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Biomedical Engineering Education through Global Engineering Teams

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Abstract— **Most industrial projects require a team of engineers from a variety of disciplines. The team members are often culturally diverse and geographically dispersed. Many students do not acquire sufficient skills from typical university courses to function efficiently in such an environment. The Global Engineering Teams (GET) programme was designed to prepare students such a scenario in industry. This paper discusses five biomedical engineering themed projects completed by GET students. The benefits and success of the programme in educating students in the field of biomedical engineering are discussed.**

I. INTRODUCTION

At some universities, engineering education remains focused on the traditional approach in which a teacher delivers lectures in front of a class room of students. In this approach, information flows in one direction only with little or no input from the student to the learning process. In industry, graduate students will most likely be working on projects with time-lines of months or years and in groups with other employees with a variety of backgrounds, both in education and culture. Many institutions, recognizing that the traditional approach does not prepare the students adequately to function efficiently in such a scenario, have developed a new approach that focuses on real-world problems requiring students to work in teams. The students are at the centre of the learning process and must use critical thinking to produce tangible results that would be of value to industry. The educator now becomes a facilitator, guiding the students and providing technical input when required, as determined by the students.[1]

An example of the new approach is the collaborative project orientated Global Product Development (GPD) course of Technische Universität Berlin (TUB, Germany), the Seoul National University (Korea) and the University of Michigan (USA) [2]. Groups are made up of two students from each partner university. They work via telecommunication from September to December on a very broad theme of a product category assigned by the teaching staff. Examples are “internet ready product”, “dual use product” or “product for learning”.

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The National University of Singapore has created a biomedical engineering (BME) curriculum built around design projects. *Toh* and *Goh* discuss the focus of the curriculum and it’s benefits to graduates when entering industry [3]. They believe their design-centred curriculum helps develop the “spirit of innovation and enquiry, integrative skills, and critical thinking skills in the students”. In particular, one of their design modules’ goals are to provide students the basic tools and skill sets to allow them to develop solutions for real world medical challenges.

Krishnan presents a model for educating biomedical engineers by project-based learning with international collaboration [4]. Within his model, *Krishnan* discusses how students should be strongly encouraged to learn new things in order to solve the problems in the project. In this way, the project becomes the driving force for learning. He believes students to be more responsive to real, complex problems. Noticeably, the paper mentions how project-based work should not be intended to replace classes, but should run congruent with these more traditional teaching techniques.

A paper particularly looking at BME education in developing countries was written by *Douglas* [5]. *Douglas* states that whilst developing countries have capabilities in BME similar to those of the developed nation, the developing countries can learn from their developed counter parts in terms of education programs in this field. To successfully solve complex problems with BME, *Douglas* states collaborative efforts between individuals of a variety of disciplines is required.

II. GLOBAL ENGINEERING TEAMS

Global Engineering Teams (GET) is such an industry, project-based course and was developed in 2004 by Marco Eisenberg [6]. Companies submit actual problems from their respective industries and students work on these problems in groups of between four and six people, for 25 weeks. Each group of students is also assigned a supervisor to act as facilitator.

There are a number of partner universities, from which students enrolled in engineering courses at these universities may partake in GET. The main partner universities at present include Stellenbosch University (SU, South Africa), Pontificia Universidad Catolica (PUC, Chile) and the Technische Universität Berlin (TUB, Germany). The students within a group vary in disciplines and culture. Only two students per team are from the same country and the team supervisor is from one of the partner universities. For the majority of the project, group members will be geographically separate, as they undertake their work in their respective countries.

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Team members communicate using modern telecommunications tools as they work on the projects. The projects from industry are usually in the area of product development or experimental/numerical analysis, but in either case are real problems which the industry partners are concerned with. The industry partner defines the user requirements and/or project objectives, and expect results that will be of high value to the company.

The course begins with a kick-off meeting in April, whereby all the students and educators spend a week together at one of the partner universities. This meeting serves to define the conceptual formulation of the assigned project and group members responsibilities in a face-to-face cooperation. During the project work, there are three milestones. At each milestone the team must present their technical deliverables in a report and oral presentation via video-conference, and they are evaluated by the professors of the cooperating universities and the industry partners. It ends with a one week final meeting in October, at TUB. In this final meeting, groups will present their results to an audience of examiners, industry partners and fellow students. [7]

The themes of the projects have varied greatly from year to year [8]. A number of projects have been in collaboration with the Biomedical Engineering Research Group (BERG) at Stellenbosch University, to train biomedical engineers within the context of global engineering teams. This paper summarizes a few of these projects as an example of project oriented learning of global biomedical engineers.

III. BIOMEDICAL ENGINEERING PROJECTS IN GLOBAL ENGINEERING TEAMS

A. *Vanguard (2005)*

The goal of the *Vanguard* team was to develop a concept for refurbishment of single-use medical products and ultrasound equipment for Brazil and Germany. The scope was to analyse the Brazilian and German market for both categories of products as well as legal restrictions in both countries. In parallel, an analysis of the technological requirements for refurbishment had to be performed. The results from analysing these multiple aspects had to be merged in a consistent strategy for the industrial partner. The team was comprised of seven students: One student of physics and one student of thermodynamics from TUB, two students of mechanical engineering from USP, one student of material science and two students of mechanical engineering from The Federal University of Rio Grande do Norte (UFRN).

The team decided to break down the work into five work packages (WP), four to be performed in sequential order and one as a continuous work over the complete time. WP 1 was analysing the process of refurbishing single use medical products. WP 2 was analysing the re-manufacturing process of ultra sound devices, whilst WP 3 was analysing the legislation in Brazil and Germany. WP 4 was planning, conducting and evaluating of telephone interviews. Here the team started on a qualitative basis and adapted the questionnaire with increasing knowledge about the market until it had a quantitative relevance. This was performed in parallel to WP 1-3. WP 5 consisted of developing a market entry strategy for *Vanguard*.

This resulted in over two hundred documented detailed phone interviews and an additional 300 pages report on the technological and legal aspects. A strategic recommendation for *Vanguard* could be formulated that indicated that an entry into the Brazilian market for *Vanguard* could be highly profitable due to 30 to 50 percent lower costs by providing the service in a Brazilian facility and a high demand especially from private clinics. The conditions under which this option should be used and the obstacles that are on the way to that market were part of the strategic report. [9]

B. *MobiMed (2010)*

This project was done in 2010, for the industry partner *MobiMed*, and was titled *Development of a Mobile Phone Based Ophthalmoscope for Telemedicine*. *MobiMed* identified a need for doctors in South Africa to be enabled to make remote evaluation of hypertensive and diabetic patients. This was as a result of nurses at rural clinics lacking the skills to evaluate patients using opthalmoscopy. The members of the group consisted of two South Africans, enrolled in a masters programme in mechatronics at US, and two Germans, enrolled in a masters programme in computer science at TUB.

The group successfully developed a working prototype. The prototype firstly consisted of an attachment for a standard digital camera and opthalmosocope (see figure 1, left). The attachment had five degrees of freedom and could be adjusted for a variety of cameras. It was designed to fit with a *Welch Allyn PanOptic* opthalmoscope.

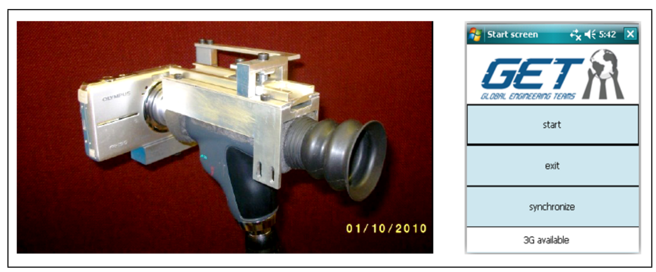

Fig. 1. The camera-opthalmoscope attachment (left) and a screen shot of the mobile phone application (right)

Secondly, the prototype consisted of a mobile phone with an application developed by the group. With the mobile phone application, the phone is able to receive the images taken by the camera of the patients eye, via wi-fi. Using the graphical user interface (GUI) of the application (see figure 1, right), the user is also able to input all necessary data relating to the patient. The final aspect of the prototype was the development of a web-based application. This web application is able to receive all data relating to the patient, including that patient's opthalmoscope images. Doctors are able to few the patient's data by accessing the web application online and administer the necessary medical advice via the website. This advice is then sent by SMS to the clinic.

C. InnovUS - Oxyscope (2010)

The industry partner for this project was *InnovUS* of Stellenbosch. One industrial engineering student and one theoretical engineering student from TUB, one mechatronic engineering student and one mechanical engineering student from US, made up the four group members.

During orotracheal intubation, which involves the insertion of a tube into the trachea, preoxygenation may be insufficient. Examples of when this might occur, are when a patient suffers from serious lung or heart pathology. The patient is then unable to absorb sufficient amounts of oxygen. Other cases which also prove difficult, are accident victims (blood and gastric expulsion may be present) or infants (small airway).

These factors provided the motivation for the project; the development of the *OxyScope*. The *OxyScope* is essentially a modification of a standard laryngoscope that incorporates a fixed oxygen supply duct, thereby preventing oxygen starvation during an intubation procedure. The group was to design the blade and then perform the necessary fluid dynamics analysis of the design to predict how it might function in practice.

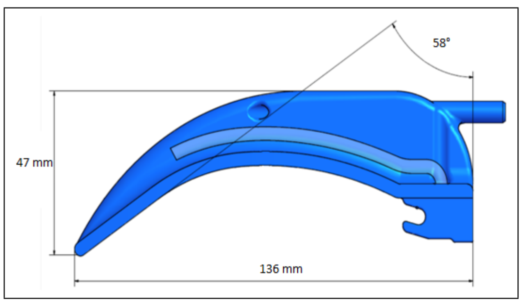

Fig. 2. *OxyScope* Blade geometry and dimensions

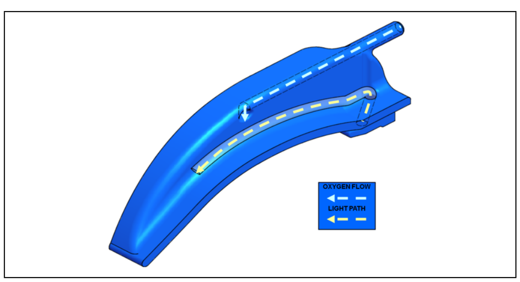

Fig. 3. Oxygen flow and light path of the *OxyScope* blade

Figures 2 and 3 show the blade dimensions, and the oxygen flow and light path of the final design, respectively. The group performed a Computational Fluid Dynamics analysis on the design, based on a 3D flow model that resembles the actual oxygen flow path within a person. The analysis indicated that sufficient oxygen is administered to the patient, deeming the project a success. It also showed that the flow of oxygen is fairly smooth and straight at the vocal chords for outlet angles of between $45°$ and $60°$, mitigating the risk of laryngeal spasms.

D. InnovUS - Respiratory Function Monitor (2011)

The team was made up of two members from US, with disciplines in mechatronics and electronics, and two members from Pennsylvania State University, with disciplines in mechanical engineering. As with the previously discussed project, the industry partner was *InnovUS*.

When a medical practitioner provides ventilation to a patient, an excess amount of air may cause damage to the lungs. The motivation for the project emerged due to a lack of cost efficient and portable pulmonary function monitors, that would warn doctors of possible volutrama to the lungs in emergency scenarios. The objective of the project was to design a portable, hand-held, flow-volume monitor. The device was to measure and rapidly numerically display, flow rate and tidal volume during positive pressure ventilation of adults in emergency resuscitation situations.

A computer-aided design (CAD) model of the prototype developed by the group is shown in figure 4.

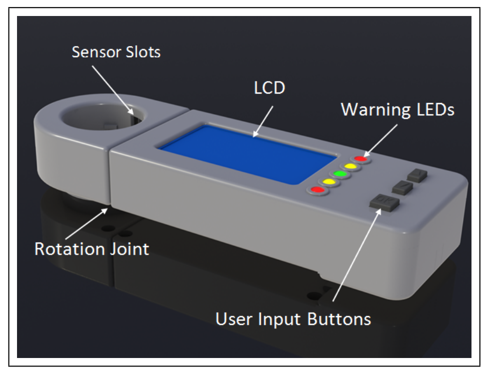

Fig. 4. A CAD model of the prototype developed by the group, with labels showing some of the components aiding to the functionality of the device

The dimensions of the prototype were $17.9 \times 5.7 \times 2.6$ cm^3. Tests were performed and the prototype was able to detect respiration flow rates with a lightweight, off-the-shelf turbine sensor. The electronic casing can be used across multiple patients, while the turbine and reducers were disposable for sanitary reasons. Figure 5 shows a CAD model presenting how the prototype will be combined with an inflation bag in practice.

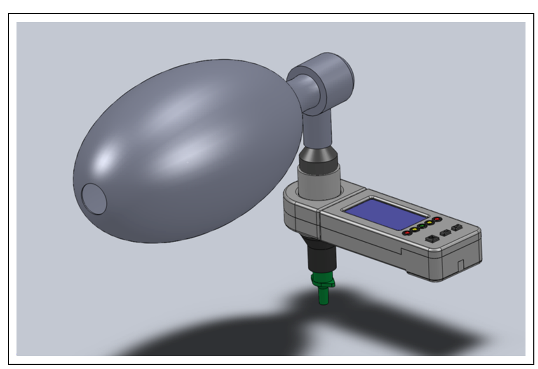

Fig. 5. CAD model presenting how the prototype will be combined with an inflation bag

E. Medical Research Council of South Africa (2011)

Obstructive lung diseases such as asthma and emphysema are conditions affecting both developed and developing country populations. These two respiratory diseases and many others such as chronic bronchitis and fibrosis may be diagnosed with the aid of a spirometer. The Medical Research Council of South Africa (MRC) identified the need for a spirometer, capable of providing an inexpensive system for clinics in rural areas to diagnose and manage respiratory diseases.

The group consisted of two students enrolled at US in masters programmes in mechatronics, and two students enrolled at TUB in masters programmes in computer science. The objective of the project was to design, implement and deploy a system that allows remote diagnoses of respiratory diseases. This included the construction of a low-cost spirometer device to interface with the mobile phone, and the development of the mobile phone application to process the data from the spirometer device. Finally, the deployment of a web-based Patient Management System (PMS) that stores the data and allows authorised users to access it, was also to be performed by the group.

Figure 6 shows a CAD model of an exploded view of the spirometer developed by the group. The turbine used was a disposable, off-the-shelf turbine. The spirometer connected to the mobile phone via the phone's 3.5 mm jack. The mobile phone application was able to analyse the signal received from the spirometer to produce a Maximum Expiratory Flow-Volume (MEFV) curve of the forced exhalation, performed by the patient, see figure 7 (right). This curve is vital to health practitioners in performing a diagnosis. A GUI for the mobile phone application was developed to allow the user to input all patient data and navigate about the application, see figure 7. This GUI also allows the user to upload all patient related data to the PMS.

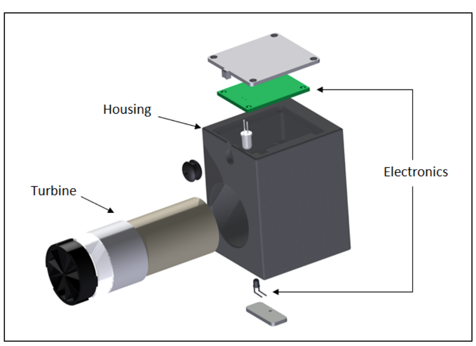

Fig. 6. CAD model presenting an exploded view showing the components of the prototype

Finally, the web-based PMS was created and functioned correctly in that it allowed users to upload patient data using the mobile phone application, and it allowed users of the website to send messages back to the phone.

IV. Conclusion

The success of the projects discussed above have led the organizers of GET to justifiably believe that it is possible to

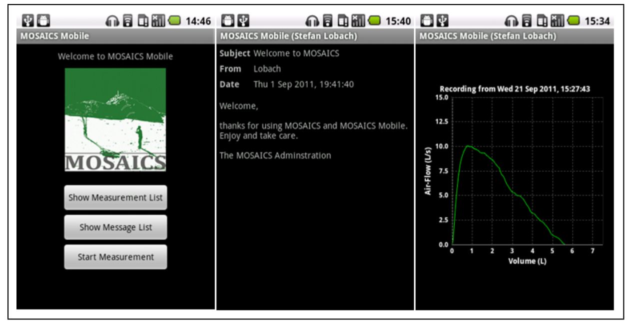

Fig. 7. GUI screen-shots, showing the MEFV curve (right).

deliver quality BME design and analysis, in a long distance, student group, work environment. The work environment created by the GET programme is highly similar to what these students will experience follow graduation if they find themselves in industry. This is of course also highly beneficial to future employers who often expect graduates to be able to "hit the ground running". Leadership and to a certain degree, decision making, are difficult skills to impute to students in the typical lecture learning environment. It is believed that GET may be a vehicle to grow and develop such skills in students.

V. Acknowledgements

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