A CASE STUDY ON A CONCEPTUAL DESIGN OF SOLAR THERMAL COLLECTORS USING A COLLABORATIVE FRAMEWORK OF ENGINEERING DESIGN AND PRODUCT DESIGN TOOLS

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ABSTRACT
The case study presented in this paper shows a project performed by undergraduate students of two UK universities on the conceptual design of solar thermal collectors. Such products are normally jointly investigated by engineers and designers to reduce their cost, while at the same time making them attractive to the consumer market in the UK. The project for students was constructed to emulate the real life situation in education. Although solar thermal collectors are a well proven technology that has been around for more than a century, they are still evolving. Designs are also changing to accommodate advances made with material technology, manufacturing techniques etc. Teams comprising of students from international product design of Glasgow Caledonian University and engineering design disciplines at City University London were physically distributed in these two locations. Various means of communication and an open platform for design tools were used by students. The different approach to the project by engineers and designers in performing the project, from the step by step analysis to the final concept of the product is investigated in the report. Designers appear as the driving creative force of the project, while engineers try to implement the designer's vision into the working product. The outcome of this report highlights the need for effective communication between different disciplines and different physical locations in order to enable both sides to contribute within their particular constraints of the project. This experience based project aims to reflect the increasing trend for design and innovation teams to be located in different geographical locations. Furthermore it provides students with the opportunity to obtain learning experience which reflects this trend.

Keywords: Solar collectors, conceptual design, engineering design, product design

1 INTRODUCTION

1.1 Overview of the project

The European Global Product Realisation (EGPR) course is an academic virtual enterprise of an industrial company and six European universities which was first introduced in 2002 [1]. The long term participating Universities are TU Delft, The Netherlands - Faculty of Industrial Design, EPFL Lausanne, Switzerland, University of Ljubljana, Slovenia - Faculty of Mechanical Engineering, University of Zagreb, Croatia - Faculty of Mechanical Engineering, City University of London, United Kingdom - School of Engineering and Mathematical Sciences and Technical University of Budapest, Hungary - Department of Machine and Product Design. The ultimate goal of the course is to develop a concept and produce a physical working prototype of the product within one academic semester using holistic approach to empower students with the set of competences required for their future employment. Furthermore it showcases the different approaches used by members of interdisciplinary groups, simulating an actual working and research environment. University students and academics closely collaborate in the realization of this course. Student groups consist of 5 to 8 members, with at least one member from each university and if possible from different disciplines [2].

Students from City University come to the course with an engineering background and little experience on performing such international and interdisciplinary projects. In order to equip them with the required experience a Preliminary collaborative EGPR project is run in the winter term just before the start of the full EGPR project [3]. Two UK universities, Glasgow Caledonian University (GCU) and City University London (CUL) participated in this preparatory collaborative project. Four groups of students mixed from both universities were formed in order to deal with the following problem; A company is looking to expand the market for solar collectors for heating water, particularly in the UK, and wants to investigate and invest in new technologies and concepts to develop cost-effective solutions and applications. The company is presented as a well-established manufacturer of solar collectors in the UK, and is well known for its willingness to investigate and develop new ideas into their products. For the company, the ultimate objective of this collaborative project is to develop new, innovative and cost-effective products which will lead to the increased business opportunities in new markets, and in particular, collectors which are easier and cheaper to manufacture, install and maintain over a 20-year life cycle. The company was represented by the GCU staff, namely a professor who has been in the field for a long time and a PhD student who intensively works in the solar thermal collectors field. This paper is written by this PhD student with the support from academics.
The students participating were required to perform structured engineering design process [4]. That process included comprehensive market research and conceptual designs resulting in at least three concept developments produced by each group. Quality function deployment (QFD) [5] was used by all four teams in order to focus on key points they wanted to expand on for the final designs.
The project commenced on the 11/09/2012 and was concluded on the 11/12/2012 with the final presentation of the projects developed by the four teams. The schedule of the project is given in the following table.

Table 1. Project schedule

Phase 1: Vision	6/11/2012	First Project review
	23/10/2012	Company and market research; customer profiling, forming vision, functional model, specification matrix, QFD
	5/11/2012	Identifying market gaps and preparing presentation for 1st project overview
Phase 2: Conceptualization	11/12/2012	Second Project Review
	13/11/2012	Concept development cycle. Exploration of product systems, operational characteristics, materials and manufacturing, user interface etc.
	20/11/2012	Refinement: Strongest proposal from the 3 concepts gets more detailed design
	3/12/2012	Preparation of professional presentation to client

2 MODULE BREAKDOWN

Three lectures in total were delivered to the students. The first one was on the technology of solar collectors, delivered by GCU. A lecture on engineering design processes was delivered by CUL and a final one on product design was delivered by GCU.

2.1 Introduction to Solar thermal collectors (23/10/2012)

The teams were briefed by an expert on solar thermal energy from GCU who was representing the company at the beginning of the course through videoconferencing. The briefing covered basic aspects of solar collectors, their basic designs, their advantages and their limitations. An overview of the briefing follows.
Solar thermal collectors can be used for both air heating and water heating. They are broken down into two categories concerning the movement of the working fluid in the system. Active systems use pumps or fans whereas passive systems rely on buoyancy of warm air or water to move around a system. The two prevailing technologies of this type of collectors are flat plate and evacuated tube collectors [6], [7], [8]. The students were not guided to use any of the two but rather just informed in

order to keep the project as fuzzy front ended as possible. The objective of the project was to develop an active solar thermal collector used for water heating with the following specification for the collector:

- The area to be between $1m^2$ and $4m^2$
- Lightweight
- Protected against freezing, overheating and to withstand weather conditions in general
- Easy to install. Installation aspects include lifting, manoeuvring, fixing and fitting the plumbing system
- To provide option for retrofitted to an older building, or installing in a newer one
- The type of manufacturing could either be a fully automated industrial process or a DIY approach.

2.2 Lectures on international product design and engineering design process

Two remaining lectures concentrated on the two aspects of the project namely, industrial design and engineering design. The former was delivered by the GCU academics with the emphasis on ergonomics, economics, and aesthetics of the product [9]. The later concentrated on engineering design process and was delivered by the CUL staff.

2.3 First Project Review

There was only one meeting in which all students and staff met in person. It was arranged on 6th November during the 1st Project review. The meeting was held at the GCU campus.

2.4 Four week interval

During the following four weeks the groups had allocated time slots for each group meeting officially organised through the videoconferencing suites at the universities. Additionally students had several meetings organised by the group members using Voip technologies such as Skype®[10]. Email conversation was encouraged between coaches and the groups and several meetings were arranged between groups and coaches. These meetings ranged from informal constructive discussions about the project to presentations of ideas for the final project.

2.5 Final project review

The final presentation took place on the 11th of December on the teleconferencing suites of both the Universities. Each team was given 20 minutes to present their work, followed by questions and discussion from the coaches. In the end of the presentations the coaches provided their feedback for the teams. Furthermore the two GCU experts acting as the industrial representatives provided their assessment about the final projects of the four teams.

3 FINAL DESIGN AND REVIEWS

3.1 Team 1 - Hotbox

Figure 1. Team hotbox

Team 1, named Hotbox, designed a solar thermal collector (Figure 1) consisting of a combination of two existing technologies, evacuated tube collectors and parabolic reflectors. This design was deemed to be technically very safe, as it is based on pre-existing technologies. Evacuated tube collectors work best in colder climates and parabolic reflectors need careful manufacturing and angle tracking in order to work at their maximum output.

3.2 Team 2 – Lux

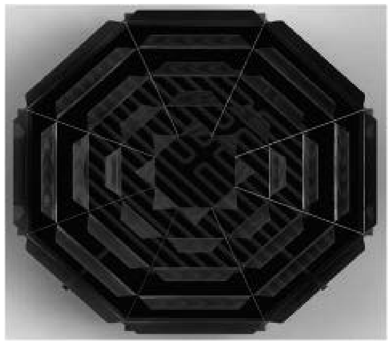

Figure 2. Team Lux

Team 2, named Lux, presented a design based on a bimetal laminate that would open on periods of high insolation in order to heat up the interior network of piping, and would close once insolation dropped so as to preserve the heat gained (Figure 2). This design appears to be aesthetically very appealing but also provides a radically new approach to solar collectors. According to the team's specification the laminate has working angle of more than 90 degrees. Material limitations exist for this concept as well as issues for it's life span arise based on the continuous mechanical stress that the bimetal laminate will experience over a typical solar thermal collector's lifetime. Another concern is with the safety of the product in situations when the bimetal petals are open.

3.3 Team 3 – Apsis

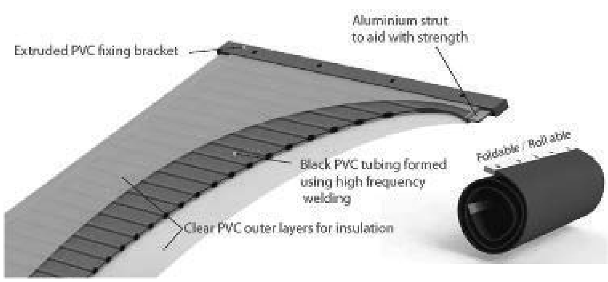

Figure 3. Team Apsis

Team 3, named Apsis, presented a flexible solar blanket manufactured from PVC that has the ability to fold and roll (Figure 2). This is a very innovative approach which may require extra care in the material selection in order for the blanket to retain it's desired properties for the lifetime of the panel.

3.4 Team 4 – Copernicus

Figure 4. Team Copernicus

Team Copernicus presented a design based on multifunctional Velux® [11] window (Figure 4) that would double as a solar thermal collector using and array of semi- transparent polymer. Since there is compromise in the transparency of the windows, this design shows much promise in the case where the windows are to be used as skylights, compared to their usage as normal windows.

3.5 Assessment

The assessment of projects was provided by the specialists in solar thermal collectors who represented the manufacturing company and it was given in three different categories namely, aesthetics, innovative value, and technical feasibility. The assessments are shown in Table 2 below.

Table 2. Assessment of individual projects

Team name	Product technology or description		GCU Specialist #1	GCU Specialist #2
#1 Hot Box Coached by GCU	Evacuated tubes + parabolic reflectors	Aesthetics	C	C
		Innovation	C	C
		Techn.feasibility	A	A
#2 Lux Coached by GCU	Bi-Metalic strips to open petals	Aesthetics	A	A
		Innovation	B-	B
		Techn.feasibility	C	D
#3 Apsis Coached by CUL	Flexible Solar blanket	Aesthetics	B	B
		Innovation	A	A
		Techn.feasibility	B-	B-
#4 Copernicus Coached by CUL	Velux/skylight window combination	Aesthetics	C	B+
		Innovation	B+	A
		Techn.feasibility	B-	B

4 CONCLUSIONS

The four groups of GCU and CUL students had two different educational backgrounds, namely GCU students were educated in industrial design while CUL students have an engineering design background. Based on experiences obtained by the coaches, there was a clear trend in distribution of work. Product design students appeared to be the leading creative force of the teams. They were not hesitant to try ideas which often looked very innovative. The focus of the industrial designer members in a group was on aesthetics and application of the concepts produced. The students with engineering design background seemed more reserved and cautious in trying out new ideas but contributed to the feasibility of the solution and engineering aspects of it. Their focus was on the application of engineering design process and keeping the capital, operating and maintenance costs down while enhancing efficiency of the developed concept.

Due to the educational and cultural diversity of students, effective communication proved to be the most important factor for success. Teams that communicated more frequently, produced final concepts which showed more thorough research and enhanced creativity. While students were working on a concept, new challenges were coming up, that were not evident from the start. These had to do with the complexity of the chosen concepts, as well as the different approaches used by members of the interdisciplinary teams. A trend that became evident was that the more the concept was worked on, the communication between members of the team was becoming more effective. Furthermore, communication with company representatives was very important; students realised that only in the later stages of the project. It again was proved that this type of projects is very beneficial to students. More collaboration between Universities would help to enhance student's experience.

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