Abstract – In this paper we propose a social design focus in multidisciplinary engineering design courses as a paradigm that can develop the human and social capital needed in modern undergraduate engineering education facing the current global challenges. In particular we propose the Social Intelligence Design (SID) approach. Social Design Based Learning (SDBL) is a promising approach that we believe helps to integrate many pedagogical techniques such as Project Oriented Learning, Service Learning, Research-based Learning, Entrepreneurship-based Learning and Collaborative-Learning. We explain how this approach has been implemented in two academic experiences where the collaborative engineering design is practiced between electronic engineering and industrial design students. We compare last year’s experience to this year’s. This approach also seems very promising for product innovation, entrepreneurship and social awareness.

Index Terms – Collaborative Engineering Design, Concurrent Engineering, Multidisciplinary, Social Design.

INTRODUCTION

Global challenges such as the economy, energy, climate change, transportation, food, security, etc. to name only few, push social organizations such as universities to redesign engineering education [1]. To solve these problems several universities and institutions around the world have stated in their missions and their student’ profiles; civic, social and citizenship objectives Moreover, to fulfill these objectives a lot of pedagogical innovations on the curriculum are promoted such as transdisciplinary education[2], sustainability[3], ethics and citizenship[4], entrepreneurship[5], undergraduate research [6], service and humanitarian engineering [7], and social capital in engineering education [15], etc.

Due to the time constraints in education there is a need for a paradigm that can teach students how to participate actively in solving global challenges. Moreover, there is not a single pedagogical answer to educate both highly competitive students with high social capital at same time[15]. Therefore, the problem is how to meet current ambitious educational missions in the most economical way. We thought that the search for a single approach is a big challenge and in this paper we explain an academic experience that we believe is a good approach in the search of the desired framework. We propose both the Social Design Based Learning (SDBL) approach and multidisciplinary teams as means to implement the most important strategies to answer the current global challenges that humankind is facing. The particular SDBL we propose is founded on the Social Intelligence Design (SID) framework.

The multidisciplinary component of our course is in agreement with modern manufacturing practices and provides the students a more real experience. Furthermore, globalization is also motivating this new kind of engineering practice. This approach is mostly know as Collaborative Engineering Design (CED) and is embraced by a modern manufacturing philosophy called Product Lifecycle Management (PLM) [8]. This paradigm is the framework behind the CDIO approach¹ and one of the main components for implementing this new manufacturing philosophy is multidisciplinary work.

In this paper we present an annual effort at Tec de Monterrey campus Querétaro, Mexico which consists in integrating two courses: one from Electronics Engineering (EE) and another from Industrial Design (ID) academic programs. The main motivation is to better our student’s education and prepare them for real life experiences, global engineering and citizenship. When we implemented the SID approach we found that this framework could answer several institutional demands at the same time.

The paper is organized as follows: section II explains our innovative institutional context; section III explains the SDBL framework; section IV describes the experience during January-May 2008 and 2009 following by section V where some results are presented. Finally, section VI concludes and provides further work.

EDUCATIONAL INNOVATION AT TEC DE MONTERREY SYSTEM

Tec de Monterrey is a private non-profit educational institution which has earned a fine reputation all around Mexico and Latin America. It is composed of 33 campuses almost in each state of Mexico’s country, with several representative offices in Latin America and all around the world and more than 1000 teleclassrooms in Latin America through which it offers industry-related and educational programs. Tec de Monterrey is accredited by the Southern Association of Colleges and Schools (SACS) since 1945 and several academic programs are accredited by ABET (including the engineering programs of the Tec de

¹ http://www.cdio.org/
Monterrey Queretaro campus since 1993), AACSB, EQUIS, as well as national accreditation associations.

The 2015 Mission of Tec de Monterrey was formulated in response to the results of an extensive survey carried out among different sectors of the society, both within and outside Tec de Monterrey. Its basic postulation is the following: "To educate persons of integrity, with a humanistic vision, who are internationally competitive in their fields, while at the same time citizens committed to the economic, political, social and cultural development of their community and the sustainable use of natural resources". In this way, Tec de Monterrey took a step forward in our commitment to Mexico and assumed a more dynamic and participative role in the task of generating greater well-being in our communities. With this mission, two great challenges are acknowledged: on the one hand, to develop in our students the knowledge and skills which are part of the professional competencies in their disciplines, which implies guaranteeing a high academic level; and on the other hand, to achieve the formation of our students according to the principles and values embodied in the mission.

To answer previous and current missions, Tec de Monterrey System has been working, developing and enhancing its Re-engineering the Teaching Learning Process (RTLP) academic model since 1995. For instance, at the end of 2007 there were almost 14,000 (70%) re-engineered courses under the RTLP model in the whole Tec de Monterrey System. Each re-engineered course includes one of the most recognized cognitive practices like Project-Oriented Learning (POL), Problem-Based Learning (PBL), Cases Methodology and Collaborative Learning (AC) among others. Currently we are implementing the service-based learning (A-S) and Learning by doing Research (ABI) techniques. The A-S initiative is mainly motivated from our Quality Enhancement Program (QEP) engagement to SACS which is oriented to improve our RTLP in ethics and citizenship. All of these results show that Tec de Monterrey is a highly innovative educational institution and that our mission includes the development of civic, social and citizenship competencies in our students.

**SOCIAL DESIGN FRAMEWORK**

Within the design world, Social Design (SD) refers to design in its traditional sense, meaning the shaping of social products and social services. Other definitions refer to social design as the creation of social reality; design of the social world. Social Design Thinking (SDT) within the design world joins developing human and social capital with new products and processes that are profitable. Social Intelligence Design (SID) is a special kind of SDT. SID attempts to integrate and understand the interactions between designing and social intelligence. It involves multiple disciplinary approaches concerning design and implementation of systems and environments, ranging from group/team oriented collaboration support systems that facilitate common ground building, goal-oriented interaction among participants, to community support systems that support large-scale online-discussion. SID also involves processes associated with the cognitive and social psychological understanding of social intelligence, providing means for predicting and evaluating the nature and consequences of communication media on the nature of discussions, interaction dynamics, and decision making. It encompasses also pragmatic considerations from economy, sociology, ethics and many other fields, for social intelligence design has a direct relation with the society. For SID, all these aspects work complementarily to each other and must be integrated intimately, for good systems cannot be built without good understanding and vice versa[9]. Some themes of SID are:

- **Natural Interactions** - covering interaction, that bring technology, work spaces, social behaviors and process aspects together.
- **Collaboration Technologies and tools** - covering innovations to support interactions within communities, covering a range from knowledge sharing systems, multi-agent systems and interactive systems.
- **Communities** - covering community media, communication patterns in online communities, knowledge-creating, network and anonymous groups.
- **Multidisciplinary perspectives** - exploring social intelligence at the intersection of different disciplines, such as, people-place-process. place-technology-interaction, that bring technology, work spaces, social behaviors and process aspects together.
- **Application Domains** - including design, workspaces, education, e-commerce, entertainment, digital democracy, digital cities, policy and business.

Figure 1 shows some SID characteristics and their granularities.

**FIGURE 1**

SID GRANULARITIES2.

By considering this framework as a focus for teaching engineering design, undergraduate students look for social

aspects and characteristics and keep their thinking at a systemic level [16]. Figure 2 shows the SID paradigm compared with the Human Computer Interaction (HCI) paradigm.

In a HCI-based system the interaction is between a human and a machine/computer/system. With a SID-based system humans interact through it and by interacting they gain social and human capital, in particular social intelligence. In Figure 1 we see that for example by interacting through a SID-based System a group of humans can enhance different granularities of social intelligence such as their conviviality, reputation, awareness, etc. Moreover, in traditional engineering design courses, a final project is developed only from the technological point of view. If the final goal of engineering design courses is to improve our society and to provide a technological solution to social problems the students are obliged to understand social change/evolution and therefore developing social and human capital on them. Therefore, we believe that the SDBL is a paradigm that enhances their civic, social and citizenship participation.

By integrating the two courses mentioned above and around the SID paradigm, we promote a desirable approach to our QEP engagement. We also approach real life work as well as product innovation and social awareness for both EE and ID students. In the following paragraphs we describe more benefits of the SID paradigm.

### Academic Experiences

One academic experience has been executed during the January-May 2008 semester. A second experience is ongoing during the January-May 2009 semester. Both academic experiences follow major steps from the engineering design process, in general: idea research stage, idea generation stage, and concept development stage and product presentation. An important innovation in our setting is the professors’ participation. There are a lot of multidisciplinary educational efforts and we did not find one where two professors from two different academic programs teach together an integrated course with students from two or more academic programs. As professors our role is to coach and guide the students' learning process. Professors meet every week in order to design and adapt the course and to discuss the same. It has been a very enriching environment for both types of professors, engineers and designers.

#### I. Academic Programs Involved

In our setting, normally two (EE and ID) academic programs participate. During the first experience some students from previous generations of EE academic programs took the course as an elective course. They were Electronic and Communications Engineers (ECE) and Electronic Systems Engineers (ESE). In the second experience we have EE, ESE and ICT (Information and Communications Technologies) students. The EE and ICT academic programs have some integrated projects both vertically and horizontally. The first is offered in the third semester; the second is taught in the sixth semester, third and fourth are taught in the eighth and ninth semesters. EE and ICT academic programs are offered in nine semesters. These programs are different from traditional engineering programs since it is closer to Architectural and ID academic programs where some courses are horizontally integrated. The last course is an industry-academic course.

#### II. Team Building

In the first experience we used an empirical methodology for team building. We formed teams of two or three EE or ID students then we put face-to-face teams of EE and ID students and giving them some time to know the team in face. At the end of the session students marked their preferred other specialty team. Specialty teams (EE or ID) were formed according to students’ preferences. During the second experience we used two tools: the Speed Teaming methodology [10] and the individual theme of interest. In the Speed Teaming methodology students interview other disciplines’ students during two minutes. This methodology is a modification of the famous Speed Dating methodology³. Once the students prioritized three themes of interest we used information from both methodologies to form the teams.

#### III. Theme Choice

During both experiences initial themes were proposed by professors. In the first experience we limited the themes to four SID application domains. They were: workspaces, education, entertainment and digital cities. In the second experience we proposed the following themes: employability, security, health, social emotion, sustainability, education and transport. One important thing to mention is that sustainability was the most important choice among students in this year’s experience. The idea behind the chosen themes is to bring the students to think at systemic level [16]. A property that we consider future engineering graduates should possess.

#### IV. Idea Research

---

To search social problems, beginning with the chosen theme, students use the mindmap technique and the questions technique. Innovations in this stage consists in the way mindmaps and question techniques are developed. They are developed collectively. Once they have a focus they use IDEO Cards [11] and apply ethnographic research. By applying these techniques they come up with a social problem (social object). All this information helps students make their hypothesis. It is worth saying that by taking the SID approach many innovations come up since there are not a lot of commercial products designed under this paradigm. In this sense students have the opportunity to innovate a new product during the process.

V. Idea Generation

During both experiences, similar methodologies were used to generate the idea. They were: scenario creation, story board (SB), use-case diagram and flow diagram. They created individually several SID-based scenarios, then they integrated in a SB all the scenarios created by their colleagues. Once the SB is integrated, students identified scenarios where actors interact with the SID-based system and they formalize with the use diagram. The use diagram is also known as use-case diagram in informatics [12]. This semester the participation of ICT engineers have enriched the course dynamics since they have additional technological tools, for instance they are using Unified Modeling Language (UML) to formalize their use-case diagram. Also since EE students do not have sketching abilities, we proposed to use the Comic Life ™ platform⁴. Flow diagram is used mostly for engineers. It is used for programming hardware or developing software. Engineering students were requested to develop their flow diagram.

VI. Concept Development

In this stage, both types of students agree on the main keywords of their work and develop a collective image board. Then ID students develop several sketches and agree with EE students. Once they agree, sketches are transmitting the ideas, they are separated in a similar way as the concurrent engineering approach suggests. EE students built a prototype and ID students build a mock up of the concept. This is, in our opinion, the most important stage of the course. We must remember that students are learning. During both experiences EE students show some kind of anxiousness since they are often educated to give a hardware solution without spending a lot of time on the design. To deal with this phenomenon we talked to them and explained carefully that every new product has its first prototype and that it does not have all the functionalities of the ideal concept. They started to understand that the main functionalities give personality to their products and that they must concentrate on them. They also become aware of the complexity of the engineers’ real life. During the first experience, EE students used previous knowledge about microcontrollers or digital electronics such as FPGAs. Furthermore, depending on the project they also learned from new technologies (especially wireless). At our engineering school professors teach 8051™ architecture and some students have the AVR™, Motorola™ or Microchip™ experience. This semester most of the concepts will be implemented in the Arduino™ platform⁵. The ideal result would be that students make at least two turns on their prototypes so they could be aware of versions or product generations. For the ideal concept EE students cooperate with specifications (mainly dimensions) and ID students develop a real model (with exploded view and CAD information). On the other hand for the prototype, ID students develop necessary mock ups and EE students develop functionality. Both prototypes are presented during the Engineering Division Fair.

VII. Concept Presentation

At the end of each stage, teams are requested to present the deliverables developed during their corresponding period. This also enforces delayed teams to finish their work and present it. Also, at the end of the semester, teams are requested to present their work during the Engineering Division Fair. Deliverables are the stand design, poster design (both publicity and scientific), videoprototype design and brochure.

VIII. Scientific Article

Teams are requested to prepare a scientific article as a final deliverable. As we are designing social products under the SID paradigm, our course is adapted to submit the concept developed by the students. During the first experience we requested the whole article at the end of the experience. This year, we are requesting advancements every evaluation period in order to send a better work. This effort pioneered the pedagogical technique declared at Tec de Monterrey System and is called Research Based Learning (ABI). To our knowledge, this course was the first in the Tec de Monterrey System to integrate both disciplines and be taught by professors from these two distinct disciplines.

IX. Evaluation

Several evaluations have been applied every month. During the first experience, we developed rubrics for each stage. We were three professors, two from ID department and one from the EE department. It took too much time to achieve and to reach an agreement. Work was evaluated mainly based on presentations. When concurrent engineering was applied each specialty team was evaluated in a separate way. During this semester, we have enriched the way we evaluate. First, attendance is very important since much of the work is done in teams. We therefore obligate students to be present. Second, we are applying collaborative learning assessments in order to get the meta-knowledge desired. In fact, we started to redesign the course under the Collaborative Learning technique since it is a granularity of SID and since

⁴ http://plasq.com/
⁵ http://www.arduino.cc/
we found it to be a good SID tool [13]. Third, we are adding Cross Disciplinary Learning assessment developed by Renate Fruchter [14]. Fourth, we are adding individual assessment each period in order to evaluate the students’ learning process. A team this year selected a project related to health at the beginning and after the first individual evaluation they chose to follow the theme of that evaluation. The theme was the one that no one had chosen, employability. This team developed everything from the beginning. It is worth noting that some teams have repeated the process two or three times during each period and this allowed them to develop better competencies. Another important change is that we are inviting researchers and professors to the presentations and taking into account their grades. Evaluations consist of 10 minute presentations with no questions. Students should be able to give concrete information during this time. In the first experience, we invited a researcher from the MIT Mobile Design Experience Lab and this year within our Academic Leader Program we received the visit of Lorraine Justice, Director of the School of Design from the Hong Kong Polytechnic University with the intention to give feedback to our students.

X. Technology

Most of the re-engineered courses are implemented in BlackBoard™ platform but according to our experience this platform is still very rigid for the richness and spontaneity of the course. Therefore, we are promoting the use of new free web-based platforms where students keep information from their collaborative Work. Most of the teams have found the Stixy platform very friendly. We also have an agreement with IUSACELL™ so many students use their BlackBerry™ Smartphone. We also invite the students to use Google Docs™.

RESULTS

By applying the SID paradigm we found that three levels of SID are promoted: the SID-based system, the students’ social process level and the professors’ social process level. These social processes add social capital [15] to our undergraduate students and to us as professors. The professors’ experience and six students’ projects from the first experience were published in the seventh international workshop on SID in December 2008 (many writing work after the course has been done). It is almost a year project. The professors’ experience and two students’ projects were invited to be published in the Journal of Artificial Intelligence and Society from Springer Verlag. One team is working towards incubation and others expressed their idea about patenting. Two of the teams are working on their implementation for product innovation. During the second experience we used extensively Google Docs for applying online questionnaires. At the end of the course we applied several questionnaires one of them related to the basic ABET criteria and complementary issues. Because of a lack of space we provide a group of questions. Most of the answers are self-explanatory.

12. In which grade do you think this course INCREASED your social capital?

1. 0% 2. 0% 3. 11% 4. 22% 5. 100% 39%

13. In which grade do you think this course INCREASED your social awareness?

1. 0% 2. 0% 3. 4% 4. 13% 5. 100% 26%

14. In which grade do you think this course INCREASED your social commitment?

1. 0% 2. 2% 3. 4% 4. 12% 5. 100% 27%

15. In which grade do you think this course INCREASED your recognition about the impact of your academic program (career) in the society?

1. 0% 2. 2% 3. 2% 4. 11% 5. 100% 31%

16. In which grade do you think this course MOTIVATE you to work on building your enterprise?

1. 3% 2. 1% 3. 7% 4. 14% 5. 100% 26%

17. In which grade do you think this course INCREASED your capacity to innovate?

1. 0% 2. 2% 3. 4% 4. 8% 5. 100% 32%

18. In which grade do you think this course INCREASED your creativity?

1. 0% 2. 2% 3. 2% 4. 4% 5. 100% 30%
We also invited professors from other departments to evaluate the projects as external constituencies. We provide a few figures to show what they think compared to the students.

CONCLUSIONS AND FUTURE WORK

In this paper we have presented a brief introduction to global challenges and main trends in engineering design practices. We also have introduced and presented Social-based Engineering Design Learning as a paradigm for embracing and integrating many modern pedagogical techniques. SID-based education cannot be confused with A-S. In A-S the most important aspect is the students’ reflections. In SID the idea is to increase social intelligence and to invent a social product or system. Since many products are designed without taking into account the social aspect, we think that the experience of this approach seems very promising for product innovation, entrepreneurship, collective intelligence and social awareness. Therefore, the SID paradigm embraces a lot of current demands in highly innovative universities.

Our current and future work is focused on: (1) assessment methodologies and on: (2) the need to understand the impact of engineering design solutions in a global, economic, environmental, and societal context (social awareness).

ACKNOWLEDGMENTS

The author very much appreciated working with Raúl Moysen from the Industrial Design Department and Eva Loya, Director of Communication in the High School and expert on Collaborative Learning for fruitful discussions and collaboration. Renate Fruchter from Stanford and Scott Schaffer from Purdue University. He also thanks Céline Roche for her orthographical and grammar help in English…

REFERENCES


http://epics.ecn.purdue.edu/