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TEACHING ETHICS IN ENGINEERING AND DESIGN, THE NECESSITY OF CONCURRENT ENGINEERING

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ABSTRACT
Mechatronics engineering is a discipline, which links together three different areas: mechanics, electronics and digital systems. This major, has proven its use in industry, it allows them to have professionals with integral knowledge and an overall notion of the developments of most machines that are working in the industry. Currently any process in a factory or business strives to become automatised and as such, this tendency has come to be widely regarded as the aim of any developing industry today.
Simultaneously, automation could come to be a problem when the engineer masterminding the operation of creating a new system does not have an integral formation with ethics at its core. Raw knowledge and the union of different theories and ideas will not guarantee an efficient and reliable new system for every stakeholder. For this reason it is relevant to create and teach a procedure to design a new methodology constructed on ethics, in order to design products and processes with a social and sustainable vision and, of course, high revenues.
The main goal of pretty much any major is to provide society with the means and tools to improve, to fix and to create. In particular to design from ethics is to incorporate an innovate engineering approach, the designers will realize that as members of a society there is responsibility and thus, they must be instructed and their endeavours must contain a strong set of principles, rights and values that can be support all that implies a society, always considering the actual and future generations, as well as the ecosystem they live in.

Keywords: Design, ethics, eco-design, sustainable

1 INTRODUCTION

The actual world is fully globalised and mostly inhabited by a society which makes profit maximization a priority. According to Goldratt, the goal of any business is to earn an income not only today but to also secure it for the future. The effort and sometimes obsession to boost profits has turned in one of the most significant causes of the recent and very often cases where, due to design flaws, either premeditated or unintentional accidents have damaged end-users and produced large economic losses. This means that economic, political and commercial interests are arguably directly responsible for the release of flawed products.
There are some cases around the world where large car companies have caused fatal injuries, as well as economic losses to the companies themselves, for example when they are forced to do a complete recall of their vehicles to fix the flaws. To name a few of them, Toyota, General Motors and Ford have been involved in this kind of situation [1,2,3]. One of the most dramatic cases, because the flaw happened while being broadcasted in worldwide television, occurred when Space Shuttle Challenger broke apart during operation. The project was launched in spite of the flaw being reported by engineers to program managers at NASA [4]. However, for the program managers it was politically important to continue the space shuttle lift off. The project was a massive failure because of administrative negligence and lack of ethics.
Elsewhere, another example happened in Mexico City when metro line 12 was built. In this case, politicians and contractors put their own interests before the safety of the people. Fortunately, there were no accidents, but additional funding was required to fix faulty railroads and station platforms [5].

Finally, one of the most known and outrageous cases of bad engineering design and manipulation of information was the Ford Pinto case, in which it was evaluated if it was cheaper to pay claims for caused deaths than to change the entire design [6].
The Design and Ethics teachers in Monterrey Institute of Technology and Higher Education, feeling a sense of responsibility towards their students, have taught methodologies to innovate products with higher functionality and lower cost, but they are trained to do so from the point of view of ethics, sustainable development and social development impact. This paper is born from the concern of students of Mechatronics Design course, from August to December 2013, who within their competence for sustainable development adapted agricultural machinery to operate using renewable energy. The optimization of the equipment involved high productivity and quality. These innovations were implemented in the greenhouse of an orphanage, so they could generate their own food at the lowest cost.
Teachers in collaboration with students have developed a simple methodology. It is based on an institutional ethics program, sustainable and social development practiced in the University, and of course in methods designed for the academic classes. The methodology generates the interface between the institutional programs and academic design programs which are used to teach to college students.

2 ETHICS IN MONTERREY INSTITUTE OF TECHNOLOGY AND HIGHER EDUCATION

ITESM has taken actions to the ethics education of their students [7]. The Mission of the Institute is to prepare upstanding, ethical individuals with a humanistic profile, who are internationally competitive in their professional fields, and where a humanistic profile is understood as having respect for the dignity and solidarity of the other people. In curricular approaches, especially in the field of engineering practices, incorporating ethics and forcing civic reflection is essential at the dawn of this century to institute a humanistic vision.
The *Quality Enhancement Plan* (QEP) of ITESM [8] aims to improve processes of teaching and learning in the area of ethics and citizenship, everything done in a structured and long-term growth (2008, p.10). The goal of this program is to strengthen students in their ethical and citizenship competencies that can be an asset in their academic and professional lives (2008, p.11). There are four competencies to be developed:
First competency
Reflect, analyze and evaluate ethical dilemmas related to oneself, their practice and their environment. In particular, the pursued objective is that graduates take their personal and professional decisions based on ethical criteria. This will involve three steps: First of all, acknowledgement of the need for ethics for their personal and social development; second, the development of the capacity for rational application of the identification and resolution of ethical dilemmas processes; finally, the development of the capacity for understanding and furthermore analyzing the fundamentals so they can build their own answers to ethical questions and objectively criticize the answers that other people have.
Second competency
Respecting people and their environment. The idea is that graduates consider how their professional, personal and social performance affects other people and their everyday environment. Specifically, the student is supported by a solid foundation of the principles that support human dignity to solve ethical problems. Also they are able to recognize that respect and tolerance are fundamental to social life principles.
Third competency
To understand and be sensitive to the social, economic and political reality. The goal for graduates is to be updated on the social, economic and political events, so they will be able to judge with an educated criterion. At this point, it should be highlighted that it is intended that students show willingness to engage in solving the problems of the community, especially when it comes to marginalized communities.
Fourth competency
Act with solidarity and civic responsibility to improve the quality of life of its community and especially of marginalized communities. Graduates are encouraged to participate in organizations or activities that contribute to the improvement of their community. The aim is that students are able to plan, implement, evaluate and engage in coordinate solidarity actions to solve problems in which to

apply their knowledge, including their career, and enrich their learning when reflecting about the experience.
This training encourages the development of individual autonomy, participation as a citizen in the community and an awareness of being part of humanity, which of course brings us to the most expensive of Kant convictions: autonomy, dignity and humanity applied to oneself and to the others. So, how to create this consciousness to students? What pedagogy and didactics are used for this extraordinary project? The answer includes a primary knowledge base which starts what might be called <<the humanistic view of the learner>> and on which it could be build objective and well-supported ethics and citizenship. This view is known as the fundamental foundation of <<humanistic profile>> which fits under the ITESM graduate profile. This vision is understood as the recognition of the legacies that humanity has given, as well as awareness of the situation. It is always open to human creativity through imagination and its implementation, creating new realities founded in an ethics and citizenship according to which requires time. This is engineering with a humanistic view.

3 DEVELOPMENT AND PROCEDURE

The Mechatronics Design course is one of the latest courses in the study plan of Mechatronics Engineering, by the time students take this course they have completed about 90% of all subjects, including three courses about ethics.
The first step of the methodology is to apply an audit of values and ethics in engineering on the first day of the course. The audit is designed by Professor Fernando Arriaga who teaches ethics at the college. Through solving scenarios and questionnaires in which students face ethical dilemmas, their commitment to sustainable and social development can be measured.
The result of the audit would allow teachers to select a specific case for each student from a database of cases in ethical engineering. In this way, it would be possible to sensitize them to all the professional competences. Reading cases and the consecutive discussion of the solutions are made concurrently with the reaffirmation of ethical skills, sustainable development and social development as well as product design techniques.
During the last months, the developers would be analyzing worldwide cases about flawed design, situations where the production process has contaminated the environment or damage to human and successful social development projects using engineering design. The actual database consists of 200 cases continuously increasing every semester.
The next phase is an open discussion between teachers and students in which they determine the ethical implications. The students are asked to research in real time the root cause of the problem, the proposed solutions and the economic analysis of saving a well-designed product versus a poor one.
Regarding a sustainable development approach [9], the project is intended to create awareness in the students about the impact our projects have in the planet, caused by current products and manufacturing processes. The forward-looking solutions cannot solve the problem only for the present, the students do discuss the impact of the solution when the product is in the horizon time of their life cycle. During these readings, students are taught to measure the carbon footprint and ecological footprint.
The carbon footprint measures the amount of greenhouse gases that are emitted as a result either directly or indirectly from the creation of a product, so for any product that students design the gases emitted are measured in two ways: from each raw material and from the finished product. Additionally, the gases emitted by the transportation of the products and of the final destination of the product (with consumer) are considered.
The ecological footprint is an environmental indicator of how a human community has affected its environment, considering both the resources and the waste generated to preserve the pattern of production and consumption of the community. It is defined as the area required to produce the resources consumed by an average citizen of a particular human community, as well as what is needed to absorb the waste it generates, regardless of the location of these areas. Broadly speaking, the methodology for calculating the ecological footprint is based on estimating the necessary area, which is selected in hectares to know the consumption associated with food, forest products, energy expenditure and the direct occupation of the land.
The ecological footprint quantifies objectively the environmental impact and may be benchmark in environmental objectives that are proposed by organizations. Its main objective is to evaluate the

impact on the planet in a certain way of life style and, it is compared to the planet's biocapacity. Consequently, it is a key indicator of sustainability.
Finally, the life cycle analysis is a process to assess the environmental burdens associated with a product, process or activity as objectively as possible. It is done identifying and quantifying the matter and energy usage and wastes produced in the environment; in order to determine the impact that the use of such resources have, so it will be simpler to evaluate and implement environmental improvement strategies. The Life Cycle Analysis (LCA) includes the complete cycle of the product, process or activity, taking into account the steps of extraction and processing of raw materials; production, transport and distribution; use, reuse and maintenance; and recycling and disposal of waste.
The third element of ethical engineering design is social development [10]. As one of the Latin American countries with serious social underdevelopment, Mexico is inhabited by communities in extreme poverty. Additionally, the proximity of the border with the United States for decades have undergone a process of migration from rural areas to both cities and abroad, which has exacerbated the phenomenon of extreme poverty for 70 years, when ITESM was founded. Graduates should have a humanistic vision to become agents of change in their own community. If the University community design products and their manufacturing processes considering ethics and a social approach, and all of them are sustainable, the result will be helping to create small business in these marginalized areas that will help to reverse poverty.
The students work concurrently in the awareness through reading cases; the concurrent work is based on the Mechatronic design model proposed by Manriquez, Gonzalez, Riojas and Lloveras [11] in which teachers make an emphasis on eco-design and normativity according to national and international security standards. Figure 1

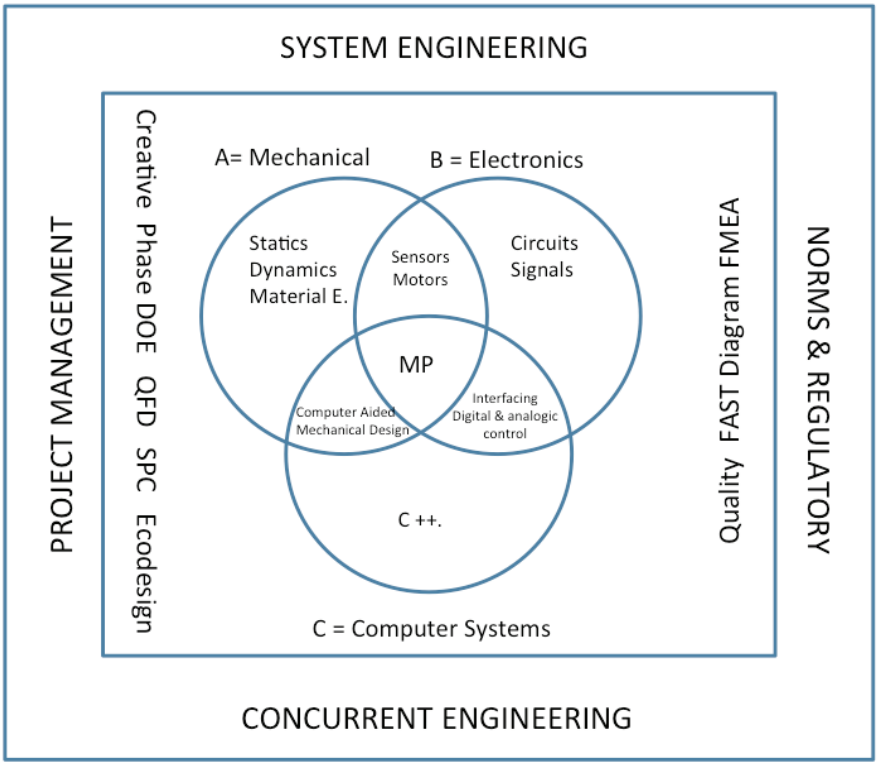

Figure 1. Mechatronic design model

At this stage, it is introduced the analysis and design of experiments for economy engineering, so it is possible to determine whether the design of the raw material and the final product is ideal with an acceptable cost. The first option in engineering design is to make products at the lowest cost to have the most profits. Introducing the design ethics within the framework, it allows students to evaluate the impact of the first option and its possible cost. The procedure constantly iterates until the combination of components and processes that results in the best product is found. The result includes a

manufacturing process friendly to the environment and the community and it implies the best revenues.
After applying design methodologies and making its economic assessment, the final step is proceed to do a new audit with the students to determine the degree of sensitization to ethical design. The last evaluation consists in a final project, the second component is a survey specifically designed to measure learning and the solution of a case where the student will share its knowledge and awareness by giving the best solution.

3.1 Success cases

During the semester August – December 2013 in the Mechatronics Design assignment there were activities with the finality to improve the technical knowledge as well as the awareness of sustainability and community service. Students were to select a civil organization (OSC for Spanish acronym) to support by executing a project designed by themselves. The organization in question was located in a marginal and poor area in the state of Guanajuato, Mexico. The project consisted in the reconversion of agricultural machinery to be sustainable and to work with renewable energies for the production of dehydrated tomatoes cultivated in a greenhouse obtained by donation.
Regarding the project requirements, the technical solution that the students had to propose was to make a redesign of the machinery, and make it functional to the needs and possibilities of the OSC, they have to consider the electrical consumption, as well as to try and reduce the maintenance and operation costs. Additionally, the operation and maintenance of the machinery should be very simple, and intuitive to be carried out by any unskilled worker. The main objective of these requirements is to increase the profitability of the greenhouse and thus, the OSC benefiting from such situation.
All these requirements make the project something different from what any student has done before. Most of the team´s integrates were senior students of their majors, but in projects developed in previous semesters, they didn't have to worry about electrical consumption, material resistance, maintenance cost, or the easiness and practicality of the actual operation. The project and said requirements also contrasts with projects in the city in a stable company with highly qualified people and a steady income, where these previous considerations (maintenance costs, easiness of the operation, etc.) held no priority whatsoever in the design process [9].
The concurrent focus was an example of the application of the methodology. It was useful to identify the relationship between; firstly, the design, next, the sustainability of the project focused in the uses of alternative energies by using organic waste to produce biogas and finally, the ethical issues. All these requirements were used together, since the creative phase, the brainstorm phase, and the mental maps that were conducing to the best solution.
In the bio design assignment, for the industrial design major, an activity was designed where the objective was the attainment of the required competences for sustainable development. The objective was made possible by linking the disciplines of bio mimics, biomimetic, bionics, and design, and more importantly the application of all these disciplines, along with assuming the moral and ethical responsibility in the design of sustainable products.

Figure 1. Products designed with ethics design focus

The results the project yielded were the design and fabrication of a low cost slipper using recycled materials (see figure 2 on the right), and a paper dish made with biodegradable material (see figure 2 on the left).
The project includes the creation of a social company to produce both products, without forgetting the social, economic and sustainable aspects, in marginal points of Querétaro city.

4 CONCLUSIONS

After the projects the students could witness firsthand the radical importance of the application of engineering with human sense, especially in developing economies such as Mexico. Only through methodologies such as the one presented in this project, notably teaching students how to solve real world problems helping their communities, is the way they can change and reduce the educational, economical, and social gap so remarkable between developing and developed countries. Revenues and engineering with human sense are compatible; the key is a strong emphasis in design solutions from a concurrent vision maximizing the relevance of ethics, as well sustainable and social aspects.
The result of the experiences designed created a methodology that involved different areas. It was dealt not only with academic and professional businesses but also with moral and ethical issues. The methodology guarantees a process that teaches the student all the perspectives of how to solve a problem and the techniques to contemplate all the needs and possible solution even when the problem involves different areas of study and thus, justifies a new focus for the development and growth of professionals. It was observed that the students do not always contemplate the different stakeholders in the project but that the methodology is another step towards such issue and their integral formation. The implementation of ethics in engineering is another step towards making possible a more equitable distribution of opportunities, raising the awareness in the professional to help those in need and, creating or innovating new products or processes hand in hand with high profits and revenues to industry all from the avail that gives ethics and a vision of a sustainable world.

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