A NEW TEACHING PEDAGOGY TO ENHANCE SOCIETAL NEEDS, SUSTAINABILITY, INNOVATION AND ENTREPRENEURIAL SKILLS

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Abstract: Design is a common element in most Mechanical and Industrial Engineering programs globally. In the design course, various aspects of product embodiment, manufacturing processes and material selection are discussed. To bring further flavour to the design course in Qatar University element such as life cycle, innovation and entrepreneurship with active learning was introduced. The students were divided in few groups. Each group had to address a societal need within or external to Qatar. The solutions address the issues of sustainability. The students were given sessions about tools for idea generation and creativity techniques. Once the problem had been identified, these groups were advised and coached to prepare a comprehensive business plan that include selection of materials and manufacturing processes, life cycle, organizational structure, how they will market their product, market segmentation and penetration, break even analysis and economic analysis as well as environmental impact. From the course assessment and student course outcomes surveys, it was found that the interest and learning curve for students increased drastically for this course. Besides improving the interest and learning curve, the approach had indirectly exposed the student to project management skills, economic analysis – balance sheet and cash flow and breakeven point analysis, lifelong learning, communication and teamwork. In whole, the approach was an interesting and led to further enhance the student learning process by using different learning styles through varied and innovative teaching techniques.

1 INTRODUCTION

Agenda 21, a global action plan accepted at the Earth Summit in Rio de Janeiro in 1992, stated that "*education is critical for promoting sustainable development and improving the capacity of the people to address sustainable development issues*" (UNCED, 1992). In line with this, one of the criteria in accrediting Engineering Programs (EAC- ABET Criteria 3c) is the ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health-safety, manufacturability, and *sustainability*.

Traditionally when students were asked to design, focus was given to the functionality of the design to fulfill customer's requirements. Almost no emphasize was given to the issue of sustainability [Nicholas, Cheryl et al., Paten et al., Smith et al.]. Importance of sustainability cannot be denied as seen by its wide spread of interest globally and is covered across many disciplines [(Carew and Mitchell]. However, this has yet to be translated to major curriculum changes in universities, especially in the engineering curriculum [Moore et al., Beringer et al]. Within the context of sustainability, the social pillar is still found to be under represented [Adamowski, and Shuvalova,]. Hence, there is a need to teach current undergraduates the importance of sustainability covering equally its three pillars: environment, economy and society.

Besides this, most engineering programs educate students to become engineers; i.e. professionals that are able to solve complex engineering problems. Little, to almost no emphasize is given in engineering curriculum to educate engineering undergraduates to venture into business by being an entrepreneur [Byers et. al.]. This is an important element especially in a society that is growing very rapidly. The benefits of start-up companies to the economy of a country cannot be denied [Lumsdaine, E. and Binks].

Keeping in mind EAC-ABET Criteria 3c and the need to generate a holistic engineer in Qatar to fulfill Qatar's National Vision 2030, the Department of Mechanical and Industrial Engineering decided to enrich its Design Course by injecting elements of sustainability and entrepreneurship along with some innovation skills. The best way to incorporate this method was through active learning – problem based learning. The objective of this paper is to share the approach and findings on the way sustainability and entrepreneurship was implemented in a typical engineering design course.

2 METHODS

The approach taken here is to have students used all aspects of their brain. One of the brain model used extensively is the Herrmann's Brain Dominance Model, as shown in Figure 1 and 2. Generally, we all belong to one of the 4 quadrants of the brain. Most engineering students and faculty members belong to either Quadrant A or D. The question is how we can use all quadrants to have a synergetic outcome? The pedagogy used here is similar to that of Just in Time Teaching (JiTT) [Gavrin et. al.].

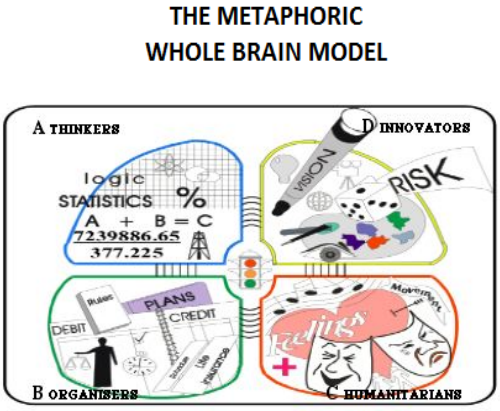


Figure 1: Herrmann's Brain Model
[Source: http://www.virtual.co.nz/index.php?n=Products.HerrmannsThinkingPreferences]

Quadrant A	***Cerebral***	**Quadrant D**
	Realistic Factual Strategic Artistic	
	Authoritarian Financial Playful Spatial Visual	
	Quantitative Mathematical Simultaneous Imaginative	
	Logical Rational Critical Change-oriented Big-picture	
	Analytical Academic Technical Conceptual Holistic Risk-taking	
Left Brain		***Right Brain***
	Dominant Organized Tactical Intuitive Symbolic Teaching	
	Risk-avoiding Conservative Expressive Reaching-out	
	Administrative Scheduled Interpersonal Sensitive	
	Procedural Sequential Supportive Spiritual	
	Reliable Detailed Feeling Musical	
Quadrant B	***Limbic***	**Quadrant C**

Figure 2: Thinking characteristics and behavioral clues of the Herrmann model [Lumsdaine, E. and Binks]

Giving traditional lectures on the issue of sustainability and entrepreneurship can be a daunting task. It is very crucial to engage students actively and to be able to measure students understanding on the topic. Since the number of contact hours in the class is limited, to maximize this, students were given activities prior to class. These activities include students conducting the definition of sustainability and participating online Entrepreneurship courses and discussions (MITx: 15.390x: Entrepreneurship 101 – www.edx.org, www.openlearning.com/courses/GlobalEntrepreneurship). There are two reasons for this approach: (1) Instructors can spend more time on concepts not clear to students (2) to have students use the brain Quadrant C – humanitarian.

Students were then divided into teams and were told to determine a problem in a developing country. The objective of this is to have these undergraduates realize and understand the societal needs of such communities. The students were asked to refine their problems by stating societal constraints for the design problem. The students use the process flow as shown in Figure 3. In the midst of developing a sound problem definition, students were required to develop Gantt Chart and progress tracker for their individual teams. This is to have the students use the brain Quadrant B – organizer.

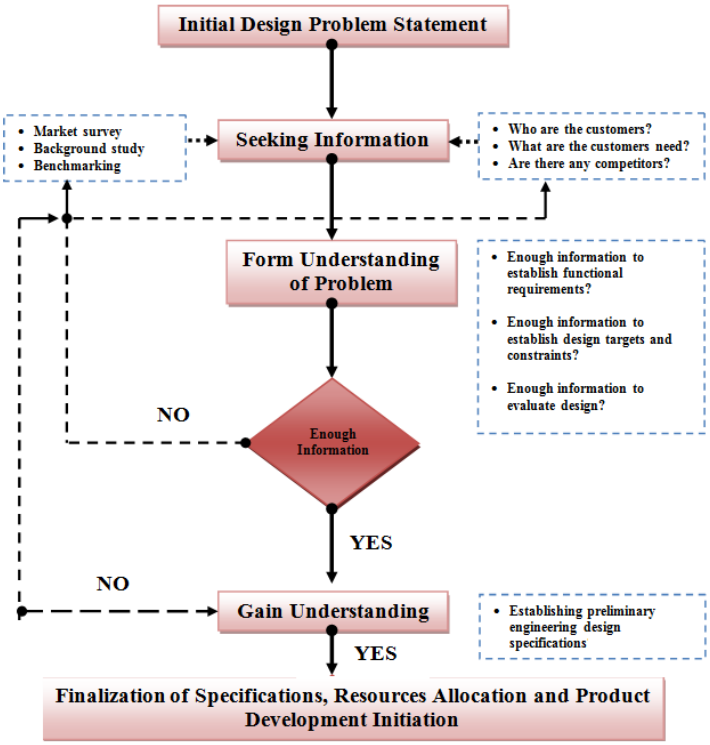


Figure 3: Problem Definition Process

In class the students were taught on several ways to be innovative in generating concepts and selecting the best concepts to solve their problems by looking at functional and cause-effect analysis. One of the tools shared with the students was TRIZ. TRIZ is a “modern brainstorming” method that allows systematic thinking by using generic solutions to guide brainstorming towards feasible/specific solutions, close to ideal.

In terms of entrepreneurship tasks, the first task was to have students understand the relevant markets, policies and competitive advantages of firms. This is very important because it provides information that

will help determine how to position a product in the market. This was followed by introducing the students the concept of a product life cycle, technological innovation and trends in evolution of a certain product. With this students can predict the entry level of a product into a market, i.e. either at the infancy, growth, maturity or decline stage. Relatively, the importance in each stage can be identified and this will translate to a more acceptable product in the market. Part of the process is to also evaluate the potential risk of putting a product into the market.

3 FINDINGS

An example of a team work will be presented here to show the teaching pedagogy taking its shape. The particular team decided to select a community in a small country called Haiti. The reason for selection is because Haiti is in the earthquake belt and frequently encounters small scale earthquakes, which causes minor damage onto buildings. Haiti‟s people are using very traditional methods in construction, i.e., by dumping everything together on the sidewalk in front of their houses and turning it over with a shovel (Figure 4).

Figure 4: Illustrating ground mixing of cement mixing in Haiti
[http://cementtrust.wordpress.com/2010/08/04/concrete-crisis-inhaiti/]

It was found that a small mobile cement mixer was needed for this community to work on repairing these damages caused by the earthquake. Now that the problem had been identified, before the team could proceed with generating concepts, they have to understand the limitations of their solution. These constraints are due to the geographical and domestic constraints. What they realize is that this particular community does not have the luxury of electricity. The team also found that fuel was not an easy access to this community too. Hence, the potential solutions should be purely mechanical driven without any form of electricity or carbon base fuel inputs. Base on this, several concepts were generated and the final decision was to go with a tricycle mixer as shown in Figure 5.

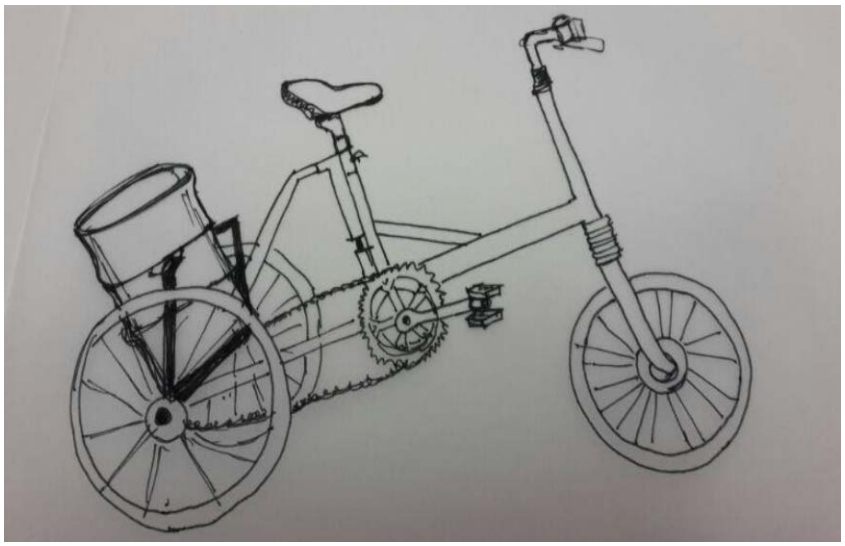
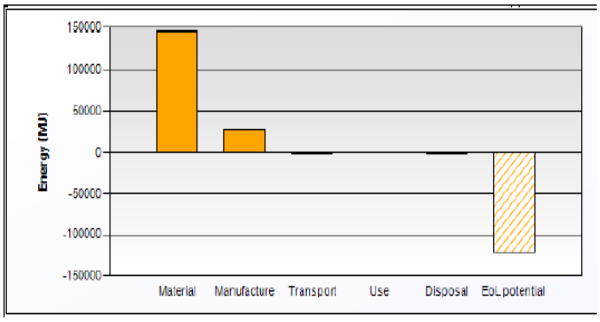
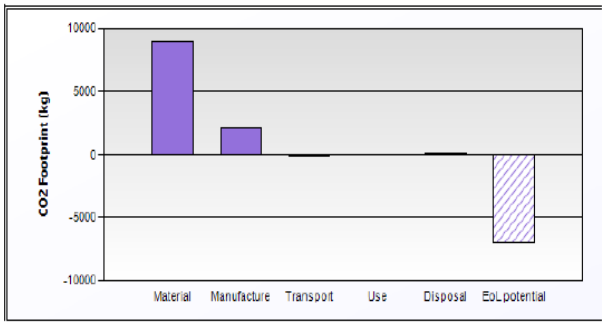


Figure 5: Tricycle cement mixer

The next part of the project was to conduct material and manufacturing selection process. Here the team took the self-learning approach to understand better on how their selection could affect the environment and what the best selection to reduce the environmental impact. For this purpose, the students did an extensive search on the literature and perform an analysis on how much energy and CO_2 emissions resulted due to different selection of materials and manufacturing processes. For this purpose, specific software was used. A sample analysis is shown in Figure 6. In the final stage, the students had to develop a plan on how the proposed solution can be marketed. In the decision process in finalizing the design, students paid close attention on how this product can be sustained in Haiti. This is important because the proposed solution should be easy to maintain and repaired by the Haitians.





Phase	Energy (MJ)	Energy (%)	CO2 (kg)	CO2 (%)
Material	1.46e+05	83.8	8.95e+03	80.9
Manufacture	2.75e+04	15.8	2.07e+03	18.7
Transport	224	0.1	15.9	0.1
Use	0	0.0	0	0.0
Disposal	490	0.3	34.3	0.3
Total (for first life)	1.74e+05	100	1.11e+04	100
End of life potential	-1.21e+05		-7.01e+03	

Figure 6: A sample analysis on the estimates of the CO_2 emissions and energy uses for each life-phase.

4 CONCLUSION

One of the important findings with regard to the learning activities at the end of the project was that all teams appreciated the process they had gone through and understand the important of societal impact and sustainability needs when involved in designing process. New innovative thinking tools such as TRIZ was also appreciated in the concept generation phase. Given the time constrain, it was not possible for the teams to successful generate a complete business plan for their designs. However, they understood the principles of entrepreneurship as well as the process of converting ideas to market place, some of the students were actually motivated to start their own venture once they have graduated. Student understand that active learning process is more than lecturers and textbooks, they became active part of the learning process, students also were excited to attend and participant in the discussion.

As stated earlier, the main object of the team project activities was to instill in students the needs for incorporating societal and sustainability needs when designing. The pedagogical approach was an active learning – problem based learning. The only difference here is that students are totally responsible for the learning material and understanding how to use the information they have received.

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