the practical application of the topics dealt with in class, the problems that arise, etc.	Number of lectures given. Number attending each lecture / number registered in the subject.	+			+		10%				50%	60%
Setting up a committee at school level with the participation of the Institute of Sciences and Education to design teacher training plans for all teachers in their department.	Number of teachers with no training plan. Evolution over time.	+			+		10%				50%	60%
	Number of reports issued by each head of department / number of reports that should have been issued.			+	+				0%		50%	50%
Failing to complete a university teacher training course - at least on a school level - taught by the University Institutes of Sciences and Education during the year the teacher joins the university, or a minimum number of teacher training courses during the year, should be a reason for disciplinary measures.	Teachers that have not taken the course. Evolution over time.	+			+							
Keeping a record of the hours each teacher dedicates to each of the four activities (teaching, research, consultancy, management), and their assessment by the directors of the different teaching units comprising each department, depending on the strengths and weaknesses of each teacher assessed. This committee will recommend a same or different weighting of hours, and record each weighting so that each head of department or teaching unit will take it into account when assigning objectives.	Weighted deviation in respect of the theoretical distribution of hours.	+			+		10%				50%	60%
Obligation to budget a standard amount to hire a "science and technology manager" to take charge of the bureaucratic aspects of projects, either of public or privately financed projects. Compliance with this obligation should be guaranteed by the corresponding Research Results Transfer Office.	Deviation in respect of the amount stipulated. Number of projects without a manager.		+		+			40%			50%	90%
Deviation of non-exploratory activites to Admin/Service staff.			+		+			40%			50%	90%
Provide incentive for exchange programmes with geographically close universities.	Number of exchanges. Evolution over time.	+			+		10%				50%	60%
Provide strong incentives for taking a sabatical year abroad or in companies: high weighting to achievement of "six year bonus" and salary bonuses, and, for example, the conditions needed to get promotion to management positions.	Number of teachers that have taken a sabatical year. Evolution over time.	+	-		+		10%	-40%			50%	20%
Make it possible for teachers helping on the doctoral programmes to combine in-company work with classes as a teacher-collaborator for a fixed period until they can apply for a permanent post as doctor or teacher.	Number of assistant teachers taking advantage of the possibility. Evolution over time.	+	+		+		10%	40%			50%	100%
Compulsorily add more categories of objectives (ej: Bloom methodology), that also include the perfection of job skills.	Number of subjects whose published list of objectives includes objectives to acquire job skills.	+			+		10%				50%	60%
Create a committee headed by the sub-deputy head of studies made up of the heads of each teaching unit, the heads of department and employers' representatives to study the coherence of the objectives, and different subject content comprising the specialisation, and the coherence between the content of each subject.	Number of proposals made.	+			+		10%				50%	60%

Fig. 9. Justification of the relevance of each action.

THE OTHER COMPONENTS OF THE TRIAD: ATTRACTIVENESS AND UNITY

Implementing these actions will not only enable process efficiency to be increased, it will also improve the other two components of the triad: attractiveness and unity. It will increase the organisation's attractiveness for its components. Since these are 'brain power' and demand continuous challenges adapted to their knowledge, implementing all these actions will involve a considerable intellectual effort. On the other hand, a large number of actions put forward implicitly involve setting up a continuous improvement system: indicators are set and the need to periodically measure them, setting alarms if the variation does not meet specific conditions. Even if the proposed actions initially lead to the indicators evolving acceptably, for each action there will come a time when it will be necessary to design and implement improvements if this evolution is to be maintained. As this situation will arise at different times for each of the actions, this continuous improvement effort will be necessary. Also, in the event of the actions not giving rise to the expected evolution of the variables, corrective actions will need to be designed and implemented that will lead to the same results regarding attractiveness. The overall actions put forward will also contribute to enhancing unity within the organisation: since all have a high degree of relevance and a system has been developed to measure their effects, the organisation's components will be able to see that their joint work is translated into improving the fulfilment of the mission. The system of continuous improvement that is an implicit part of implementing the actions will also cause successive improvements or corrective actions that are implemented to have the same (or greater) relevance, which means that this effect will be boosted.

CONCLUSIONS

From the work undertaken the following conclusions may be reached:

- The golden triad model may not only be applied to classic business organisations but may also be extended to another type of organisation such as the university.
- Grouping ideas by KJ and then analysing causes using Ishikawa diagrams is a very powerful tool for improving processes: by using these tools it has been possible to obtain fifty actions for improving the fulfilment of the mission.
- The Relevant Actions Methodology, which enables the relevance of every action proposed to be quantified, is very useful for eliminating any actions that are not heading in the right direction to improve what is the 'core'. Such a

combination of tools aiming at fulfilling the mission better introduces a constant measurement, relevance ranking, countermeasure creation, and improvement system that can be considered a generalisation of the ISO 9000 standards, in the sense that such a system produces a virtuous cycle in the organisation as well (improve—solve mission-relevant problems—learn—create and store knowledge—create new problems because of the new knowledge—improve) but additionally gives priority to the most mission-relevant problems and guarantees the presence of challenges to the intellectual capital of the organisation . This is especially necessary in such 'brain-power driven' organisations as the university.

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