Design and Production Engineering. Some moving frontiers of the engineering education in Brazil

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Abstract – **In this article we present an experience integrating design, production engineering and projects of social interest. Between design and production engineering there is an important overlapping zone with relevant implications for the education of engineers. That zone consists of teaching activities, university research and extension programs. We have analyzed the recent experience of the Production Engineering Program (COPPE/UFRJ), in its Master's and Doctorate courses as well as in the development of projects of social interest. This experience points to a promising partnership both in an intra-university level (with the Department of Industrial Design of the Fine Arts School in UFRJ) and in an extra-university level (with stakeholders involved in projects of local and community development). Our focus is on learning processes developed in the experience. We claim that design is a critical element in pedagogic mediation for it assists problem solving and it allows synthesized recognition of solution characteristics and properties. Drawing is for design teaching as the alphabet is for reading. Both are intellectual technologies that underlie possibilities of intervention in reality by instrumental technologies.**

Index Terms – Design and Production Engineering; Engineering Education in Brazil

ENGINEERING: DESIGN UNDER CONSTRAINT

A recent important study of the National Academy of Engineering in the United States of America recognizes that engineering is, since its origins, a "profoundly creative process", and suggests a very provocative definition: "a most elegant description is that engineering is about design under constraint" [1].

This definition advances a significant connection in the practices of engineers and designers, which is possibly the core aspect of any education intended to correspond to the one proposed by the National Academy of Engineering: "the engineer designs devices, components, subsystems, and systems" [1]. That is to say, there should be a significant overlapping zone between education processes of both engineers and designers. One positive consequence, at least, from that proposition is that there is ground for a fertile interdisciplinary interaction.

According to the study of the National Academy of Engineering, the activity of an engineer is directed to the creation of "a successful design" [1]. Concerning the meaning of this success, the study provides important indications: "in the sense that it leads directly or indirectly to an improvement in our quality of life and must work within the constraints provided by technical, economic, business, political, social, and ethical issues" [1].

Exploring the overlapping zone between the education processes of engineers and designers, we observe more than the enlargement of the technical education *stricto sensu*. Educating in this zone is not reduced to the incorporation of a bunch of technical skills (though, of course, they are relevant). This zone of interface provides the future engineer with a broader capacity of problem solving as they learn to autonomously identify, formulate and structure problems.

In this article, we focus on the meaning of this interface between engineering and design for education and we analyse a Brazilian empirical case, in which that interface is explored with emphasis on problems and topics of social interest.

Our perspective brings up to date some provocative ideas from a classical work by the Brazilian anthropologist Gilberto Freyre [2], who lists different types of engineering and gives priority to social engineering, which "... is concerned more with the creation of new ways and styles of social living than with the adaptation of a social group behaviour to pre-defined norms of social living" [2] (original Portuguese text: *"preocupa-se mais com a criação de novas formas e novos estilos de convivência social do que com a adaptação do comportamento de um grupo social a normas pré-fabricadas de convivência")*. Similar to what occurs to the other types of engineering, [2] claims that every social engineering project starts with a problem.

In this article we would like to highlight the possible importance of what we call *social interest design* (that could be identified as a work field of social engineering, as conceived by [2] in the education process of engineers in the contemporary world.

The study of the National Academy of Engineering denies that engineering is only about applied science and states that "technology is the outcome of engineering; it is rare that science translates directly to technology, just as it is not true that engineering is just applied science" [1]. It is clear that

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some components and processes are characteristic of engineering and technology.

What is critical in contemporary world, however, is that innovations "are occurring at an astonishing pace, especially those in information and communications technology, which are most apparent to the public, and this has important implications for engineering practice and engineering education in the future." [1].

Our text is intended to indicate innovative possibilities in the engineers' education process. We understand that the interface engineering/design, (and more specifically production engineering/*social interest design*) opens those possibilities. Design enables the actualisation of ideas, making them concretely available in their diverse possibilities. Social interest in turn concerns the inter-human space, where there are asymmetric reciprocities determined by will, knowledge and power. That evokes the relational nature of human condition, which is not only technically but also, and mainly, ethically shaped [3].

The recommendations of the National Academy of Engineering are that "technical excellence is *the* essential attribute of engineering graduates, but those graduates should also possess team, communication, ethical reasoning, and societal and global contextual analysis skills as well as understand work strategies" [4].

Thus the study of the National Academy of Engineering aims at "reengineering" the engineering education system, but without losing "the essence of engineering: the iterative process of designing, predicting performance, building, and testing", which "should be taught from the earliest stages of the curriculum, including the first year" [4].

Our perspective is in agreement with those recommendations so that "the engineering education establishment should strengthen the ties binding engineering education to practice not only through curricular design and provision of co-curricular activities, but through the experiences of engineering faculty in industrial research, product design, and/or production" [5].

We argue that *social interest design* is a fertile field for the integration of pedagogic experiences of designers and engineers' education processes. The Brazilian case presented corroborates that view: the academic cooperation between the Program of Production Engineering of COPPE/UFRJ and the Department of Industrial Design of the Fine Arts of UFRJ with initiatives in teaching, research and extension.

SOCIAL INTEREST DESIGN: A POSSIBLE INTERFACE BETWEEN PRODUCTION ENGINEERING AND INDUSTRIAL DESIGN

In a special edition of the *Journal of Design Research* the professor of the Engineering School of MIT, Louis Bucciarelli, claims that the issue of *design as a social process* should be approached with special emphasis on how social values and norms have consequences in choices and specifications of product form and functioning [6]. Our proposal of a *social interest design* seems to be in agreement with Bucciarelli's approach.

The *social interest design* is linked to an ethical commitment and a cognitive intention: a situated practice of design and the rooting of the different kinds of knowledge in their *original symbolic sites*, both converging on the consolidation and enlargement of the cultural and relational human heritage [7 - 8].

The connection of the engineer's education process to the practice of *social interest design* leads to the articulation of various experiences and competences in an intra-university level and in an extra-university level (i.e. between the university and groups of interest). This dialogical opening to other knowledge areas can be significant for the communicative dimension of the engineer's education process, emphasized in the study of the National Academy of Engineering: "a strategy for realigning engineering education must be developed within the contexts of understanding the elements of engineering and recognizing the importance of constant communication with the public and engineering community stakeholders on the goals of education" [5].

The interface *production engineering/social interest design* may contribute to move frontiers of knowledge in contemporary engineering, towards the multiplication of information in systematized fields of knowledge. Besides, it may contribute to redefine *constraints.* That is a strategic question for the pedagogic project of the engineer's education, if we take into account the possibility of learning relations renewing the capacity of dialogue and intervention in reality. This effort may be optimised by a *co-design activity*, similar to what Manzini e Vezzoli suggest [9]. This means the formulation of theoretical frames and a dialogical perspective on research and projects, establishing relational binds between interlocutors; which goes beyond merely instrumental relations with objects of knowledge and experimentation.

The *social interest design* is accomplished in *co-design*, thanks to the fact that designers have their responsibilities based not only on considerations about technique or form, but also, and primarily, on ethical judgements about methodologies [10]. In this perspective, the first thought must be if the projects or products deserve attention. For engineers and designers to be able to make that evaluation, it is essential to include this ability in their education.

However, *social interest design* is still about design. And we believe that *drawing* is a critical element playing an important role in this mediated pedagogic process [11]. In this process, *drawing* has a double role. Firstly it assists in problem structuring through the solutions it brings to light; secondly it allows a concise recognition of the characteristics and properties of a certain solution. Those processes of solution structuring and construction are in a very significant way mediated by the *drawing of sketches* that enable interaction between different stakeholders.

In a research about clothing design, the design of the pilot piece can be understood analogously to Ivan Illich's [12] ideas about the alphabet as an intellectual technology that has its applications optimized by instrumental technologies: parchment, paper and press. In the same way instrumental technologies such as CAD - *computer aided design* - optimise the production of various artifacts [13].

In this analogy, it is important to say that neither press nor CAD promotes or creates the critical rupture; they optimise it. This rupture occurs primarily in the immaterial plan, in the

conception of the text or of the pilot piece; they are immaterial technologies. The interpretation and translation of design into artifacts can be considered implications of the intellectual technology generated in the conception, development and fabrication of the product [13].

In the next section we talk about the empirical case, consequence of the particular cooperation between LTDS - Laboratory of Technology and Social Development (Production Engineering, COPPE/UFRJ) and LIDIS - Interdisciplinary Laboratory of Social Interest Design (Industrial Design, EBA/UFRJ).

A CASE OF COOPERATION BETWEEN ENGINEERING AND DESIGN IN THE FEDERAL UNIVERSITY OF RIO DE JANEIRO

The Graduate Program of Production Engineering (COPPE/UFRJ) is presently organized in three areas or research lines: Management and Innovation (GI); Operational Research (PO); and Evaluation of Industrial and Technological Projects (APIT). GI is the most connected to *design;* it has incorporated the old area of concentration, Product Engineering, in which most of the activities in the interface engineering/design of the graduate program were accomplished since the beginning of the program. GI develops studies related to the processes of innovation, dissemination and implementation of technological changes in several economic sectors (manufacturing and services). The techno-methodological perspective of this area is solidly founded on multidisciplinary approaches. GI curriculum includes the following disciplines: Project, Product and Process Development; Information Engineering; Strategic Studies; Social Initiative Management, etc.

The course of Industrial Design of the Fine Arts School (DI/EBA/UFRJ) sees the professional activity of Industrial Design as the creation, analysis and development of formal concepts of industrial products. According to this conception, the professional works with design methods and specifications that optimise the function, value and appearance of the product, for the mutual benefit of producer and user, and respect for the environment. This course offers two qualifications: Product Project and Visual Programming. Students choose one of them at the moment they enrol in the selective process. The qualification "Product Project" has the objective of providing a solid basic education in the area of Industrial Design, so that students are able to evaluate and define the user/object relations through the mastering of project techniques, bidimensional technical representation, physical model construction and electronic mock-ups, besides the knowledge about industrial processes of fabrication. The qualification "Visual Programming" has the objective of preparing the professional that will work in the following areas: System in Design, Photo Design, Interactive Hypermedia Design and Narrative Illustration.

The laboratories LTDS and LIDIS are developing a tight academic cooperation. This cooperation results in activities of teaching, research and extension, whose main objectives are shortly described below.

The *Creative Communities and Sustainable Lifestyles* (CCSL) project intends to investigate practices of social innovation in communities and their implications for the promotion of sustainable life styles in several contemporary urban contexts. The structure of the project is a collection of case studies, from different contexts. Existent experiences in the European Union are compared with cases in three developing countries (Brazil, India and China). The project is not limited to a simple identification and collection of significant experiences, though. It is aimed at discussing the possibilities and conditions for the implementation of the original formulation in a way that the original experiences be significant in different contexts. Learning with these experiences of social innovation may contribute to the dissemination of sustainable life styles in the contemporary world [14].

The CCSL project was developed by Ezio Manzini from the Polytechnic (Milan) and François Jégou from Strategic Design Scenarios (Brussels). It is an initiative of *Task Force on Sustainable Lifestyles,* linked to multilateral cooperation programs of the United Nations, members of the *10 Year Framework of Programmes on Sustainable Consumption and Production*, commonly known as *Marrakech Process*. In the frameworks of the CCSL project, four similar scenario building exercises are being held in Brazil, China, Europe and India with groups of students from different local design schools.

In Brazil the local partner in the CCSL project is LTDS, which has been working in interaction with LIDIS. An integrated work group was composed of graduating students in Design (DI/EBA), Master's students in Production Engineering (PEP/COPPE) and *stakeholders* from the initiatives considered relevant to the project. Professors from LTDS and LIDIS also participated actively in the CCSL project.

The activities of this work group unfolded in three scenarios with different foci: *food, neighbourhood and co-housing.* The elaboration of these scenarios is based on the composition of a *story board,* with concise text, visual schemes and a panel with photos of a certain initiative, all inserted in a *blog*. For the photographs to be taken, sketches of the most characteristic scenes of each scenario are done. These sketches become a reference for the participants of each scenario to develop their own story board. Sketches play a key role in communicating the most representative ideas of each scenario and in organizing the scenarios. They are essential elements for the integration of the stakeholders participating in the project.

Possible implications of the elaboration of these scenarios:

- Generate initiatives and projects aiming at the development of sustainable products and services, with focus on the local reality.
- Identify the social, interpersonal and human relations, which enable the sustainable solutions.
- Identify conditions that may make the implementation of these initiatives in other sites possible.
- Identify the urgent conditions of these initiatives, in relation to the basic concepts of the CCSL project, which are i. creative communities; ii. sustainable life styles; iii. social innovation.

For the development of creative solutions in the process of scenario-oriented Design, sketches gain the role of a project tool. This role, which is in the origins of Industrial Design

teaching, had lost some space for computer tools of project support, such as CAD (Computer Aided Design). With those computer resources, students resist or have difficulties to express their ideas with sketches. Thus, the methodology proposed by the scenario-oriented Design leads to the return of sketches in the attempt of creative solutions. CAD is a finished tool and its functions are organized in packages that correspond to the project phases and to the project commercial rates. As the development of sustainable solutions is realized in a specific situation, those packages are not useful; it is necessary to visualize the idea in the situation. That is why sketches are such a valuable means of communication: the ability to express ideas through sketches means the possibility of improvising situated responses. We do not mean drawing as an art piece (which would require a higher level of qualification from the designer), but as a means of expression and communication, which implies that the ability of drawing is a requisite almost as universal as the verbal communication. These are the results obtained from the participation of under-graduate students in Design and graduate students in Engineering in the CCSL project:

- a higher capacity of response to the matters of the situation;
- A more skilful creative expression due to the enlargement of communicative resources.

The attachment of LTDS and LIDIS to the CCSL project has implications for the teaching activities in the graduate courses of production engineering (mainly for the Master's course) and also for the design graduating course of EBA. That not only concerns the direct participation of students in work groups such as the one mentioned in this article. It also concerns the internalisation of learning and products from the different phases of the project into disciplines of the curriculum (such as Ergonomics, Product Project, Management and Methods in Design) and the elaboration of final works and Master's dissertations in the thematic areas open by the project.

As a logic result, a new research line is being developed, integrating vertically graduating and graduate activities in the Federal University of Rio de Janeiro in the area of *strategic design, design for sustainability, and design for social innovation, with a focus on scenario building and solution development.*

This initiative is in agreement with the priority given by the Brazilian government to the generation of human resources and the promotion of *design as a strategic sector for the Brazilian development.* That priority is attributed by the agencies of research promotion and support of the Ministry of Education and Ministry of Science and Technology, through their policy on science, technology, innovation and industrial development.

The theoretical-methodological perspective of that research line is according to the ideas of Professor Ezio Manzini from the Polytechnic of Milan, once it assumes that *design strategies address the pressing issue of the culture of consumption and require thinking beyond 'the product'* [15]. At this point it becomes important to consider a number of 'leapfrog' strategies and product-service systems that suggest ways of achieving welfare, which does not necessarily involve material, tangible products. These strategies demand

innovative design thinking with the ability to confront and overcome cultural and economic norms. The exercise of building scenarios and the development of solutions are supported by the images, which play a central role in the interaction of designers, production engineers and other stakeholders. These images usually do not exist and need to be created and developed. In this process design gets pedagogic and communicative relevance by expressing ideas, identifying problems and solutions through graphic representation.

An important consequence of the activities promoted by the partnership between LTDS and LIDIS is the coming of Professor Ezio Manzini to Brazil in the second semester of 2007, sponsored by the School Program of High Studies of the governmental agency Coordination for Improvement of Higher Education Personnel (CAPES) of the Ministry of Education. During his visit, Professor Ezio Manzini will offer a graduate course in PEP-COPPE, open to other Brazilian design and production engineering graduate courses, thanks to resources of distance education mediated by computer.

The course *Design, Social Innovation and Sustainable Development* to be given by Professor Ezio Manzini has two objectives.

- To give the participants the opportunity to have a theoretical and practical insight in the strategic design tools, as they are implied in promoting social innovation in everyday life.
- To increase the participants' capability to recognize promising cases of social innovation and develop enabling solutions in order to enhance these cases and promote their consolidation and dissemination.

The course will have two modules. The first one has a theoretical standpoint and establishes guidelines to identify promising cases of social innovation for sustainable development. The second one focuses on the discussion about some cases gathered by the participants in the meantime between the two modules. The second module aims at formulating intervention projects along the lines of design-oriented scenario building.

The partnership between LTDS and LIDIS also has important consequences in university extension projects, which may use design in popular entrepreneurships. The developed extension projects respond to the demand of the popular entrepreneurs. The actions of the partnership LTDS and LIDIS are founded on the intellectual technology generated in the conception and production of artifacts of different production chains (such as handicraft, clothing manufacture, art, culture and leisure). This intellectual technology exists to support the development of new products, value aggregation to existent products, work and income generation, and the intensification of design use in other popular entrepreneurships.

The activities developed:

- Mapping and classification of popular entrepreneurships in incubators of Rio de Janeiro according to the type of entrepreneurship, business plan and estimated return (income generation and personal satisfaction).
- Organization of Innovation Workshops about the process of artifact development: inspiration sources;

colors and shapes; materials and fabrication processes; finishing; wrapping; representation techniques; work exposition and presentation; product certification and registration.

- Planning, organization and promotion of public events to show the activities developed in these Workshops, in order to stimulate the interaction between them and the community.

These activities of university extension have as main partners the Popular Entrepreneurship Incubator and the Afro-Brazilian Incubator (IA) of the Palmares Institute of Human Development (IPDH). The interaction of the work groups of LTDS and LIDIS with the facilities of IA encompass the following productive chains: commerce and services; clothing manufacture; tourism; handicraft; art and culture; gastronomy; marketing and social service. Another important partnership is with the Incubator of Popular Entrepreneurship (IEP) of the city of Nova Iguaçu, in the metropolitan area of Grande Rio.

The meeting and dialogue with the partners were fundamental to elicit expectations and demands to be considered in the definition of the Innovation Workshops, organized around the following suggested themes: artifact creation and development, inspiration sources, colors and shapes, product and process development, wrappings, visual identification and certification.

The Innovation Workshops have their own dynamic in each productive chain. To understand these activities, field observations are conducted, followed by photograph taking, filming and recorded interviews. The observation of each activity is based on the elaboration of visual schemes. The sketches drawn in A4 paper representing the main points of each entrepreneurship serve as a map to guide the observations of these field activities.

The horizon of expectations open by the extension activities of LTDS and LIDIS is concentrated on the conjoined development of solutions adequate to product presentation; difference making; market expansion; product and work valorisation; and the internalisation of knowledge of design as a strategic element in the incubation of entrepreneurships.

In the extension activities developed by LTDS and LIDIS association, Innovation Workshops are an active exercise of *co-design*. These workshops enhance *situated innovation*, rooted in the popular culture. They also underlie the production of an instructional material that, supported by the communicative resources of *e-learning*, can be additional help in the consolidation, autonomy and auto-organization of a series of entrepreneurships of social interest. In this way they contribute to the situated and sustainable development, following the guidelines in [15].

CONCLUSIONS

In this article we present an experience in engineering teaching, developed in the Federal University of Rio de Janeiro, and interpret it taking as a theoretical reference the framework presented by the National Academy of Engineering of the United States of America, concerning its prospective studies about engineers' education.

Considering the provocative proposition of the study of the National Academy of Engineering that *engineering is about design under constraint,* we sought to highlight the interface between production engineering and design in engineers and designers' education processes. We claim that design plays a pedagogic role (particularly the *sketches*), by allowing the visualization and communicative expression of theoretical propositions. Not intending to transform engineers into designers, our proposal is to make them familiar with the use of this tool as an element of communicative mediation and idea visualization in interactions between different professionals and stakeholders.

We observed that the Design students who participated in the Creative Communities for Life Styles project and who had access to the scenario-based methodology, during the project discipline in the course of Industrial Design in the School of Fine Arts, developed independent and more creative solutions than those who were guided by traditional methodologies of project. We believe that those traditional methodologies ascribe to the teacher a prescriptive role of telling students what they have to do. Conversely, because our methodology is the result of a personal research of each student, it provides him or her with a commitment to the solutions of their project in a way they become responsible for it. Our propositions were corroborated by the students' recent performance in projects of scientific initiation during the school year of 2006/2007.

Finally, the Brazilian case presented illustrated our opinion that the moving frontiers in the engineering education should not only be understood as an expansion of activities under the same fixed constraints. Moving frontiers in the engineering education should mean primarily changes in those constraints.

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