AN ‘ENGUSTRIAL DESIGN’ EXPERIENTIAL EDUCATION APPROACH

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ABSTRACT:

The aim of this paper is to introduce the *EngUstrial Design education ap*proach integrating *ENGineering* and *indUSTRIAL* design aspects used by the authors at the University of Malta. This approach is aimed at addressing the goal of educating mechanical engineers that are able to comfortably engage in both numeric and artistic activities. This paper discloses our challenges to implementing such an approach together with our emerging experiences in providing bachelor level design education at the University of Malta. Based on case-study observations, this paper outlines a number of lessons learnt that can be exploited by others interested in developing an EngUstrial Design training curriculum to help breed individuals that have a mix of both numeric intensive as well artistic design capabilities.

Keywords: Mechanical Engineering Design, Industrial Design, Artistic, Numeric

1.0 INTRODUCTION

Students of mechanical engineering degrees are traditionally exposed to education programmes that are predominantly composed of numeric intensive topics. These include fluid mechanics, thermodynamics, statics, kinematics, material degradation, finite element analysis and others. In recent years, a career in the domain of mechanical engineering has evolved to now cater for the development of a range of products. These span from micro-scale devices such as those found in biomedical system to large structures forming part of super-sized aircraft. As a result of this evolution, the mechanical engineering domain covers a large range of man-made systems. Due to this wide range, there exist instances when mechanical engineers are mainly concerned with purely technical issues e.g. the detailed design of an internal combustion engine. However, there are also instances (see Figure 1) when engineers have to increasingly design solutions that are both technically sound and also aesthetically pleasing e.g. the design of an external IC engine forming part of a motorbike.

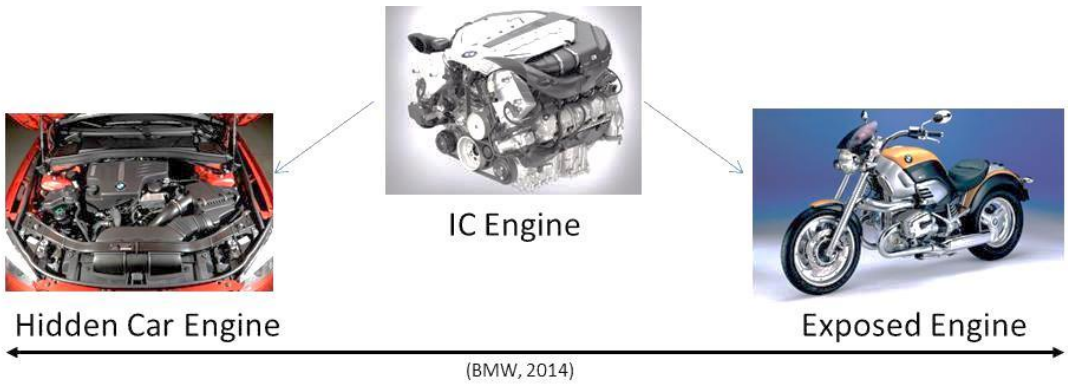

Figure 1: Typical purely technical versus mixed technical-aesthetic engineering system design

This evolving demand on practicing mechanical engineers means that they cannot be solely educated in purely technical topics, but that ideally, they should be also trained to acquire more aesthetic/creative skills. As a result of the current, numeric intensive education approach, industry frequently compensates for this weakness by improving team diversity. Thus, it is common to for instance see design teams made up of a mix of mechanical engineers, product designers and industrial designers.

1.1 LIMITATIONS IN MECHANICAL ENGINEERING DESIGN EDUCATION

Undergraduate mechanical engineering education including that at the University of Malta is typically focused on providing students with a strong numeric knowledge base enabling them to cater for technical oriented issues. This is for example even clearly stated in the education that needs to be undergone by engineers in Europe if they want to be awarded the *Eur Ing* title issued by FEANI (Feani 2014):

"An Engineering Education must provide a thorough knowledge of the principles of engineering, based on mathematics, physics and computer science appropriate to his or her discipline. Any engineer listed in the FEANI Register is guaranteed to have had such an education."

Due to this FEANI criteria, undergraduate mechanical engineering education programmes have little space if any for other topics such as aesthetic design, emotional design, etc. At the same time, the authors are aware that mechanical engineering graduates are finishing up in jobs where purely mechanical engineering principles are not sufficient. For instance, the authors' experience with mechanical engineers employed by organisations involved in developing automobile dashboard switches clearly indicates that these need to be competent in various technical topics such as metal fatigue, materials, tolerances, precision engineering and others. The authors are also fully aware from feedback provided by industrial partners that such engineers also need skills and competences that will allow them to generate solutions that are also attractive and pleasing to end users. To get an insight of the impact academic formation had on the design capabilities of graduates, the authors carried out a small survey with a number of postgraduates from different countries attending a PhD summer school on Integrated Product Development (http://www.eng.um.edu.mt/

~dme/jcb/ipdss/) a number of whom already had working experience. Although this cannot be claimed to be an exhaustive survey, it is interesting to note the clear tendency (see Table 1) arising from the sample of individuals evaluated.

Issue	**Response**
It is a mix of upbringing, personality and training received at the University that has an influence on whether you prefer numeric activities or else prefer non-numeric activities such as sketching	54.5%
Products that sell well on the market are those that provide a good combination of great functionality and appearance/shape	81.8%
‘Design’ education programs should be setup to train people that are equally good in technical/numeric issues as well in shape/aesthetics	90.9%

Table 1: Empirical feedback concerning impact of education on design capabilities

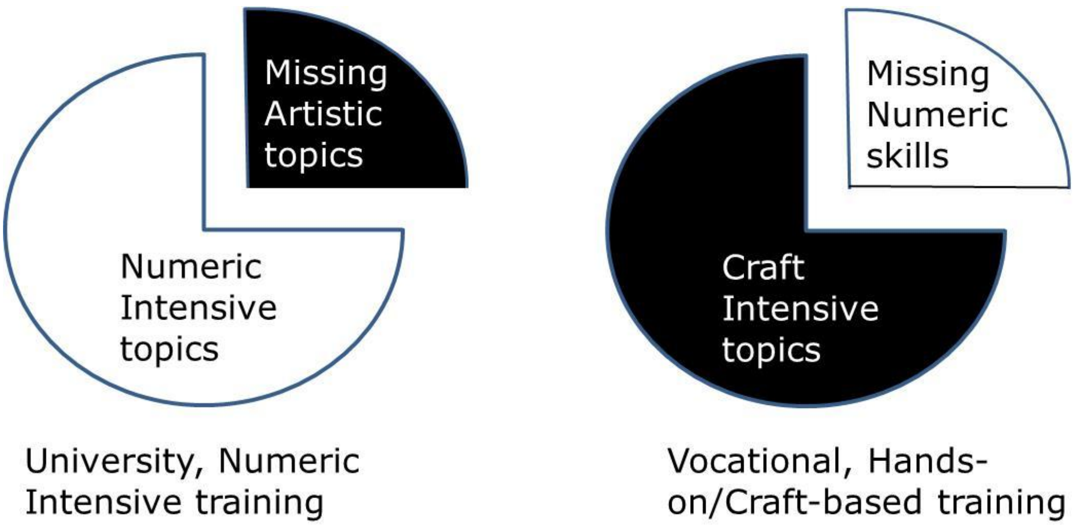

Figure 2: Tendencies in Traditional Mechanical Engineering Design Education

Regarding vocational-based mechanical engineering education, the authors exposure to such graduates is that these undergo less numeric intensive and much more hands-on training. This view is also reflected in (Ricky, Yuk-Kwan Ng, 2011) who state that such education should not merely develop students’ skill-based craftsmanship, but also nurture creativity, analytical thinking and problem solving through academic development. In essence, mechanical engineering education in Universities tends to be (Figure 2 numeric intensive whilst training for the same field through vocational degrees tends to be more craft-based and artistic. This trend does not however mean there is a rigid dichotomy between the two as exceptions do exist.

2.0 VISION OF A PRESCRIBED ENGUSTRIAL DESIGN APPROACH

The authors embarked on the research reported in this paper with the aim of improving this limitation by prescribing an improved engineering design education scenario. Their research hypothesis was that mechanical engineers would be able to design better solutions that are collectively technically sound, feasible to produce and at the same time appealing to customers if they are to experience training through an integrated approach based on both engineering design and industrial design/craft disciplines. The authors thus envisioned that mixed, integrated training takes place as from the undergraduate degree so as to set the mind sets of students in the right direction as early as possible. The other feasible option is that graduate mechanical engineers embark on postgraduate training in for instance craft/industrial design – however in the opinion of the authors, passing such integrated knowledge at postgrad level is rather late and there is not guarantee that all gradates will embark on further studies in the field.

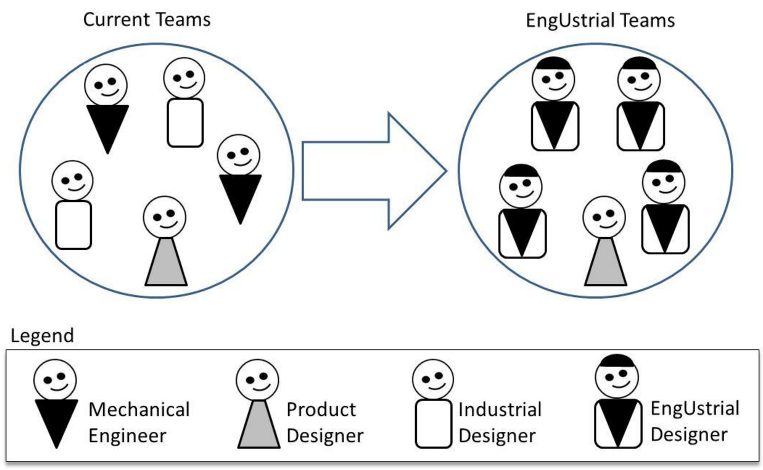

Figure 3: Design teams with a mix of team members versus Teams with EngUstrial team members

The vision the authors had is to help shift from the current situation (Figure 3) where design teams are made up from predominantly a mix of designers each trained in a different field to instead, teams made up of designers who have undergone *an EngUstrial Design* education programme integrating ENGineering and indUSTRIAL design i.e. teams composed of *EngUstrial* design competent engineers.

2.1 RATIONALE FOR AN 'ENGUSTRIAL DESIGN' APPROACH

The rationale for an EngUstrial design approach is not simply based on what the authors envision to offset limitations in engineering design education. The need of having mechanical engineers competent in both numeric intensive topics as well as equipped with craft-based/artistic competences is also reflected from feedback provided by employers to authors. In addition, the experience gained by one of the authors in a two year sabbatical that involved a substantial period in a firm designing and producing consumer products for a global market was crystal clear: project leaders had to regularly balance the demands put forward by the artistic/industrial designers, the engineer designers and also the financial managers. A similar argument was made by BMW's design director (Bangle, 2000) who stated that he mediated between the corporate and artistic mind-sets within the company. Hence providing training that produced mixed mind-sets would offset this situation.

2.2 RIGHT OR LEFT BRAIN PREFERENCES

The dichotomic model of the brain being split up between left or right orientations is indeed debatable. The authors themselves are aware of some individuals that are able to cope well with both left and right labelled competences. However, irrespective of the myth whether the brain is left-right structured, the fact remains that certain people *prefer* and excel in numeric intensive activities, whilst other *prefer* and excel in artistic/creative activities.

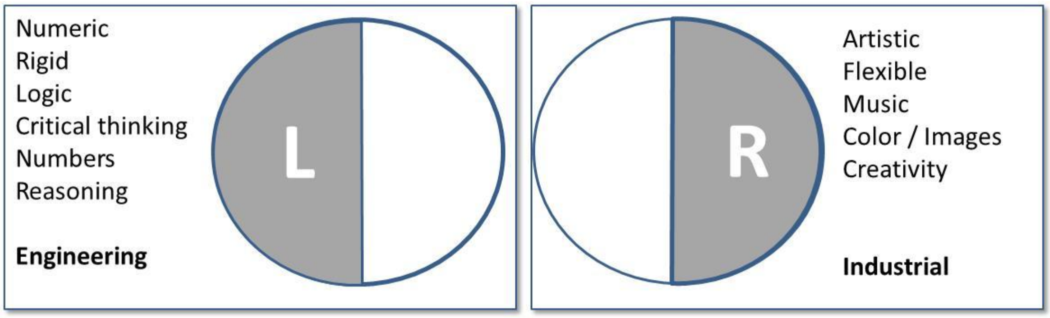

Figure 4: Characteristics of EngUstrial Designers versus Industrial Designers

Thus, whether one agrees with the dichotomic concept of a *Left* or *Right* oriented brain model, what is clear for the authors due to their several years of reflecting on their training experience, is that individuals do have tendencies to either prefer artistic rather than numeric activities or vice-versa. Hence for the purpose of the research reported in this paper, the authors refer to individuals *preferring* numeric/logic/critical thinking activities as Left (L) oriented individuals (figure 4) whilst individuals preferring creative, artistic activities as Right (R) oriented individuals.

2.3 NEED TO EXTEND STUDENTS BEYOND THEIR L-R COMFORT ZONE

The underlying EngUstrial design training approach is to thus systematically motivate individuals to move beyond their comfort zone i.e. left-oriented individuals (see Figure 5) are trained in performing right-oriented activities and vice-versa. In this way, individuals will gain valuable skills beyond their normal preferred competences.

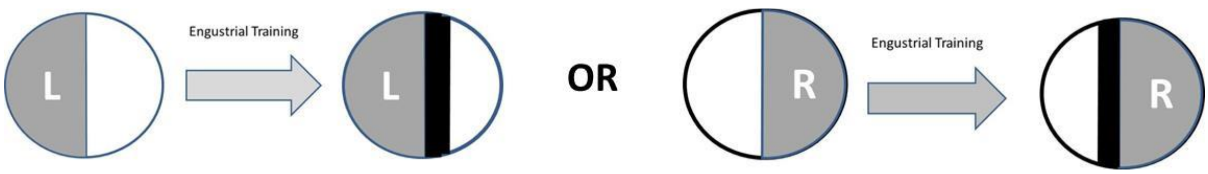

Figure 5: EngUstrial Design training intended to extend capabilities beyond the comfort zone

3.0 ENGUSTRIAL DESIGN TRAINING IN MALTA

The benefits of having students trained both from a left-oriented (L) and right-oriented (R) mind set are in theory logical to see. L-oriented individuals will gain some skills from a R-oriented side and vice-versa. In reality, in the case of the Engineering Degree at the University of Malta, the main weakness is that the content is too left (numeric) oriented. Hence irrespective of the L/R tendency of the individual students, the engineering design course needs to be complemented with mainly right (artistic) activities to provide a more balanced i.e. EngUstrial design training approach. However, achieving this goal in practice proves rather challenging for a number of questions:

- How can you persuade traditional engineering faculty staff that adding a range of non-engineering topics to an engineering degree course is beneficial?
- How can you motivate students that adopting a L+R training approach is beneficial?
- How can you facilitate a student's time-table to allow a L+R training approach?

Persuading Engineering Faculty Staff

The authors have over time found it challenging to persuade engineering faculty staff on moving away from purely engineering topics. On the contrary, there have been repeated attempts to increase L-oriented (numeric) topics. On a number of occasions, certain faculty staff criticized engineering design projects as they 'do not involve sufficient mathematical calculations'. The authors, based on feedback they received from industry were still convinced that their L+R design training approach was indeed the right one in the long-term for students. They have thus for the time being avoided the route of formally adding R-oriented (non-numeric) topics. As an alternative, they took up the route of motivating interested individual students on registering for extra curricular credits as outline further below.

Motivating Students to a L+R Training Approach

Students do not traditionally want to engage in more academic work than is necessary for them to graduate. Hence, expecting them to learn additional things is indeed a challenge. However, the authors have gained a number of years' experience that through the right and convincing motivation, a substantial number of students do actually engage in additional training activities. For instance, for over 6 years, the authors have managed to convince more than 30% of registered engineering design students to engage in a collaborative design exercise that takes place between the University of Malta and the University of Strathclyde (UK) (Wodehouse, Breslin, Farrugia et al., 2008). For this exercise involving collaborative sessions spread over several weeks, students gain nil credits. However, many register as they are motivated that this exercise will help advance their practical skills which they will find useful once they graduate. To somehow compensate for the time they spend on this exercise, students participating gain a 'Certificate of Participation' issued by both Universities. At the end of this exercise, the participating students do report back that it was indeed a rewarding experience and they actually recommend it to others. Hence on similar lines, students at the University of Malta, being trained along an *EngUstrial design* *approach* are motivated to engage in activities that will help extend their capabilities beyond their comfort zone.

<u>Facilitating Students’ Time-Table for L+R Training Approach</u>

Allocating time for engaging in learning skills beyond their comfort zone in an already busy time-table is indeed a challenge. However this challenge was offset because since several years, the University of Malta runs what is called a Degree*Plus* programme (www.um.edu.mt/degplus). It is not a core obligation of University of students to register. However, students are motivated on enhancing their profile through the options it offers. DegreePlus allows students to enhance their educational experience, profile and CV while studying for their degree. On the other hand, to make it easier for students to consider taking up a set of DegreePlus modules, all degree programmes have to leave two fixed weekly slots for such modules i.e two hours on Wednesday and Friday between 12.00noon and 14.00 hrs (see Figure 6).

B.ENG.(Hons.) IN MECHANICAL ENGINEERING Yr. II (SEMESTER 1)

	Monday	Tuesday	Wednesday	Thursday	Friday
08.00 - 09.00			MEC2340 - FLUID MECHANICS I - TS - **ELT**		MFE2101 - ENGINEERING METROLOGY - **LABS**
09.00 - 10.00	MEC2340 - FLUID MECHANICS I - MB - LABS - **FLUIDS LAB**	~~ENR2101 - ENGINEERING SYSTEM AND COMPONENTS - PV/PM/AR - TBA - (4th November only)~~		~~SOR1211 - PROBABILITY - VM - TBA (GROUP A)~~	
10.00 - 11.00	MME2203 - FERROUS AND NON FERROUS METALS - BM - LABS **(Science & Eng Students)**		MFE2101 - ENGINEERING METROLOGY - TBA - **LABS**	MEC2300 - ENGINEERING MECHANICS - KINEMATICS - MM - **TBA**	MME2203 - FERROUS AND NON FERROUS METALS - BM - **ELT**
11.00 - 12.00		ENR2101 - ENGINEERING SYSTEM AND COMPONENTS - PV/PM/AR - **ELT**			
12.00 - 13.00	MME2203 - FERROUS AND NON FERROUS METALS - BM - LABS **(Eng. Students ONLY)**		**DEGREE PLUS**	MFE2004 - COMPUTER AIDED ENGINEERING DESIGN - LF - **CAD LAB (Starting from 6th week) - GROUP 2**	**DEGREE PLUS**
13.00 - 14.00		MFE2004 - COMPUTER AIDED ENGINEERING DESIGN - **WKS 1-5 - JCB - ELT - ALL GROUPS ; 6th week onwards - PF - CAD LAB - GROUP 1**			
14.00 - 15.00			MEC2340 - FLUID MECHANICS I - MB - LABS - **FLUIDS LAB**	~~SOR1211 - PROBABILITY - VM - TBA (GROUP B)~~	ENR2101 - ENGINEERING SYSTEM AND COMPONENTS - **LABS/VISITS** - PV/PM
15.00 - 16.00		~~ENR2101 - ENGINEERING SYSTEM AND COMPONENTS - PV/PM/AR - GWD2 - (4th November only)~~		MFE2004 - COMPUTER AIDED ENGINEERING DESIGN - JPB - **CAD (Starting from 5th week) - GROUP 3**	
16.00 - 17.00					
17.00 - 18.00	MFE2101 - ENGINEERING METROLOGY - FEF - **ELT**				
18.00 - 19.00					

Figure 6: Fixed and Regular DegreePlus Time-Slots at the University of Malta

3.1 THE UOM ENGUSTRIAL DESIGN TRAINING APPROACH

Hence, based on the previous arguments, mechanical engineering students undergoing training at the University of Malta’s (UOM) Faculty of Engineering are motivated to follow the design training framework outlined in Figure 7.

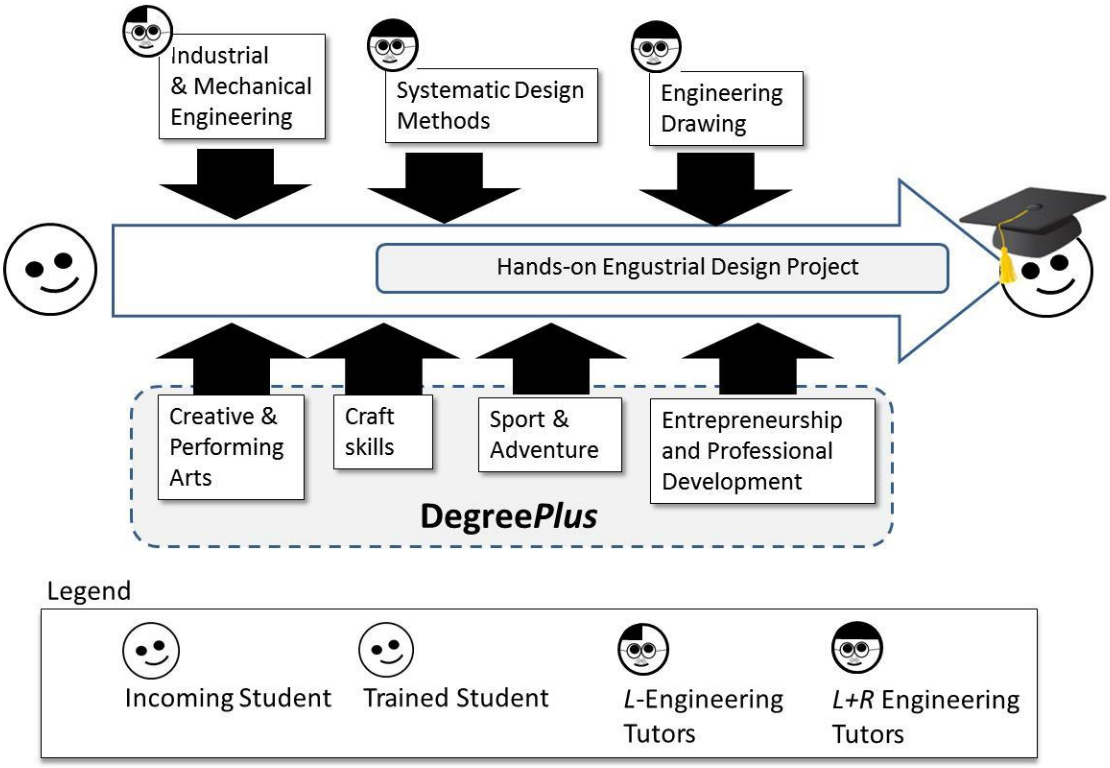

Figure 7: An EngUstrial Design Training Approach in Malta based on DegreePlus

Thus be exploiting the *DegreePlus* opportunity, the authors motivate students registered for the traditional Engineering Design course to also voluntarily register for Degree*Plus* modules that are of the right, vocational/artistic/physical type such as:

- Performing arts: DGP0930: Drawing and Painting
- Performing arts: DGP0940: Graphic Design
- Communication: DGP0980 Presenting Science Communication
- Entrepreneurship: DGP0103: Entrepreneurship
- Entrepreneurship: DGP0109: Financial Literary
- Music: DGP0707: Guitar
- Sports: DGP0800: Sports and Adventure Programme

In this way, students who volunteer to go down this route were undergoing training based on an EngUstrial design training approach as they were acquiring traditional numeric intensive competences as well as right oriented/creative/artistic skills.

3.2 LECTURER'S ATTITUDE IS KEY FOR EFFECTIVE TRAINING

A key aspect of the EngUstrial Design training approach is the mindset adopted by lecturers themselves. Traditionally left-oriented individuals have a difficulty in appreciating right-oriented aspects. As outlined earlier, a number of Faculty staff do actually expect to see more numeric intensive work and analysis and much less synthesis/creative/artistic training. Thus a key aspect of adopting an effective EngUstrial design training approach is that even the engineering tutors need to be willing to take a L-R attitude in their lecturing/mentoring activities. To improve this situation, the UOM EngUstrial Design training framework is based on involving lecturers that are L-R prime movers and that have very good working relationships with industry. Based on their own experience, the authors are of the opinion that lecturers can improve their L-R perspectives by:

- Getting **real world design problems** from industry as these have challenging specification, deadlines and budgets;
- Spending **time in industry** – for instance one of the authors spent substantial periods of his two year sabbatical carrying out empirical research observations in product development. Such exposure to the real world gives academics a very beneficial experience as they can get to know various facts including what the strengths and weaknesses of designers are.

3.3 TYPICAL STUDENT 'ENGUSTRIAL DESIGN' PROJECTS

To allow students to experience and EngUstrial design approach, student projects should require them to collectively engage in both R and L-oriented activities such as:

- Generate creative/innovative solution concepts/sketching (R)
- Generate detailed technical/functional design solutions (L)
- Involve numeric calculations (L)
- Involve analytical thinking eg. QFD (L)
- Design For 'X' (DFX) thinking (L)
- Consider Aesthetics/ User Emotions (R)
- Making physical prototypes (R)
- Marketing / sales/ financial planning (R)

For example, a group of students (Agius Anastasi, Borg, et. Al 2013) was given the goal to design a portable, foldable device for lifting persons from wheelchairs. In certain cases, especially when dealing with elderly people, lifting them up from wheelchairs, this presents a lot of challenges to the facilitators. Whilst lifters for handling bedridden patients at homes do exist, a device which assists facilitators when outside a home, is currently not available on the market. To this end, the goal of this design project is to develop a portableand foldable device for lifting persons from wheelchairs,which must satisfy a number of characteristics such as being lightweight, portable, adheres to international safety standards, has a competitive price, is aesthetically pleasing and can reach an annual product level of 1000. To achieve this goal, the respective student mechanical design team members had to experience using both a number of L-oriented and also R-oriented desogm means/tools such as those outlined in Figure 8.

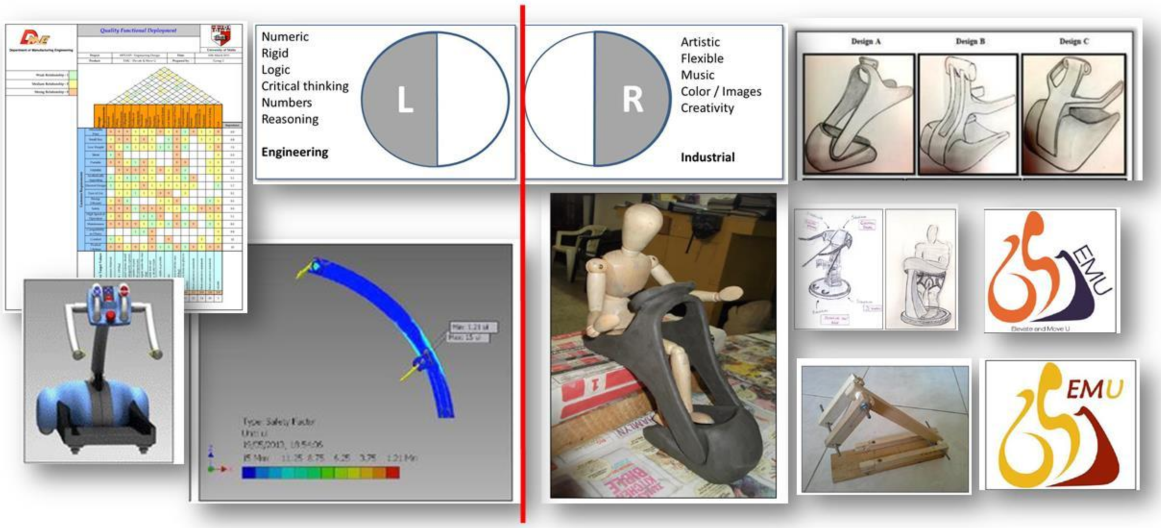

Figure 8: Typical mix of L-R oriented tools/methods used by student design team

3.4 THE IMPACT OF AN ENGUSTRIAL DESIGN TRAINING APPROACH

In order to assess if the envisioned engustrial design training approach provides improved benefits, the authors set out to evaluate the impact this has on training mechanical engineering students. Assessing the impact of an *EngUstrial Ddesign* training approach is indeed a subjective exercise. In principle, the ideal evaluation of this approach would be in the long-term by studying the career success and product design contributions made by graduate of the mechanical engineering degree. Given this is difficult to achieve, the authors resorted to a shorter-term evaluation approach based on observations resulting from their training experience. To enable a fair degree of evaluation, the authors have assigned projects to student teams composed mainly as follows:

- Type 'X' Teams: these are teams consisting of members that did not register for DegreePlus modules i.e. students following their engineering degree in a traditional way only and who do not have a history of training in right-brain oriented activities such as performing arts, sports, music etc.;
- Type 'Y' Teams: these are teams consisting of members that registered for at DegreePlus modules i.e. students that besides following their engineering degree also register for modules of the performing arts type, sport or have a history of training in such topics in the past. Hence Type 'Y' members are students who would have undergone an EngUstrial design training approach.

The selection of type 'X' versus type 'Y' team members was performed through a questionnaire given to students in the beginning of the academic year. Based on a range of questions, the authors classify individuals as mainly relevant for being part of a team 'X' or part of a team 'Y'.

3.5 CASE-STUDIES' OBSERVATION RESULTS

On average, each student design team consisted of (six) 6 members and over a four year period, the number of teams observed were a total of twenty (20).

Impact	**Type 'X' Design Teams**	**Type 'Y' Design Teams**
Technical quality of Solution Concept	✓✓✓	✓✓✓
Consideration of Industrial / Production Aspects	✓	✓✓✓
Solution's Novel Aspects	✓✓	✓✓✓
Solution is User-Oriented	✓✓	✓✓
Solution Presentation Style	×	✓✓✓
Solution Analysis (e.g. FEA)	✓✓✓	✓✓
Marketing / Commercial Aspects	✓	✓✓✓
Appeal of Solution to Industrial Evaluators	✓	✓✓✓
Appeal of Solution to Academic Evaluators	✓✓	✓✓✓
Potential to Patent/Commercialize	✓✓	✓✓
Team Cooperation & Knowledge Sharing	✓	✓✓✓

×= Poor ✓ = Good ✓✓ Average ✓✓✓= Very Good

Table 2: Observations concerning Type 'X' and 'Y' performance

When assessing the data/observations collected of type 'X' and type 'Y' teams, the results obtained are as outlined in Table 2 above. These reflective results do in no way provide a precise, objective picture of the impact an EngUstrial design training approach has on students. Nevertheless, the data collectively reflects that type 'Y' student teams generated a solution that was relatively better when compared to that generated by team 'X'.

4.0 LESSONS LEARNT FROM ENGUSTRIAL DESIGN TRAINING

The collectively positive results obtained encouraged the authors to share their experiences so that the engustrial design approach be taken up by others involved in training mechanical engineers. The lessons learnt are:

- Getting engineering faculty staff to agree that students will benefit if new non-numeric modules such as craft/art are formally introduced in a course degree is difficult to achieve;
- If correctly motivated, engineering students are nevertheless willing to acquire non-numeric skills through extra curricular activities;
- For effective EngUstrial design training, student project ideas should be sourced from industry and the goals set should have a good mix of objectives that require both 'L' and 'R' oriented input;
- For effective EngUstrial design knowledge transfer, engineering tutors need to be willing and also trained to take a L-R attitude in their lecturing/mentoring activities. Motivating

tutors to perform a sabbatical period in industry will indeed be useful for an EngUstrial design mindset;

- Engineering students will greatly improve their design skills if they can be given access to R-oriented education on topics such as performing arts, drawing, science communication, sports adventure, aesthetics and design for emotions.

5.0 CONCLUSIONS

Global trends are increasingly evolving the nature of mechanically engineered artefacts. As argued in this paper, there is thus a need to extend engineering students beyond their L-R Comfort Zone. One way of how this can be achieved is by prescribing an EngUstrial design training approach. Although it is indeed difficult to prove that the results obtained are solely due to the approach adopted, the reflections made are nevertheless encouraging. Thus, the authors preferred route of future training is indeed one increasingly based on the EngUstrial design approach. As implemented at the University of Malta, the mechanical engineering students did not undergo less numeric intensive training – rather they were motivated to take upon extra curricular credits that added value to their academic formation. It is also very encouraging for the authors to see their students being employed as design/innovation engineers with some of the world's most international firms. It is therefore hoped that the positive assessment of this EngUstrial design training approach be a motivation for others to exploit it and develop it further for the benefit of mechanical engineering design stakeholders.

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