

CHAPTER 2

Vertical and Horizontal Integration of Education

2.1 Background

Industry has repeatedly and clearly demanded of higher education institutions to explicitly broaden the scope of undergraduate engineering education objectives [1-3]. The globalization process has intensified this trend and corporations currently consider social competencies such as client orientation, teamwork, and leadership, as valuable as technical expertise and know-how in first job hiring for engineers. The profile of an engineer in the fast growing technology market is also evolving towards that of an entrepreneur and, as a consequence, basic management skills are essential for the engineering profession.

The ABET's Engineering Criteria 2000 [4], the U.S. standard for accreditation, explicitly requires that engineering programs demonstrate that their graduates possess communication, multidisciplinary teamwork, and lifelong learning skills. The Industrial Research and Development Advisory Committee (IRDAC) has adopted a similar stand, when advising the European Commission on the revision of higher education European programs; the Bologna Process specifically calls for a greater investment in new basic skills such as digital literacy, learning to learn, social competencies, entrepreneurial skills, and language learning [5]. On the other hand, the concern at the university level is how can engineering curricula accommodate all these additional learning requirements without extending studies or losing depth?[6] The task at hand is to vigorously and comprehensively reform the curricula and overcome the Taylorist paradigm [7] of fragmented curricula, organised within disciplinary boundaries. The challenge is to reengineer programs, including the teaching processes, in such a way that science and engineering knowledge and skills can be acquired together with social competencies.

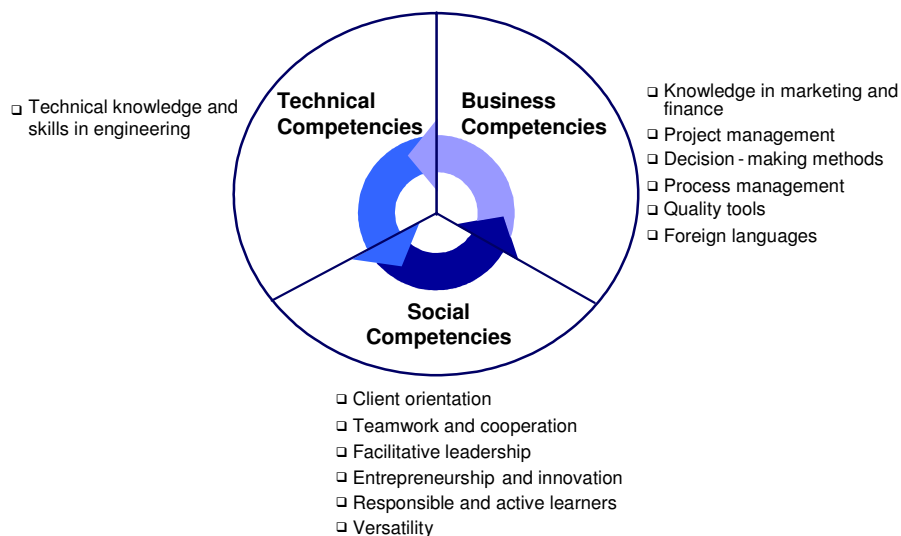


Figure 2.1. Underlying Abilities for a Global Chemical Engineer*

* Survey of chemical manufacturers in greater Tarragona in 1994

Figure 2.1 illustrates in a brief and comprehensive manner the abilities that then best described a global engineer, classified in terms of technical foundation, business competence and social competencies. The challenge was to embed into the chemical engineering curriculum the competencies given in Figure 2.1. Project based and cooperative learning methodologies were both considered, since they would enable students to acquire technical and scientific knowledge and to simultaneously develop the social competencies needed in real life work settings [1], i.e., while solving real life problems in collaboration with others. During the first semester of the 1995-96 academic year (see Figure 1.5), the so-called integrated design project (IDP) was tested in the first year of the ChE program [8]. This approach combined the two learning methodologies mentioned above with the particularity that the 1st year students worked in teams led by 4th year students enrolled in a project design practice course (PDP), which meant an indirect way of integrating knowledge and processes vertically. Initially the IDP integrated horizontally only two 1st year engineering science subjects and was very restricted in scope. The basic IDP layout is depicted in Figure 1.4. The fact that 1st year professors acted as clients of the projects is a key factor in the current study, as discussed in the following subsections.

This chapter describes the underlying preliminary hypothesis and framework that supported the adoption and implementation of a competency educational model, where technical foundation, business competence and social competencies could all be simultaneously considered. Figure 2.1 illustrates the underlying abilities of these three supporting pillars.

2.2 Preliminary Steps Towards a Competency Based Model

The current research project started with the following hypothesis:

- The social environment generated by the IDP model should be adequate to deploy social competencies in a natural way
- The role of clients should be central in the new competency based system as it was so in IDP model, since students are driven by performance evaluation
- Social competencies should enhance students' mid term learning and through way of integration with the educational system increase their productivity, without hindering technical and scientific content

In order to prove this hypothesis the necessary external interventions were adopted accordingly. The analysis of the above hypothesis led to the conclusion that it was essential, both for the IDP model and for the transition towards a competency based educational organization, to consolidate teamwork and test the impact of the industry recognized external intervention "Enhancing Team Performance ©" [9]. Also, it was decided that initially some of the competencies needed, could be grouped under the category of coaching competencies [10]. Annex A includes a copy of the paper that resulted from this initial work, and which was presented at the FIE Conference in 2002.

In order to validate these statements, the following mandate was initially put forward:

- Establish a partnership with Dow Chemical Ibérica, with the support of the Dow Chemical Company where the author was a former employee, to obtain change management technology, external interventions and training materials, consultancy and facilitation
- Integrate the design of social competency building into an overall change management effort
- Prototype and test the effectiveness of the social intervention “Enhancing Team Performance ©” related to teamwork
- Define a model framework to deploy and evaluate the impact of this intervention and the rest of interventions that will finally be adopted
- Test the initial model at the School of Chemical Engineering in Tarragona, Spain for validity and further development

2.3 The Academic Organization Selected

A number of factors lead to the selection of the Chemical Engineering School of Tarragona (ETSEQ), Spain as the best candidate to obtain evidence and to develop and test the competency based educational model. Dow Chemical had a long standing fruitful collaboration with the ETSEQ that started back in 1977. Based on that alliance, it became reasonable to assume that both parties would be interested in the research project. In addition, the colleagues from Dow Chemical Ibérica in Tarragona are well recognized within the corporation for their help and support. Later on it will be discussed how invaluable the local resources were in assisting the project. The students and the university faculty shared that same level of enthusiasm. The ETSEQ has a long standing tradition of innovating ways to teach and to involve faculty in effective teaching methodologies [8,11-13]. Based on that culture, a significant effort was made in order to accelerate and upgrade the new way of educating future chemical engineers. This effort was appreciated all the more given the fact that the concept of reengineering and empowerment is quite recent [14].

Not too many business organizations around have conducted successful reengineering in a sustainable manner, let alone applications in non profit organizations like the academia. Thus, the current effort in curriculum development is a forefront runner in the area of implementing sophisticated novel business concepts in an academic organization. This fact calls for appreciation of the pioneer work of a team of professors, who started this journey in the mid-1980s. Their effort received professional acclaim starting 1997, when the department of Chemical Engineering decided to use outside expertise, particularly in the form of industry consulting and support as a way of intensifying and structuring the department’s approach towards an improved engineering curriculum. The proposal of this joint university-industry research project was a perfect match, as it combined the strengths of the business organization (change management expertise) with the strengths of the school (vision, change readiness, change leadership and infrastructure). The foundation of the school’s reengineered curriculum is the so-called “integrated project methodology” work, which was already established in the early 90’s [8,11,12], as highlighted in Figure 1.5.

2.4 The Change Management Technology

The shift in academic organization required by the implementation of a competency based model, with external interventions, was supported by a suitable change management technology. For obvious reasons the “Dow Global Change Management Framework” was adopted, as it is a robust and well established technology [15]. It is summarized in Figure 2.2.

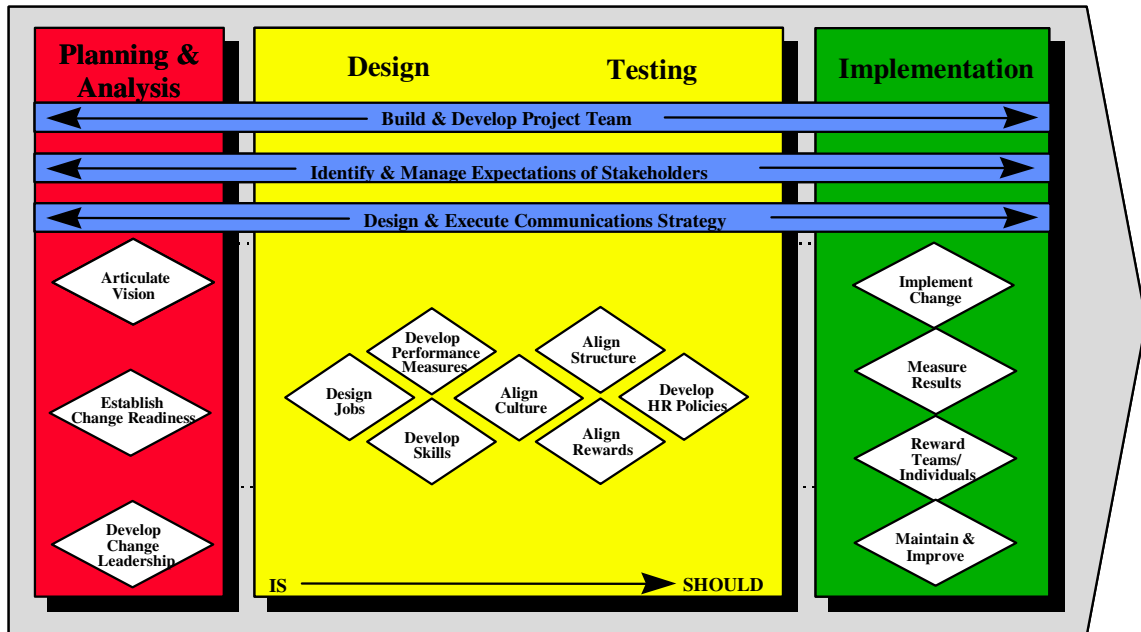


Figure 2.2. Dow Global Change Management Framework

The Dow technology described in Figure 2.2 provides an excellent framework for conducting any given major reengineering, be it for business or a non profit organization, like academia. Instead of looking just at the micro objective of “competency building”, this model suggests an integrated view looking at different components and their interdependencies. The key message here is to build vision, change readiness, and appropriate leadership to drive any change process up front. The use of this technology definitely increases success chances in the change effort, as it helps avoiding some of the pitfalls mentioned earlier in chapter 1.

Throughout this research project the change management framework will be referenced, as it provides an excellent road map to design, test, and implement the social interventions and evaluate their effectiveness.

2.4.1 Building the Vision

As the change management technology prescribes, the first task in any major change initiative is to “articulate vision”. In order to do so, the current strategy of the School of Chemical Engineering was revisited [16]. As it was too narrow in scope, two workshops were conducted [17]. Professional change management consultants from the Dow Chemical Company, including the author, facilitated these sessions, with faculty, staff and school managers participating. The outcome of these workshops is condensed in the following figure 2.3.

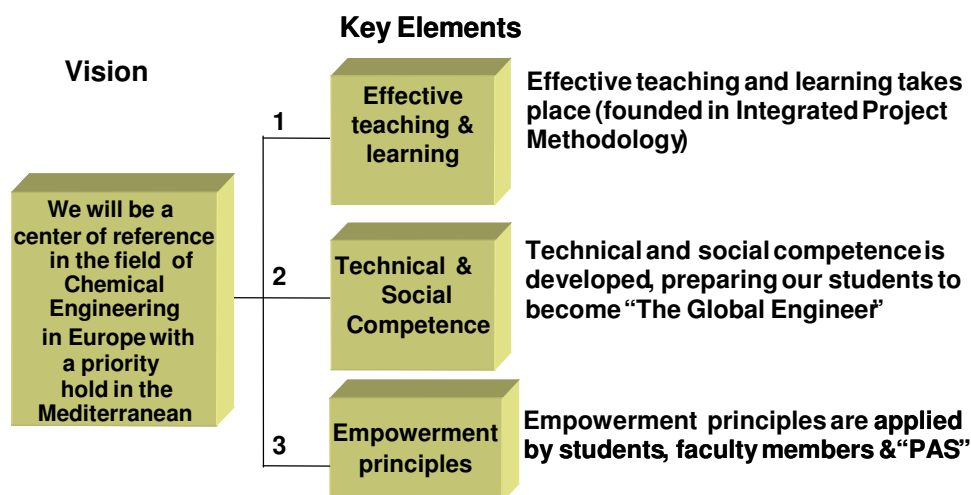


Figure 2.3. Strategy and Key Elements

The revised strategy currently contains a compelling vision statement, key elements and operational definitions. As such, it provides a framework for the competency based model implementation. Values were also adopted; they are listed in chapter 4. To clarify each key element in Figure 2.3, further detail was communicated to all people involved at the ETSEQ and was also provided to all stakeholders. These details are included below for completeness:

- **Effective Teaching and Learning.** We recognize that there are different ways of teaching and learning. Not only will we assess our current teaching methods, but also explore and apply new methods, such as integrated learning, experiential skill building, learning by doing, etc. The integrated project methodology will be intensified and enhanced by injecting new teaching technologies
- **Technical and Social Competence.** Historically the focus has been on technical skills. However, the future trend requires a simultaneous build up of social skills. The present task is to build technical competence through the development of social competencies. The focus will initially fall on teamwork with emphasis on coaching, due to the specific needs of the 1st and 4th year IDP (which was in place when the current work started: the paper included in Annex A covers the coaching effort by the author, with the support of the professors involved)
- **Empowerment Principles.** Our decision making processes are reliable, effective and transparent. We will delegate authority down to the lowest possible level. All students are an integral part of the processes of our school. The prerequisite to succeed with above work is leadership at all levels

As stated earlier, this research intended to build up on existing work and infrastructure as much as possible. Hence social competency building was synchronized with the integrated project methodology. The next level of detail was added to key element number two "Technical and Social Competence" in Figure 2.4. This resulted in an operational framework to design and execute the road map for implementation given in Figure 2.4. The road map for implementation incorporates elements from the European Foundation for Quality

Management (EFQM) and gets inputs from the “Enhancing Team Performance©” surveys and from the empowerment assessment process, which would be implemented when the model is completely deployed with respect to IDPs and external interventions.

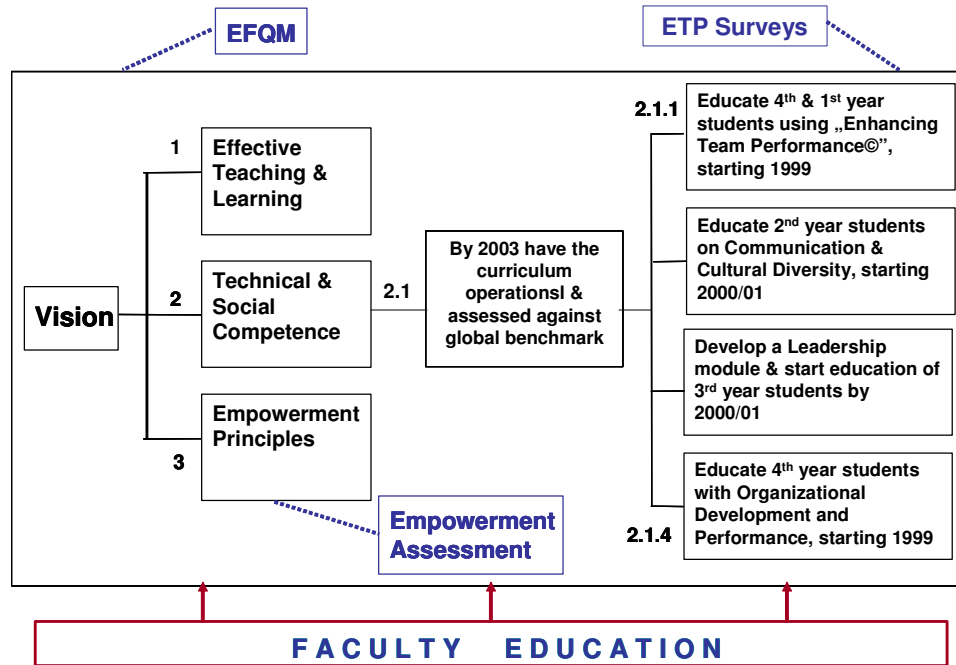


Figure 2.4. Roadmap for Implementation

The plan currently put forward contains detailed objectives and plans, as well as milestones and measures for success. The preliminary evaluation process and its corresponding measures will be explained in more detail in chapter 4.

As a note aside, putting this strategy to work with the faculty has definitely increased “change readiness”, and helped to build up ‘change leadership’ – the prerequisites for successful change. The next step is specifying how to build these social skills and integrate them into existing curriculum.

2.4.2 Building Competencies and Identifying Transformations

After intensive research and screening of future industry and societal needs and trends [1], and taking into consideration the dominant client satisfaction scheme, adopted for the IDP model depicted in Figure 1.4 (see ref. 8 for further details), it was decided that the four competencies mentioned and discussed in subsection 1.3 (teamwork and cooperation, human interaction, leadership, and system thinking) should gravitate around the central competency, client orientation. Also, the need to satisfy clients should sequentially suggest any other missing social competencies. This process of selection, which is explained in detail and justified in chapter 4, led to the inclusion of five additional competencies: versatility, entrepreneurship and innovation, responsible and active learners, organizational development and performance, and organizational leadership.

Once the decision was taken to focus on these nine social competencies, the task at hand became allocating the set of external interventions needed to incorporate them into existing integrated project methodology, which in turn should be spread across all engineering curriculum beyond the 1st and 4th year project. The next task was to prioritize the external interventions. It was then decided that teamwork and cooperation were essential and they were selected and used to assess the external intervention scheme as well as students' opinions about the emerging new educational model. It should be realized that:

- Teamwork enables learning and building of competencies in general
- Teamwork is a concept, which is easy to comprehend in all cultures [unlike Organizational Development or Facilitative Leadership]
- Teamwork helps reducing conflict and increases effectiveness

Besides these generic factors, there was yet another important decision making factor. The TRACOM Group generously offered their support and made available their excellent learning resource called “Enhancing Team Performance©” [9]. Ultimately, this was the decisive factor in defining teamwork as initial external intervention. This learning resource was delivered first in form of a workshop and is described next.

2.5 The Fundamental Intervention Teamwork and Cooperation

In order to substantiate the hypothesis of this research (see chapters 2 and 4), an intervention plan was put forward allowing to measure the baseline, introduce the team building intervention, measure the effects of that intervention, and draw correlations with performance improvements. In other words, a completed cycle of “Plan-Do-Check-Act” [18] was conducted for the social skill of “teamwork and cooperation”. For the remaining eight competencies, supporting external interventions are proposed, using a similar pattern. In chapter 4, where the new competency based educational model is presented and discussed, all external interventions are outlined and fitted into the curriculum. The learning resource selected for teamwork and cooperation was “Enhancing Team Performance©” [9], kindly supplied by the TRACOM Group. This methodology is widely used throughout industry and has a longstanding record of success (see for example <http://tracomcorp.com>).

“Enhancing Team Performance©” is set up as a supporting process in modular form, taught by certified trainers and coaches according to the standards of this vendor. The learning resource itself is comprised out of an introduction module, called Fundamentals, followed by nine additional modules, which are built up on one another:

- Common Purpose
- Team Capabilities
- Change
- Team Norms
- Communication/Conflict
- Recognition/Reward
- Team Operating Procedures

- New Member Integration
- Evaluation

Along with the intervention comes a survey, which is normally used to assess the dynamics and consequently the performance of a given team [9]. Initially a decision has been taken not to use this survey. The reason for that is the fact that the project teams were nearly in the process of formation. That meant that team leaders and team members were not able to answer the questions in a meaningful manner (e.g. “How well is your team performing”). It was proposed to use the vendor survey, once the teams have been established and functioning.

To assess the baseline, follow the development and monitor the journey of the project teams, a series of surveys were developed. The surveys designed are shown in Annex B. In chapter 3 a closer look is taken at the process of survey validation, based on practices and knowledge in this area [19].

One of the key issues when designing social interventions is integration of competency building activities into the curriculum regular work, alongside a structured approach in the area of change management. The importance of this approach has been already highlighted above. In support of that approach and to sustain it, the following measures concerning the delivery of the intervention were taken. In compliance with an agreement [20] regarding permission to use “Enhancing Team Performance©” by the TRACOM Group, tutorial sessions were initiated with the aim of educating professors and school staff by exposing them to the material in a two day workshop. Because of language issues and a subsequent need for simultaneous translation, professional expertise was kindly supplied by the Dow Tarragona team. Not only are they certified coaches of “Enhancing Team Performance©”, they are also fluent in Catalan - the official language of this Spanish province, Catalunya. In these co-facilitated sessions, participants were exposed to the principles of ten modules of “Enhancing Team Performance©” as well as facilitating the material. That was quite a unique undertaking, as some of the professors have been exposed for the first time in their professional career to some very different methods of teaching, e.g. by means of using experiential team building exercises [21]. Again, it is noteworthy to mention that this exercise supported the necessary culture/behavior change as required by the change management process described before. In a cascading manner over periods of months, other professors (joined by faculty members like PhD students) were exposed to this methodology. At this point in time it is fair to say that by then the department of Chemical Engineering possessed sound knowledge of the teamwork methodology and was on its way to building strong social competencies as a cultural habit.

The faculty members who had already received the tutoring, had to educate in turn the team leaders and team members of the integrated project. A plan on how to spread the teamwork competency across the 1st and 4th year students during the first academic year could now be designed and executed.

After a general two day introduction at the beginning of the new academic year, a better tailored tutorial took place for all the new students. Being based on needs and requests of project teams the various modules of “Enhancing Team Performance©” were injected into the work of integrated project methodology. It

is important to mention that the trained “Enhancing Team Performance©” coaches supported the project teams on an on-going basis as skill building would not be otherwise sustainable. It can be noticed during the surveys evaluation stage that the ability to communicate effectively and handle conflicts (as issues arise) is of fundamental importance and has to be dealt with on continuous basis. That explains the need for the process coaches to be available and accessible at all times, as otherwise team members would go back to their original individualistic behavior, rendering team work skill building unsuccessful.

The surveys evaluation clearly points out the importance of on-going coaching (chapter 4). In chapter 5, where future improvements are discussed, it is underlined yet again that professional team coaching on continuous basis is vital to ensure that there is no erosion of growing supportive team behaviors. Or, as Igor Strawinsky put it: “Knowledge which is not used and applied does not exist” [22]. Overall research unanimously supports the above recommendation [23]. Figure 2.5 illustrates the correlation between learning investment and competency building, and performance increase.

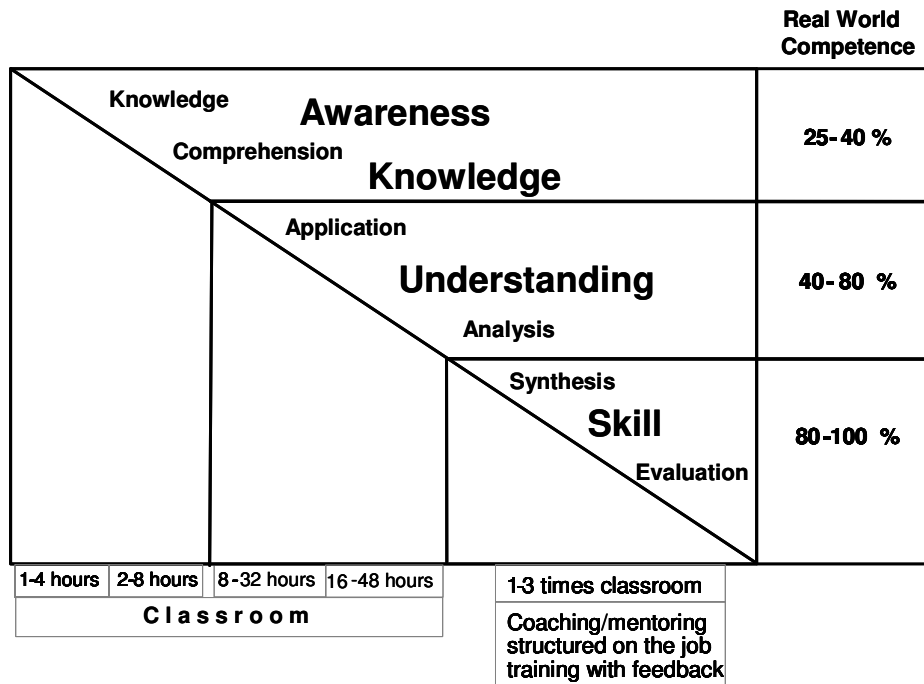


Figure 2.5. Correlation of Competency Building and Performance

2.6 Transformational Changes and Learning

In addition to the considerations made earlier about building social competencies and identifying transformational changes, the ten competencies selected should be examined from the learning processes point of view, together with the changes, that should simultaneously take place at all levels within the educational system. These aspects are discussed next.

The concept of organizational change as used in this research refers to planned, organization wide change. The ultimate objective is to create a model, whereby organizational transformation happens in the least disruptive way and delivers sustainable results. This is an ambitious task, as very often the models are either

exceedingly theoretical and lack implementation capabilities [24] or merely describe trial and error effort with difficulties to extrapolate results to other organizations. The present research tries to bridge these two approaches by using robust models with heavy emphasis on learning, gained from nearly a decade of implementation work. This work has been primarily carried out by the Dow Chemical Company, whereby the results obtained involved literally thousands of employees from all kinds of countries, cultures, nationalities, religions and levels in the organization. It is therefore valid to assume that the experiences, results and conclusions can be projected onto other organizations with a high likelihood of success, as the testing over this decade guarantees implementation.

2.6.1 Transformations and Competencies

Any organization is ultimately centered on purpose, which can be generally described as “achieving client satisfaction”. While serving this purpose, an embedded dilemma is manifested. As the client’s needs change, the organization has to change as well in order to closely follow the client’s movements and to guarantee client satisfaction. Every considerable change in client needs prompts organizational transformation. Figure 2.6 illustrates the phenomenon within the framework of the current study.



Figure 2.6. Client Satisfaction and Transformations

A change in client needs should trigger a change in the individual behavior in given organization. Research supports the assumption that the only thing which can be changed in an organization is the individual with his/her attitudes and perspectives [25]. Change always happens at the individual level. The change of individual behavior triggers organizational transformation. Once organizational transformation has taken place, the new way to work has to be institutionalized in order to ensure sustainability of changes. Erosion would be detrimental to the required changes, as the organization gradually slides back to the ‘status quo’ or the starting point of the change initiative. However the above concentric spiral with its dynamics requires a number of skills to achieve the desired result.

For each of the three levels of transformation given in Figure 2.6:

- individual
- organizational
- institutional

a competency-building process is needed. The set of competencies must concentrically emerge with the purpose to satisfy clients. The first competency required for this purpose at the individual level is versatility. An individual within a client service organization must be able to perceive change in client needs and change accordingly. Productive performance during change requires versatility as the individual is likely to be catapulted out of one's comfort zone. To cope with inflicted stress, a high degree of versatility is needed, as one has to adapt by changing one's views, perspectives, assumptions and behaviors.

The next skill under scrutiny is entrepreneurship and innovation. Versatility has brought about capacity to adapt to change. It now has to be followed by creative ideas which are required to respond to the new challenges imposed by the client. On institutional level entrepreneurship will aid translating creative ideas to tangible business opportunities.

The next layer of the concentric model is system thinking. Business opportunities have to be put into perspective and the whole system of individual and organizational interaction has to be reconsidered. Critical reflection of one's position in relation to the new system will consequently trigger new learning. It is most likely that a number of skills will become obsolete and will have to be replaced by new skills. The skill transformation calls for responsible and active learners or else no change will happen. Gradually a theme of "life long learning" [26] emerges on the business horizon. This notion is quite a challenge in itself as it conflicts with traditional way of looking at education. A prevailing belief goes that once graduation is behind, there is "only work to be done". The last circle of individual transformation – facilitative leadership - leads to the sphere of organizational transformation. Facilitative leadership is a pivotal point, whereby the impact evolves from individual into collective scale. The individual affected has completed the personal transformation cycle and is now skilled and ready to spark changes in others.

Organizational transformation initially starts within the smallest nucleus of the organization, which typically happens to be a team or a small group. The team reinforces the changes with cooperation and collectively analyses the client needs. When several teams or small groups interact, the level of complexity increases exponentially [27]. This calls for a higher skill level of human interaction. As change grows, the likelihood of miss communication and errors by default is usual. A good skill set of human interaction, aids in minimizing these side effects of change. This concludes the final circle of organizational transformation.

Now as the individuals and the organization are mutually aligned against the new client needs, the attained changes have to be institutionalized. This happens by injecting three critical skills into the organization: Organizational Development, Organizational Performance and Organizational Leadership. The first institutional skill is work management. The relevant procedures and system documentation have to be updated, so that the new operating discipline reflects the client needs.

Interaction across organization has to be reflected in business and work processes, which are aimed at client needs. Figure 2.7, which is repeated as Figure 4.2 in Chapter 4, where it is discussed in detail, illustrates how the individuals within organization and the organization itself are aligned by the appropriate process management [28]. The last circle in Institutional Transformation is Organizational Leadership. The senior management of any given organization has to ensure that the transformation is complete and translated into results. The latter has to initiate an appropriate evaluation cycle to validate the degree of transformation on the three levels against client satisfaction. Furthermore, intelligent tracking mechanisms are needed to ensure continuous improvement and monitoring of the client needs in order to stay up-to-date and connected.



Figure 2.7. Concentric Structure of Competencies Centred at Client Orientation.

In the above figure, the gray levels identify sequentially outward the individual, organizational and institutional transformations (figure 2.6), required to attain the central client satisfaction and the development of the ten selected competencies.

2.6.3 Transformation through Structured Education

The discourse of the previous sections clearly points out to the need of a large amount of education and competency building to achieve sustainable transformation. With the aim of being efficient, the taxonomy of educational objectives needs to be followed [29,30]. The well organized learning process suggests a hierarchy of six levels, as described below:

1. Knowledge – getting familiar with and memorizing information

2. Comprehension – paraphrasing text; explaining concepts in jargon-free terms
3. Application – applying course material to find solutions to uncomplicated problems
4. Analysis – solving complex problems; developing process models and simulations; troubleshooting equipment and system problems
5. Synthesis – designing experiments, devices, processes and products
6. Evaluations – finding an alternative and justifying the choice; optimizing process; making judgments about the environmental impact of engineering decisions; resolving ethical dilemmas

Throughout this research the above taxonomy has been followed. Initially, knowledge in form of “Enhancing Team Performance©” training was conveyed. Comprehension was tested through various surveys. Throughout the duration of the integrated project the knowledge application has been validated. The analysis took place over the survey period and the integrated project work, bringing about improvements which resulted in enhancements – a characteristic typical to the synthesis stage. Finally, the overall evaluation happened in form of surveys, judging the outcome of the integrated project, as well as providing recommendations for future work as documented in chapter 5.

By the token of application of the above taxonomy, the ABET accreditation criteria is equally fulfilled [4]. For that reason, it is viable that the School of Chemical Engineering of Tarragona applies for the official accreditation of ABET.

2.7 Creating Support for Change

There is a fundamental need in any organization for implementing structured approaches towards a major change. Consequently, the necessary infrastructure for successful implementation of the current proposal for the ETSEQ had to be consciously created. The following four items were considered:

- Develop Change Leadership. In a series of workshops, faculty members and above all professors, have been exposed to the change management process and its application. During this exercise, the participants realized how much of a change that would mean to the way of “running business” or in other words “teaching”. In addition, a number of selected professors and PhD students were assigned a stronger leadership role in order to enable the changes. However, maintaining the leadership level to reengineer the curriculum and sustain the changes, will yet require considerable effort. As a supporting measure for the above, university management reviews (i.e. dean, etc.) were organized not only to assure top leadership support, but also to provide resources (in form of PhD students, graduate students, and credits for professors, when participating in the new way to teach) for the necessary culture change
- Build and Develop Project Team. As discussed above, a small group of professors/PhD students were additionally educated to perform the role of a

project team. The group meets on regular basis to review progress and provide improvement plans to the school to maintain the momentum

- Identify and Manage Expectations of Stakeholders. The ultimate objective is engaging the total organization, or in this specific case, the total school. In order to do so, upfront education sessions have been provided at the beginning of the new academic year, so that the students were informed by their professors/leaders concerning the plan forward. For that purpose, two-day teamwork skill building introduction sessions (“Enhancing Team Performance©”) have been set up to develop a common foundation throughout the entire school
- Design and Execute Communication Strategy. It would be an exaggeration to state that there was clear and well articulated communication strategy. However, all the above efforts of education and communication have definitely resulted in an increased awareness and support of this reengineering project

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