ENGINEERING EDUCATION: CRADLE OR GRAVE FOR CONCEPTION PROCESSES OF SUSTAINABILITY?

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Abstract. Engineers are expected to be the players that synthesize the conceptions and projects coming from diverse fields of social knowledge in order to materialize devices and establish productive processes and organization. This way they are historically professionals that, at the end, transform Nature landscape. These last years, mainly after Rio 92 international event and ISO 14.000 series, however, have been times for new engineering performance. In the last centuries the engineering steps of conception, project, prototyping and production management upon a rationality based on scientific knowledge, were oriented mainly by perspectives such as cost-benefits and effectiveness. This social and technical rule has been under deep revision. It comes to be common sense that methodologies used by engineers for creation must now incorporate issues related to sustainability point of view. And also that companies, where engineering does live, are no longer insulated self-ruled environments, but ought to be beings interconnected to others entities, under ecosystem responsibility parameters. However, how to migrate from common sense arguments to engineering education? As the majority of products, processes and companies that will dominate the next decade landscape is still to be created and the engineers are expected to make them feasible, education may be the cradle for the new conceptions demanded by society or the grave for most expectations. How to translate sustainability concept to product attributes or process parameters demanded by engineering standards and technical and legal procedures? Two interconnected experiences are presented and analyzed in this paper to discuss these main questions. The first one is a recent empirical observation of engineering strategy and work in some Germany companies and research institutions. The second one are some academic initiatives to introduce life cycle assessment attributes in traditional project methodology, and industrial ecology in process analysis as an exercise of changing rationality for engineers

Keywords*: engineering education, sustainable thinking, life cycle assessment, cleaner production, green design.*

1. INTRODUCTION

The space can be conceived as a collection of systems of objects and actions that cannot be dissociate (SANTOS, 2006). As there are natural and human objects and actions, men can transform and produce space by means of technique. In this conception, each human individual or group interferes in Nature and produces space. This is as old as human existence and as extensive as the man power to work on natural phenomena along his history. The space-time human beings live in modern times is much more a human made space, than a Nature landscape, given the predominance of human processes over natural ones. This scale of action is supported by knowledge and was conduct by ideology. The knowledge was embedded in rationalism-positivism paradigm and the ideology was based on narcissism and consumerism.

In this long historical process, Engineers are expected to be the players that synthesize the conceptions and projects coming from diverse fields of social knowledge in order to materialize devices and establish productive processes and organization. This way they are historically professionals that, at the end, transform Nature landscape.

Engineering conquers are the highest level of positivist rationality in essence and in scale, dominating Nature powers and creating means of production that could free mankind of brute labor.

The global production and commerce structures take this ideal and *modus operandi* through all geographic and social frontiers, worldwide.

Recently or lately, depending on critical point of view, this rationality and production system is facing more general criticism. Beyond the processes that disseminate and deepen social welfare inequalities, there are acute environmental misbalances too much evident to be ignored.

The concern about the future under the menace of finite and ending resources used freely give birth to sustainability concept. Perhaps the most well recognized landmark for sustainability is the Brundtland report in 1987 (WCED, 1987). The perspective of social, economical and environmental representation of the reality and the emerging problems called triple bottom line basis is something frequently improperly evaluated.

The superficial or ingenuous preliminary analysis of the problem can label it as marketing theme or even as a new management approach for the old same problems, but this reductionism is being

over helmed by the risk perception of ordinary people. Green concerns could be thought some decades ago as something merely ideological and restricted to radical initiatives, but green design translate such a sound materiality that cannot be a challenge rejected by the world of Engineering.

2. PARADIGMATIC CONSIDERATIONS

The paradigmatic representation of Science revolutions proposed by Kuhn (Kuhn, 1962) if adopted, would lead to interpret the problematic of sustainability and green concerns-solutions, not only as a methodological challenge, but as entire new paradigm construction demand.

Design is a very complex activity and, perhaps, one of the best natural fields to identify engineers playing their genuine skills. There is an ancient educational tradition since Descartes (Descartes, 1637) of how to prepare the youth to achieve proficiency in this multidisciplinary task, based on solid scientific modeling of phenomena using physical conceptions and mathematical language. However, how to conciliate a design based on new paradigmatic nature with an education focused in methods that emerge from a different and almost opposing former paradigm?

Education has been used, historically, as a technique to perpetuate the values and the social ideals conceived and used by older generations in the new ones, somehow, strengthening a belonging bound among them, inside family, company, religion, policy, nationality, ethnic and other social institutions and systems. The sense and the need of preservation since ancient times have, not only transmitted techniques of production, but obliged, in many cases, the newer generations to use them.

However, social live admits no stagnation and the education of young citizens, in the end, just perpetuates an endless change. The superposition of former and new conceptions and approaches to life complexity includes the whole of diverse Sciences produced or the diverse paradigm of sciences.

The tension between old and new elements can be observed in all common live events, but constitutes a social crisis when collective survival is involved. The common sense of preservation is struggling against unsustainable future perspectives since the end of the last century. This concern vitalizes the contradictory between an economical and a social hierarchy to organize Society (Munda, 2008). The environmental consequences of each model delimitates timing and legitimacy for demanded decisions.

It seems to be that the conception of production, effectiveness and design based on economic parameters ought not to be in eternal belligerency with social or environmental reality, but there is actually no philosophical, economical or political strong model to materialize this balance in practice.

Using paradigmatic considerations it could be said that humankind needs a new ontology to depict reality. Besides this, the rationality of strict quantitative accounting, that has already demonstrated to be inadequate to overcome social problems, it is even more fragile to deal with social and environmental coupled questions. This represents a typical epistemological problem, still unsolved.

3. INITIATIVES TOWARDS SUSTAINABILITY

It is unsound to conceive Education or any other social institution based only on methodological guidelines apart from ontological and epistemological fundamentals, as they are undeniably bounded. However, as the temptation to solve important problems quickly is very strong, it is not uncommon to find proposals to reform traditional institutions and processes concentrating efforts in method conception, believing just in changing methods. Conversely, there are initiatives to improve processes and reform organizations and operations management committed with sustainability consistently conceived.

3.1. Life Cycle Assessment in Automotive German Industries: Some Remarkable Impressions

In 2006 one of the authors visited officially two automotive companies, one technologic university and three research institutes involved in cooperative researches in Germany. The visits have placed inside PROBAL- Program of Cooperation Brazil-Germany e were part of a research project. The project involved, in Brazilian side, two federal institutions of superior education with experienced research teams and, in German side, the net of institutions already listed.

The general purpose was to investigate how automotive companies with plants both in Brazil and Germany communicate with stakeholders and the great society concerning demands for sustainability and, particularly, the use of sustainability reports (Nunes et. Al., 2008). The research in the companies takes the indicators of sustainability provided by the Global Compact and the Global Report Initiative Guidelines (GRI, 2009) as assessment reference. The objective was to identify interesting aspects for further data collecting accordingly the framework of the project. A special attention was reserved for the nature of interaction among productive sector agents and R&D institutions the project was dealing with. The interests in R&D institutions were more comprehensive, as beside information about interaction with automotive and other sectors companies, academic aspects regarding the knowledge production management were also observed.

Among several practical initiatives relative to sustainability concept development and respective consequences in visited companies, the most remarkable process was the way they manage to work as partners to develop alternative fuels production from biomass wastes coming from diverse sources.

The companies visited used intensively Life Cycle Assessment - LCA in all projects of products and production processes. The cleaner production concept is very easily identified and is developed and employed using LCA support. It was highlighted in a technical session dedicated to "Comparative Life-Cycle Assessment of Sun Diesel and Conventional Diesel Fuel", focused on CO_2 emission reduction, in full compliance with DIN EM ISO 14040. The two companies worked together in pursuit of promoting synthetic fuels created from biomass.

Other important work observed used LCA to deal with the end of life of automobiles in Europe produced by one of the companies.

The R&D institutes visited integrated a network in with pilot-plants served to biomass studies, including that originated from organic waste, to produce alternative fuels among other products. The ongoing researches observed are conduct under multi and interdisciplinary perspective, but, also are very well articulated with teaching and consulting activities tuned with enterprise efforts.

In the center of this whole development, is the strategic diffusion of LCA thought, per passing the local level and in fine synchrony with Euro community networks dedicated to relationship and cooperation, including actions in other continents, as was the present case.

A contrasting situation occurred with Brazilian subsidiary companies, as it was, beyond all means, unachievable to reproduce the same research framework used in German holdings. The access to Brazilian plants was never formally denied, but actually never happened.

Adopting some expressions coined by contemporaneous authors like Anthony Guiddens, Ulrich Beck and Scott Lash (Guiddens et al., 1995), it was evident that, in times of *reflexive modernity*, threatened by new types of risks and problems that affect confidence and safety in professional playing of engineering, beside worldwide scarcity of existing natural resources, the Society is demands a *new engineering performance*. Germany is clearly ahead in this challenge, in the way as it deals with subjects and questions concerned to the sustainability paradigm and how to manage and integrate scientific and technological knowledge to develop demanded solutions. There is a fundamental strategy being systematically conceived and implemented based on educational systems.

3.2. Sustainable Thinking Network in Engineering Research and Education

Paradigms can be used, accordingly to Kuhn (Kuhn, 1962), to understand the pathway through which Science is built, but, nowadays, it seems to be something more to be projected and executed, like a social conception prepared with foresight. For the authors, along the last five years of observations and reflections, it is clear that sustainable demands transcend mere methodological frontiers and this fact determines a new paradigm construction, as it is not still available (Munda, 2008).

The most visible piece of this ongoing construction is the emergence of a new conception for production and project organization, taking into account a set of values and an ontology quite different form those used by engineers, currently.

This can be observed and confirmed in practice; wherever social systems are pressing structures and agents to change their common doing, in attention to Nature and Society concerns. In the case, for instance, of automotive German companies, it can be outlined a complete reorganization of design steps and process decisions to incorporate sustainability issues.

What is changing? To begin, the project solutions observed are mandatory dependent of the environmental consequences of materials and production processes chosen. Some new facilities are being built up under the same rules.

What is the great challenge? With which theoretical basis, with which valid methodology and upon which material data should such decisions be taken?

Meanwhile ontology and epistemology are rebuilt, in methodological terms; Life Cycle Assessment emerges as leader accounting technique with large acceptance among official and private organizations.

LCA, however, cannot work without national and even worldwide inventory, in one end, and, in the other end, make it urgent to assess social, economical and environmental consequences altogether. These processes are not local, neither can be thought inside one single company, the biggest it can be, but must be taken in a global perspective. The supply chains, the production chains, the environment and all necessary data are almost ever global.

3.3 Network Perspective

The social solution adopted to deal with this huge and complex modeling task is networking, global ruling and cooperation, and international common data validation.

For something like sustainability, that is intrinsically complex and has not yet any consolidate nor accepted theory ground, organized Society demands, at least, transparency of discussions and, in some manner, GRI –Global Report

Initiative – "a multistakeholder governed institution collaborating to provide the global standards in sustainability reporting" (GRI, 2009) - is playing this hole for a large number of social agents. GRI methodology refers do LCA for detailed accounting purposes.

These initiatives, which are far away from a satisfactory elaboration level, are supported by and interconnected to research centers and government plans in a network conception. Engineers are, in many circumstances, ahead of this social movement, but are not alone.

This is a recent social process which has no clear leadership established and can be accomplished in time by other countries and companies around the world. Local phenomena, otherwise, are dominant in sustainability discussion and in global accounting. This central question determines, in the first step, the need for local data collecting, local modeling and local methodological development. The next step is to connect local and global models and data. This scenario is really an open border for scientific and technological knowledge production, as well as, social self-organization and business.

3.4. A Network Project

Some organizations and companies in Brazil, native or stranger, are already engaged in sustainability thinking initiatives and manage to produce GRI reports or LCA of processes and products following ISO 14.04x standards. Some of them take these initiatives merely under international governance guidelines.

In this context the authors have being working to tailor a net of players, involving master and undergraduate engineering students as well as researches and professors of partner institutions in Brazil and in Germany.

In Fig. 1 there is a static representation of the dynamic network structure conceived and actually alive.

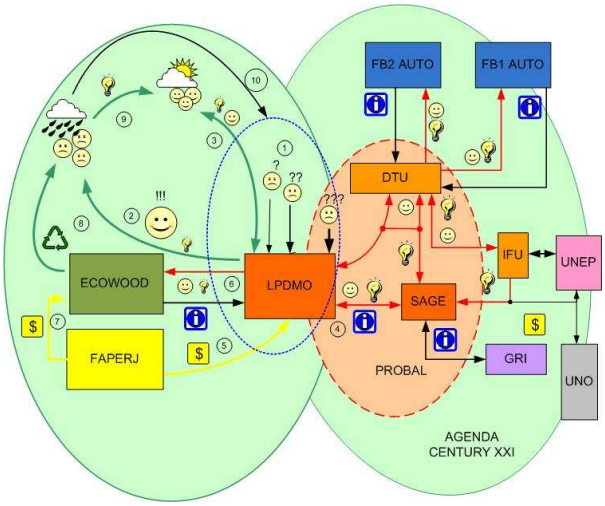

Figure 1 Network for Sustainable Thinking conceived around CEFET/RJ-LPDMO

Some conventions must be previously introduced. Institutional agents are geometric forms (rectangles), the spaces of actions are inscribed in ellipses, and human agents are yellow faces: Smiling faced actors are the ones somehow in touch with sustainable thinking, the sadly ones, are just worried about it, or under negative environmental or social impacts (under dark rain). Interrogation and exclamation points signalize questioning or affirmative action. UNO is the UNITED NATIONS ORGANIZATION and UNEP is UNITED NATIONS ENVIRONMENTAL PROGRAM. LPDMO is Laboratory for Research and Development of Models, in CEFET/RJ, a technological university in Rio de Janeiro. SAGE is a research laboratory for Advanced Management Systems in UFRJ, a traditional federal university in Rio de Janeiro. FAPERJ is an official local sponsoring agency. DTU is Darmstadt Technologische Universität, a technologic university in Germany. PROBRAL (CAPES-DAAD) is an official interchange project between Brazil and Germany. ECOWOOD is a private company producing "plastic wood" made from industrial wastes, located in Rio de Janeiro. IFU is the Institut für Umweltinformatik, a private institute that is developer and owner of UMBERTO software. GRI is Global Report Initiative. FB1 and FB2 are two automotive German companies. Yellow lamps mean scientific or technological expertise or innovation flowing. Money and Information flows are represented traditionally. Green shadowed areas are the influenced by the initiative under discussion, around LPDMO and AGENDA FOR CENTURY XXI. Orange painted areas are knowledge resources in partnership with LPDMO. The dashed perimeters indicate academic extensions. The blue dashed one is mapping LPDMO initiatives and the red dashed line maps PROBRAL influence area.

There are 10 ball-marks and several flows indicated in the diagram by means of colored arrows. The red lines are used for academic or scientific flows, the black lines indicates information or demands from external agents to

academic agents. The yellow line is used for direct funding flows and the green lines, for actions impacting positively environment or Society. The arrow top types indicate orientations: unidirectional or bidirectional flow.

The former research steps (mark 1) aimed performance evaluation in a broad sense, covering engineering education, in one side, and management of engineering processes in so called productive organizations, in the other. The question, to make it short, was - how to mediate subjectivity and objectivity in daily reality of engineers and theirs Professors, in order to deal with complex times, processes and organizations, when engineering education, traditionally, remains in Positivism scientific paradigm? The backstage of it were contemporary social demands that highlight the triple bottom line conception of sustainability. Integration of management standards and processes for environmental, social and economical aspects, as well as professional education of agents, to deal with it, were the theme for Master thesis and articles inside de research group (mark 2). AGENDA FOR CENTURY XXI and MILENIUM PROJECT from UNO were always embedded and used as horizon guidelines for researching and discussion with students and colleagues, besides other external agents (mark 3).

The next step (mark 4) was to search others interested groups and interplay in sustainable thinking. The UFRJ-SAGE and DTU partnership in PROBRAL context was the material result of interchange efforts. The IFU associated with UNO – UNEP gave LPMDO a free research UMBERTO license for the first year and this make it possible to explore initially LCA technique. The first Master thesis dealing with local plastic bags production with recycled material, and some academic papers were soon produced. This work involved a private company in Rio de Janeiro and made it clear, the importance of accessible empirical environment to reach valid results. (mark 2)

The next step was to introduce formal lectures about ST and LCA imbedded in ISO standards for master degree students and also the same theme for undergraduate students individually involved with introductory scientific work. Further, (mark 5) with several works ongoing and other candidate students, the group applied to FAPERJ and obtained funding for software and hardware acquisition to improve LPDMO. There were, also, resources (6) for field researching and the need of a formal partnership with a private local company. ECOWOOD (mark 6) was contacted and became a strong ring of the network agents' chain. ECOWOOD shares technical information with LPDMO and receives scientific support for innovation and funding (mark 7). This relation provides LPDMO the empirical laboratory for researching and developing best green products and processes (mark 8). Each player inside green ellipse experiences sustainable thinking accordingly his (her) own levels of interest and maturity. The intentional diversity of the cast of players is interesting, embracing, now, since young engineering students of the first two years of graduation course up to master degree students and senior researchers. The opportunities to study and research are sponsored by networking, common facilities and accessible software and knowledge. Formal disciplines for engineering graduation and master degree students give pedagogical guidelines and theoretical fundamentals for academic purposes. The field work started with a plastic bag company, then involved ECOWOOD and now includes other companies that connect themselves to LPDMO through their professionals officially sent or self-interested to become Master students.

4. RESULTS

There are several institutional significant results, as there is now a visible network alive, where there was nothing before. Institutional partnerships and technical engineering knowledge produced and transferred to productive companies are desired and socially relevant results, too.

The firm ECOWOOD is under deep reorganization and this has much to do with open-minded dialogue with academic partners and a new overview of itself and of the market influenced buy a sustainable thinking exercise. The product *ecowood* probably will materialize sustainable concepts in a very concrete and practical sense very soon.

But, besides organized resources, layouts and other touchable indispensable elements, there is something essentially important for sustainable thinking: doubt and curiosity! The young engineering students now inscribed in LCA graduation discipline as well as first semester students group, with no contact to them, answered of free will and recently a short inquiry. They were asked if they knew the term sustainability, if they could give some short explanation about it , if they could foresee any bound between their future professional practice and sustainability and, at last, which kind of contribution, if any, could their engineering education course give them, to accomplish, in the future, a professional conduct oriented according sustainable thinking. The youngest group of 15 students unanimously declared to have heard something about sustainability and among them, some managed to clearly explain it. The correlations with professional practice were, as expected, superficial and vague. The discourses focused social responsibility concerned to individual behavior, much more than to professional playing. They seemed to be prepared to answer what and why, but they could not see and say how. The other group of students, in which many are already trainees or practicing students in engineering companies, produced quit different speeches. It is remarkable for some of them the absence of any solid fundamental beneath some marketing campaigns of companies and organizations that self-claim to be sustainable or worried about it. They also question how to couple traditional project methodologies they are currently learning and being trained to, with LCA conception. Other future engineers find it comfortable, as something natural and next to other familiar tools, to project process flowcharts using Petri nets, onboard UMBERTO. This second group is deeply interested in how to use LCA to practical situations at the reach of the arm.

The other students, especially Master degree ones, can be grouped in levels of interest. Some research process mapping oriented to ST and uses LCA and UMBERTO as technique and tool, correspondingly. Others, somehow, deal with the challenging question of process/product project and management using integrated environmental, social and economical concerns. Many of them work on real processes and projects that belong to their own daily professional space. They are producing new technical and professional relations in these places.

What can be expected in the next years from this social-technical network? At least, it is most wanted a feasible dialogue between traditional engineering education and sustainable concerned education, in terms of practical project and conception methodologies. The natural and continuous current development of LCA, standards and governmental politics and rules will change rapidly the professional environmental for just graduated engineers in the next years, and in two years, many of our students will be, somehow, aware of it. The can, however, be more than capable professionals, and play leader holes in life-cycle oriented engineering projects and processes, as could be observed in some Germany automotive companies.

5. FINAL COMMENTS

The social-technical movement observed in Germany towards sustainability was briefly related, and a strategic network conception was spotted. This empirical experience altogether with local conditions and values owned to Brazilian research teams gave rise to a network conception and implementation. This complex and multiplayer living experience was related and although recently born, seems to be promising.

Networking demands partners, funding, language, ideology, direction, guidance and time! So does the paradigmatic construction claimed in this article. For this commitment, Education is the central question. The fundamental thought that a new paradigm must be constructed to support all current methodological efforts to develop cleaner production and greener products, cannot exist without the essential contribution of education.

Engineering and Engineers education can be the cradle for the sustainable conceptions the society is immediately demanding, but can be also the grave of all hopes.

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7. REFERENCES

Anthony Giddens; Ulrich Beck; Scott Lash. São Paulo: Editora Universidade Estadual Paulista, 1997.

Beck, Ulrich et al. Modernização reflexiva: política, tradição e estética na ordem social moderna.

Descartes, R. Discourse on the Method ("Discours de la Methode"). An introduction to Dioptrique, Des Météores and La Géométrie, 1637. France.

GRI (Global Reporting Initiative). Sustainability Reporting Guidelines 2006. Available from: http://www.globalreporting.org/NR/rdonlyres/812DB764-D217-4CE8-B4DE-15F790EE2BF3/0/G3_ GuidelinesPTG.pdf. Access on 30 May 2009.

Guiddens, A. A Construção da Sociedade. São Paulo. Martins Fontes, 1989.

ISO 14040 (2006): Environmental management - Life cycle assessment -Principles and framework, International Organisation for Standardisation (ISO), Geneve

Kuhn, T.S. The Structure of Scientific Revolutions. Chicago: University of Chicago Press, 1962.

Munda, G. Social Multi-Criteria Evaluation for a Sustainable Economy, Springer, 2008.

Nunes, K.R.A.; Valle, R.; Peixoto, J.; Hartard, S. Sustainability benchmarking in Brazil and Germany: Study case of the Automotive Industry. In: Proceedings of GBID (Conference of Global Business Innovation and Development), Rio de Janeiro, Brazil, January 16 -19 2008.

Santos, M. A Natureza do Espaço. 4ª edição. São Paulo: Editora da Universidade de São Paulo, 2006. WCED -World Commission on Environment and Development, 1987. Published as Annex to General Assembly document A/42/427.

UNGC (United Nations Global Compact). About Us: The Ten Principles. Availablefrom:http://www.unglobalcompact.org/AbouttheGC/TheTENPrinciples/index.html. Access on 30 May 2009.

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