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DESIGN IN ENGINEERING EDUCATION AS A CONTRIBUTION IN HUMAN "REAL PROBLEMS" SOLVING

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1. Introduction

This paper develops aspects of the potential of Art and Design in Engineering Education and has the objective to develop arguments in favor of enlarging the scope of Engineering Education programs with Design concepts and practice as part of education for XXIst century Engineers.

Design roots are in history, social practices, language, economy, etc. Design concepts in Education add complexity to reasoning processes that explicitly value intuitive thinking processes; it may help the student to "unmask simplicity" [Simon 1973]. Our thesis is that we should continuously improve how we train Engineering students to use Design and as a consequence let them begin create and analyze discourses [Foucault 2003]; it allows them to avoid that so many things run away thanks our "tender certainty", an attitude that negatively limits Engineers' ability and potential for personal and professional growth.

We accept that studies of natural, human and artificial environments is a normal subject for studies in philosophy and religion, science, technology... all these studies are part of a wider range of conceptual or action-driven sensorial experiences. Designers are professionals well equipped to "unmask this complexity into simplicity". Designers can create experiences that impact human-mind as an individual member of social or collective entities. Moreover, utopian and utilitarian ideas of society have crafted social mechanisms made of ideal principles that promote, accept or restrict the ability of individuals to participate in different kinds of transactions and exclusions in real world. The educational reality that we claim alters social mechanisms if we adopt the Designers' wisdom into the Engineers' culture.

The paper is part of a holistic research in collateral concepts to Engineering education as intelligent society, success, knowledge, culture, and opens a discussion of a new paradigm that values this softer and human dimension of reality and our interaction while creating new technical systems.

A second objective of our research is also our understanding on the constant evolution and interaction of Engineering and Design with the dynamics of the changing XXIst Century society, and why a regressive approach can affect negatively an information society that can opt for an intelligent society. We recently used the previously listed set of ideas in the teaching of Chemical Engineering Projects; the method supports works on real, human problems. Students must experience group's dynamics, after basic theory is explained, proposals are discussed and preliminary designs embedded the basic principles described in this paper. Solutions obtained from the students encourage our effort and will be subject for future research; a set of findings are described in this text and more specifically in par. 4.

2. The tradition of teaching and learning in Engineering Education

2.1 Still on tradition

We consider as tradition a series of habits that may endure a few generations; specialization and corporate management skills were a success during the first industrial periods and it finally determines "successful careers" for many good professionals. XXIst Century society Designers, Engineers and Managers face a different challenge as intellectual services revolutionize the world economies [Quinn 1992] with knowledge and service based paradigm for industry.

Teaching and learning of Engineering develops an important kind of private knowledge but is not only focused on the kinds of traditional intelligence as it will be described hereunder. We find engineers in diverse tasks and in all functional levels, that leads them to specialized or generalist professional careers using the last Centuries habits. Professional engineering practice for specialists is then conceived mainly as a summary of basic science, applied science as a problem-solving approach, and a series of "specific skills to support practice"; this teaching and learning is operated as "telling and listening" and "demonstrating and imitating" consisting of "follow me by doing" and "joint experimentation" [Green et al. 2001].

Basic science for engineering studies combine the tradition of assembling Physics, Chemistry and Mathematics knowledge that is immediately useful in technical or technological problem-solving; some of the problems continue as the drafted principles can remain unchanged during decades; other natural sciences like Biology, Geology... are studied mainly as applied science: Educational systems promote specialization of students in undergraduate studies.

Many Engineers work as experts that look for "job security"; but our creative destruction system does not provide with a bright prospect for job stability. Our specialist Engineers sit behind the "driver's seat" position of managers and/or marketing executives only in case specialists provide bright solutions to real-world hurdles.

Part of the students find challenges more interesting than becoming specialized agents, acting as if they were drivers. Generalist professional careers are developed towards managerial or responsibility functions; then a more creative approach is seldom developed; "errors avoidance" is best practice for promotion to upper positions or responsibilities (flattening and delayering of organizations nullify the promotion incentive) an approach that is confirmed by the following argument: summarizing Engineering students' skills were made to solve specific problems, their task was primarily oriented to understand or apply different structures of predictable problem spaces. Ends are objectives rarely are part of their decision options, and their task easily develops into "developing the wrong skills" [Quinn 1992].

Again, Engineers could do better if they are trained on the not so easy to predict problems as Designers do; they understand and promote solutions that fulfill economic, aesthetic, functional requirements, constraints, conditions and objectives. But often, the unpredictable, beyond measurements factors that drive change are not considered even if present scenarios are quickly changing. Part of the error may be due that perception and personality variables were seldom studied in Engineering schools, a kind of knowledge and skills that artists and designers experience daily. The good or common sense of Design talent connected with Engineering Education generate freedom to decide new ends and obtains improved solutions as it was our purpose described in the introduction.

2.2 The new approach at work

Engineering schools are the result of economic structures that required a continuous flow of trained professionals and of course they contribute to the success of our social and economic model. We train Chemical Engineers for the Chemical Industry; Managerial positions in diverse fields drain the ranks in well-paid managerial jobs. In par.3.1. we will describe how and why a vision of the patterns of the evolution of economic structures changes the personal and professional needs of our future Engineering professionals.

We saw how Art, Design, Engineering and Architecture began distant and divergent lives during the industrial revolution, but real or ideal, they share many common and contradictory grounds. But as inertia is proportional to mass, changing speed or direction is much more difficult when inertia is so big. Nowadays, European Union and individual nations are in the process known as Bologna that must first provide future graduate students with skills necessary for the “labor market”. Part of the discourse is on the benefits of specialization and on gaining competitiveness for Global Markets; our competitive posture must target “activity share” not “market share” [Quinn 1992]. Competitiveness that lasted often through generations and historical crisis, is build on competent people flexible enough to surf on the adequate combination of specialization plus openness or aptitudes to gain future specializations along their lifetime. For many it is important to succeed on integration in today’s labor market; we must also enable their decision for the future, in a fastest changing labor market that will force or free these persons to decide a different role for which they must be ready to adapt. The industrial society has turned into the information society, a different era. We continue to build systems where many persons are equipped with the incapacity of crossing the line [Deleuze 1987]. The lines first are crossed by a minority, rare individuals that may feel socially excluded. There will be again many lines that must be crossed in the future as excellent. The paper shows arguments that may help our Engineers to cross as many lines that are needed. So Designers and Artists did in the past, are now currently doing and will continue in the future.

In the so named “Knowledge Society”, another paradox present is that often societies consent to mute the voice of Social sciences, Art and Humanities. Motivated on students’ shortage, as an example, Spanish authorities proposed to reduce the nummber of University careers and specially suppress studies of “Humanities”. On the contrary, we need Humanities in a much more visible or explicit way. We limit in our Spanish system the teaching of Social Sciences, Art and Humanities as a Basic Science or we simplify it into applied experiences as information, data or part of specific and very precise/specialized subjects, i.e.: ergonomics relates to biological factors that drive performance at work. Something similar happens with many natural sciences; as an example that of Geology, where knowledge is limited in a similar way, hundreds of Barcelona citizens suffered during 2005 a sudden collapse of their buildings due to a serious incident boosted by a series of misunderstandings in the construction of an underground tunnel. Real world requires enough flexibility to admit that possibly a not desired complexity was embedded in that flawed design, and geology can be as essential as social sciences are to our future Design Engineers; in a fast changing world we cannot assume or imagine that authors will be able to promote causation in wide boundaries making products useful and safe for human stakeholders, unless good Design is applied. We must consider that functions can turn into obstacles when artificial systems are beyond the designed boundaries, and this may happen often because real world is increasingly becoming unpredictable, even nature is often responding to our experiments actively and generates disasters that are increasingly unpredictable.

But still some educational systems may not recognize what we miss. As another example, Drawing for engineers is often so specialized that no mention is made to for example Leonardo da Vinci, or Duhrer and others. We may miss again a lot. Students pass it, as a software course; teaching of Drawing is limited to a set of industrial specific rules or norms, described as Graphic Expression and practical applications of Computer Aided Design systems. Drawing as a lifelong education would perhaps be reduced to learn how to use of upgrades of version “n” to “(n+1)”.

3. Intelligent societies and Engineering Education

3.1 Economical Politics and Innovation Dynamics: Society and Engineering. A vision using Kondratiev’s cycles

The study of Long cycles in Economy [Nefiodow 2001] is a methodology that clarifies links between Macro and Micro Economy. Macro and Micro generally are extremely useful to describe short and long term scenarios: a traditional duality that makes understanding of real world economy extremely difficult; cycles and change impact economy and social sciences in general. Engineering and society mutual vision followed these changes. The Structural forces for change and Design had always a mutually positive cooperation. When combining International Political Economy, Technological Innovation, and the vision using Kondratiev’s cycles we can see how our recent history and society changed. Recent historical periods we may use to classify a kind of political and economical dominance are four (in italics), and technological or economical cycles described are five plus the new that we may not discover yet:

- *Period 1. Pax Britannica:*
- Steam-powered machines and cotton (1800-50)
- Steel and railways (1850-1900)
- *Period 2. WWI and II, and transition to a new dominant state:*
- Electrical and chemical technologies (1900-50)
- *Period 3. US dominance:*
- Petrochemical and automobile technologies (1950-90)
- Information Technologies (1990-20xx)
- *Period 4. Disequilibrium until a new dominant power may emerge:*
- Sixth Kondratiev (20xx-...)

Three of the more recent groups of the previously listed Kondratiev periods use enormous quantities of Energy and Materials; during first periods production of goods was dominated by the industrial or manufacturing plant beginning in Period 1. Energy and materials availability made possible new categories of products. Textile, coal, steel manufacturing and construction, machinery is each one a name of sectors that made possible a massive transition of human, material and capital resources from agriculture to industry. The industrial plant was the focal and dominant point; most of organizational culture of industry was also dominant and adopted by public administrations, hospitals, banking sectors...: hierarchical organization, specialization, mass-production or processes remain unchanged. Design too responded and made contributions to these models. During Period 2 on a similar way, chemicals, electrical equipment, petroleum and petrochemicals used a similar model. Their success again was the base for the future evolutions and disruptions. The use of authority or power in the first five Kondratiev cycles, was determined by hierarchy, the main organizational objective was to maximize the output, material oriented, money and status achieved big importance, management concern were financial results and workers were marked as being "under"; educational career was concentrated in pre-professional stages. The dominant and the dominated conflict made possible that the "dominated" of the developed world could enjoy improved living conditions. This evolution made possible an extraordinary growth of Big Manufacturing Corporations and afterwards of Big Service Corporations. All Big Corporations priority is the management of "information and financial markets". Crisis and increased potential and requirements made possible the creation of a "service economy" where creating and communicating "concepts" or "ideas" gained importance; manufacturing of goods was stepped to a second level and globalization makes possible bigger distance relations.

Again design and designers did and do important contributions. Information can also be use to alienate, but as previously the contradictions will turn probably the situation to a new society; this society finally will need compromise, sharing values and decisions, loyalty, motivation, competences, and life-long education. Team work or group work where Knowledge is treated as an important asset must be used as we do in our Chemical Engineering Projects courses. Any degree of said "knowledge" as any ideal representations have limits, our position in this networked world is by far much more complex. Intelligent person may tell that a person is"knowledge"-able person; but too often we ask ourselves why an "intelligent person or society" can be so stupid. As we evaluate the concept of "Intelligent society", we see there a concept that includes success and failure. Stupid societies use existing beliefs, ways of conflict solving, evaluation systems and living styles to diminish private intelligence possibilities [Marina 2006]. It is visible through the history of Design, how the contributions of Design and Designers have accelerated the pace of change, altered living styles, improved the quality standards of society and increased the intelligence of society and individuals.

3.2 Using human skills for the new revolutions: information and intelligent society

We may use well a lot of complexity but we may lack of impetus (using concepts from [Bacehlard 1970]. Impetus is human's driving force. Real "success" is made of inventing ends or purpose and of achievements [Marina 2004]. We often concentrate only on the second part as it is simpler to measure;

our organization of the civil society is based on putting limits to the number or kind of persons that may contribute in the first. We need intelligent persons for intelligent societies.

Human beings develop thanks to all of its experiences. In spite of that, our educational system has a tendency towards specialization as we said before; we may also use a quote from the Bauhaus movement as the author proclaims [Moholy 1997] : future needs the entire or integral human. What is really revolutionary is the right of every individual to enjoy a satisfactory activity fulfilling its innermost needs, providing a good life balance, and freeing vital energy. Designers use the entire and integral human activity as Engineers can also develop for themselves. Following [Moholy 1997], the author stated that the designer must act and think according to their time, using the great potential of the individuals. They also insist that "science, art, economy, technical knowledge, educational methods and their integration should be constantly clarified inside society". The best "clarification" is creating environments that let persons drive in this direction. A new challenge is now visible; complex, recent phenomena contributed to a growing number of scenarios where causation drives human: extreme conditions when environments break down. We never considered kinds of constraints being so different from those applied satisfactorily in original designs; we see that traditional boundaries of existing solutions must be revised. The importance of Design is obvious.

One of my greatest satisfactions has been meeting and discussing with senior Engineers proficient in Philosophy, Art, Economy, Politics, as well as in Technology; as one of these persons says: Culture is too important to leave it to cultural specialists. We may also add that the engineering profession is too important to leave it only to overspecialized engineers or managers; engineers have been able to organize and give the required kind of impetus to top-management teams. Successful designers are open-minded professionals. Both deliver actions that exert a deep impact in our society. Most of these persons that altered human and social artifacts increased our common cultural capital integrating both: successful achievements and ends. Students deserve having the opportunity of access to the kind of capabilities that gives the chance that "normal persons" grow to "extraordinary" persons.

4. Research and Findings.

Groups of students of Chemical Engineering of the Engineers' School of Barcelona are alumni of the Project Engineering classes. After theory and comprehension of previous concepts and values, they must continuously work during a semester five exercises that finalize with an oral and poster presentation. Teams are formed by 3-5 members choosing a topic preferably other than Chemical Engineering Plant Design; they are allowed to study social, humanitarian, and political based topics and must develop practical Design, Engineering and Project Management skills.

Students are encouraged to look at the complexity of problems, unmask simplicity while they work in teams that interact or share information. Students' assignment begins with the conflict description and particular or proposed solutions, alternative proposal/analysis/recommendation, stakeholders' analysis, criteria, requirements, constraints analysis, etc. All systems proposed must consider legal, social, economic, environmental, aesthetic, etc. or other relevant topics; imaginative proposals and communication of solutions are valued for grading. Their activity goes through an initial "fluid state" where texts, interviews, or data finding is a main part of the process. In the early stages, no solution must be "frozen" and errors or mistakes are appreciated. Kick-off of a final plan or proposal is only accepted when sufficient activity has been concocted outside the specialized boundaries of Chemical Engineering and hard sciences.

Recent cases studied are:

- A set of wireless kiosks combining the proximity of the kiosk sellers and the interaction of IT's,
- The strategic plan of an environmentally sensitive area
- A plan for drinking water supply in arsenic polluted areas due to volcano activity
- Instruments for safer car driving
- Intelligent fibers used as part of a warning system of health problems, etc.

Their proficiency in chemistry, electronics, control science, materials engineering, etc. combined with field research and analysis, made them suggest imaginative solutions that may be used as a base to define possible innovations. Most of suggestions refer to new material properties or processes oriented to face problems that otherwise would never be defined as they combine multi-disciplinary hard and soft-sciences, a common activity for Designers, made in this case by future Chemical Engineers.

5. Conclusions

New technological, political and economical cycles will ask for the participation or contribution of Design. Complexity of artificial systems is accompanied by complexity in human systems, and impulse is essential to unmask simple and genial solutions that Designers can promote.

Engineering education still follows traditions that are close to last century cycles, reflecting the importance of the human structure created in a kind of society that is in constant evolution; this generates also a tension as it was generated in the social and economic conflicts of the past.

Design is a door open to access into Philosophy, History, Art, Economy, Politics and Technology that can help develop the extraordinary and intelligent persons we need for the new Information Technology cycles. Opening ways to analyze this discourse can avoid missing many things that we must not let run away; this is the subject of future research with a comparison on different educational models. Overspecializing will probably be corrected thanks to the need of adaptation of individual persons to the evolution of human society and its artifacts.

Design will be a good mirror for the actors involved in society; it will show the different transitions and facilitate the impetus required under these transitions to intelligent Engineering professionals that may understand our need of an intelligent society that in future would solve real human problems.

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