

DEVELOPING TECHNOLOGIES AT CITY UNIVERSITY

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ABSTRACT

Developing Technologies (DT) has been facilitating and supporting design, make and test engineering projects linked to real needs in developing countries for 8 years. Its aim is to use student project work to provide low-cost technical support to organisations working in developing countries. DT operates as a UK registered charity that was initially based at Imperial College London in 2002, moved to City University London in 2008 but still operates in both institutions. These projects provide both a valuable educational experience for the students and can also have a beneficial impact in helping to relieve poverty in the target countries. Projects are found from a range of clients and are vetted to ensure they provide a good learning experience and a useful output can be achieved within the resources available to the students. Students are highly motivated by working on real projects with the potential to help poor people in developing countries. Examples are given of a number of projects that were started by students at Imperial College and are now being implemented in the field. A further example is given of a large group project for 15 students based at City. DT raises funding to support projects, particularly for overseas implementation, and also to support an experienced engineer to co-ordinate exploitation of projects and help with supervision of projects. Five projects are now in progress at City University, four individual projects and one group design project. These are all in Mechanical and Automotive Engineering but it is hoped there will be interest to diversify into other disciplines.

Keywords: Student design projects, international development

1 INTRODUCTION

Two of the major global challenges currently facing society today concern sustainable development and world poverty. It is widely recognised that engineering disciplines within higher education have an important role to play in any response to these challenges, in developing capacity for low-cost sustainable solutions to a range of real-world problems, particularly those that promote solutions to global poverty. As yet, however, such potential within universities remains relatively small globally. Students are typically aware of the problems of world poverty and are interested to give both time and energy to efforts aimed at solving these problems. If combined with a recognised course of study for which they can be credited, the effect is beneficially compounding in both generating useful work to help solve problems of poverty yet at the same time create a high degree of motivation to students to learn and develop engineering knowledge and skills which leads to the second benefit. Global concerns also present key motivating factors for the study of engineering. Indeed, a recent submission by the Royal Academy of Engineering [1] highlights the desire to make a contribution to society as a key factor in students' choice to study engineering. One recent study Hokanson et al, 2007 [2] further suggests that underrepresented groups in engineering, particularly women, may be attracted to careers which they sense offer scope to have a positive impact on society. Meanwhile, a recent report by the Henley Management College [3] reports the numbers of students opting for engineering courses in the UK in the 10 years up to 2004 remained static, with less than half the engineering cohort choosing to enter the engineering profession after graduating from college. A recent report from the Higher Education Funding Council for England similarly confirms the overall picture in identifying engineering as a subject to be targeted as 'strategically important and vulnerable' [4], pointing also to a decline in the number of engineering students as a proportion of the higher education population. There thus remains a pressing need for undergraduate engineering education to address student motivation.

In response to this but also to encourage efforts to reduce developing world poverty, a new mechanism was devised in the form of the UK Charity Developing Technologies (DT). It was set up in 2002 initially at Imperial College London and later moved to City University London in 2008 but still operates in both institutions. The purpose of the charity is to generate suitable projects and support engineering technological development through student project work with the aim of producing useful solutions for the developing world.

As can be expected, this is not a straight forward thing to achieve given two particular challenges:

- 1) Ensuring projects are appropriate with potential for reducing poverty – these are typically generated by Non Governmental Organisations (NGOs) within the countries with which DT works so DT is responding to genuine needs.
- 2) The projects are suitable for student project work in the context of engineering higher education degrees. The projects must neither be too simple nor too demanding and possible within the timescales defined by the degree programme. Many projects are run over two or more years however as required.

In order to meet these challenges, a Professional engineer with substantial experience of engineering in the developing world and higher education, the Developing Technologies Coordinator is employed. The charity DT raises money through various sponsors predominantly to support this post. In addition to this, further work is done by trustees and other helpers on a voluntary basis.

2 ASSESSMENT OF THE DEVELOPING TECHNOLOGIES APPROACH

A detailed assessment of the work of Developing Technologies was carried out and reported in Kahn and Pullen [5]. This study outlined an evaluation of the effectiveness of the partnership between Developing Technologies, Imperial College London and the development professionals, looking at its role in educating students for development work. Two specific issues were considered relating to enquiry-based learning that had received relatively little attention: how to ensure fairness to students who are pursuing lines of enquiry that involve varying levels of challenge; and the connection between the underlying basis for an enquiry and student motivation, with the link in this case made through sustainable solutions that are designed to tackle global poverty. This evaluation explored a human basis for education: realistic enquiries that in specific ways addressed issues of global concern, with the support a charity. While it was recognised that this stage of the research was drawn on a relatively limited set of data, it was possible to draw initial conclusions on the effectiveness of the partnership, and also highlight a number of key issues. The study also found ways in which partnership had enabled engineering students to assist in contributing solutions to world poverty as a part of their degree programme. Not only could student work be of direct value but such an approach has also been seen to underpin learning that is driven by a process of enquiry. Education within other professional disciplines similarly offers scope for student enquiry that directly serves the interests of others. This is particularly likely to be effective where students offer professional services on a pro bono basis, in collaboration with academics and professionals operating within the field. They are thus able to draw on a deep well of motivation that may help to underpin student enquiry.

3 PROJECT EXAMPLES REACHING THE STAGE OF IMPLEMENTATION

3.1 Drilling water wells

This project came via the DT website from a small community organisation, Rural Water Aid (RWA), working in the Bo region of Sierra Leone. RWA was attempting to hand-dig water wells for local villages but meeting problems in penetrating rock to reach the water table. Help was requested to develop a low-cost drilling technique to reach the water. An initial review was carried out to ensure no ready solutions existed and to develop specifications for a student project. The vital need for improved water supplies in developing countries to reduce water-borne disease is well documented. In sub-Saharan Africa around 300 million people do not have access to a clean water supply and to achieve the Millennium Goal to halve this by 2015 will require almost a million new wells. Sierra Leone is one of the poorest countries in the World with one of the greatest needs for improved water supply so that the project was considered to have great potential to improve the lives of local communities and also have impact on a wider scale.

Most wells are drilled by large commercial rigs which because of their size make access to rural areas a problem and because of high cost make water wells expensive. Hand-digging and manually operated drills are common but limited in capability. The review suggested a niche for a low-cost drilling rig at

the lower end of the above range that was appropriate for rural areas and provided potential for setting up local drilling enterprises.

The problem was set as a Year 3 Design Make and Test project at Imperial College in 2005/6 and taken up by a group of 4 students. Their first tasks were to carry out a literature search and to liaise with the client, RWA, to clarify the need, constraints and specifications. This led to the concept choice of a percussion drill in which heavy tools are repeatedly raised and dropped to sink the well with a range of tools to break up and extract the soil and rock. The specifications set were to drill to depths of 30 to 40m using tools weighing up to 250kg with an average drop depth of 2m at 10 drops per minute. The main technical requirement was to find a suitable power source of 5kW and design an appropriate transmission to drive a winch at around 120rev/min with a clutch to repeatedly engage and disengage the drive for the lifting and dropping of the tools. This involved a number of challenges including the high reduction ratio needed, the inertia of the tools and transmission and limiting over-run of the winch. After considering various options the chosen solution was to combine the power and transmission by using a motorcycle driving through a rolling road arrangement. A separate clutch was designed involving the use of a motorcycle wheel mounted on a hand-operated lever to drive a flat pulley. This gave a solution appropriate for manufacture and maintenance in developing countries. This rig is shown being tested in Figure 1 with bags of sand being used to simulate the tools. Having proven the design in the student project it was taken over by a graduate volunteer who, after discussions with the client, adapted it to use a pick-up instead of the motorcycle and then manufactured drilling tools to successfully drill a 15m well on a property in Kent. This provided the confidence to transfer the rig to the client in Sierra Leone which was done by the volunteer in 2007. The initial trials in Sierra Leone are shown in Figure 2. These trials showed that a 20m well could be drilled in 3 to 4 days at a cost of around £750, about half the cost of hand-digging which could take 2 to 3 months, and able to drill in soil conditions where hand-digging was not possible.



Figure 1. Student prototype drill rig



Figure 2. Drilling well in Sierra Leone

There have been further volunteer placements in 2009 and 2010 to work with RWA in improving drilling techniques and investigating the feasibility of setting up a water services enterprise. A number of community wells have been drilled leading to a contract to provide 4 wells for the Gola Forest conservation project. In addition a partner UK charity, the Africa Research Institute, has upgraded the DT rig design to incorporate a diesel engine drive instead of the vehicle drive. This rig has been widely tested in Tanzania and also demonstrated in Zimbabwe.

3.2 Motorcycle ambulance-trailer (MAT)

Some of DT's projects result from identification of a general need rather than a specific need from a client. For example, this project is based on the co-ordinator's previous experience as a rural transport consultant. Surveys in a number of countries in sub-Saharan Africa (sSA) showed a major concern of rural families was a lack of effective and affordable transport for health emergencies. This was particularly the case for women since many emergencies are caused by maternal and infant problems. This need has more recently been recognised in Millennium Goals 4 and 5 which deal with infant and maternal deaths. It is widely agreed that the key factor in achieving these goals will be to provide a

skilled attendant at all births and an integral component of this is to improve access to affordable emergency transport services.

Conventional ambulance services are scarce in sSA because of their high initial and running costs. The need for a lower cost ambulance was tackled by the co-ordinator in a study of options resulting in the concept of an ambulance-trailer towed by a motorcycle. A prototype was manufactured and tested in a pilot project in Tanzania, successfully completing over 10,000km in an emergency service from a rural health centre to a referral hospital, a distance of 48km, and saving a number of lives.

The concept was taken over by DT in 2004 with a student project at Imperial College to review and improve the design which included a finite-element study to minimise the weight of the frame. Two prototypes of the improved design were then manufacture with a partner in Zambia, the Disacare Wheelchair Centre, through a volunteer placement and trials initiated at Government Health Clinics. The design details are shown in Figure 3 and one of the prototypes in Zambia in Figure 4. The volunteer working with Disacare technical staff produced a comprehensive manufacturing manual which is available through the DT website.

Unfortunately because of very limited funding and the lack of resources in the clinics the trials have been rather stop-start and have not yet yielded the data needed to promote the concept on a wider scale but it is hoped to rectify this in the near future. In the meantime the project has yielded a number of student projects both undergraduate and post-graduate mainly investigating the dynamics of the trailer and its interaction with the motorcycle including three group projects to design and test ideas for low-cost suspensions to improve the comfort of the patient. Overall this project with its considerable human appeal has provided a very motivating and educational experience for about 25 students

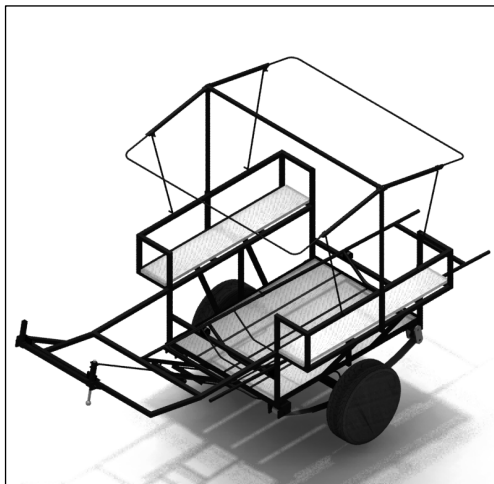


Figure 3. Design details of MAT



Figure 4. MAT prototype in Zambia

4 LARGE GROUP PROJECT EXAMPLE - VEHICLE FOR RURAL AFRICA

BEng and MEng Mechanical and Automotive students at City University undertake the Design Module as group exercise forming a core part of 3rd year plus 4th year for MEng.

Until recently, the major option for students was Formula Student in which a small racing car is designed, built and tested as part of a competition. Projects under this umbrella are run at nearly all engineering schools and departments in the UK and many other countries. One other option was available but for few students. It was hence decided to offer students an alternative with the support of Developing Technologies. Unusually, the topic was not generated in response to a direct request from overseas but generated by the Developing Technologies Coordinator based on many years of experience of what is really needed as a solution to transport limitations in sSA.

It was known that the majority, often 70 to 80%, of people in countries of sSA live in rural areas, generally in poverty. They are mainly subsistence farmers, growing enough food to feed their family and if they are lucky a little surplus to sell in the local market. The latter is their main, and often only, source of income that is needed for education, health care and other household necessities. Increasing this level of income is considered to be the main means of helping rural people improve their livelihoods and grow out of poverty.

Trips to the local market are generally lengthy, often more than 5km and sometimes over 20km, and usually on poor earth or gravel roads. Affordable transport is limited and the main means of transport

is by walking carrying loads on the head or back. This a considerable burden in time and effort, especially for women who do much of the carrying, and is a major constraint on development. The need is for low-cost vehicles with good load-carrying capacity that are cheap to run. The poor roads limit speed so that low power, low speed vehicles are far more fuel-efficient and environmentally friendly.

The objective of this project was hence set to develop a vehicle to meet the above need, the Vehicle for Rural Africa (VFRA). This was to be aimed at use by transport service operators who would carry people from the village to market at affordable fares. The specifications for the vehicle were defined as follows:

- Low-cost, i.e. maximum of £1,000
- Capable of transporting up to 0.5 tonnes on rural roads
- Maximum speed around 25mph
- Appropriate for manufacture and maintenance in rural Africa

The project was offered in October 2009 and only 4 out of a potential 40 elected to do the project. The students who chose this project were undertaking a considerable challenge both in attempting a new project and also being such a small group. Directing students to achieve a set purpose such as Formula Student and yet meet educational goals is not an easy one. The VFRA project was similar to Formula Student in this aspect whilst being very different in others. The advantage of having a real problem to solve was substantial in increasing motivation but in a group project, students of different abilities and effort work at different paces. The format of coursework submissions adopted from Formula Student is given in Table 1. Note that there are two 11 week terms and the third term is taken up mainly with final exams and the individual project.

Table 1. Format of submissions for the Part 3 and 4 Design Module

Submission (Name and brief description)	% Marks	Deadline
Design I – Name and describe function of part or parts responsible for	5%	Term 1, Week 2
Design II - Create Product Design Specification for part or parts	5%	Term 1, Week 6
Design III – Produce a number of design concepts and critically assess	10%	Term 1, Week 10
Design IV – Final Design with engineering analysis leading to full CAD definition	25%	Term 2, Week 1
Design V – Production of high quality manufacturing drawings	10%	Term 2, Week 5
Design VI – Final report summarising entire design process and final design	15%	Term 2, Week 9
Manufacturing Plan - Gantt chart stating tasks and milestones for manufacturing	5%	Term 2, Week 8
Presentation 1 – Summary of progress, input into communication skills	5 %	Term 1, Week 11
Presentation 2 - Summary of progress, input into communication skills	10%	Term 2, Week 11
Conduct of task – Marks given for effort, attendance in plenary and team meetings	10%	N/A

Initially it was planned that the students would follow this format but it became clear that given the size of the task and the small number of students it would not be possible. Instead the four students were guided by close supervision of the Developing Technologies Coordinator and the marking scheme was modified and adapted accordingly. The students designed a vehicle as shown in Figure 5 and partly manufactured it. However, it became evident that there were considerable design problems to overcome so the project was offered in the following year. All four students volunteered to stay on after their exams and submission of their individual project report to work on the VFRA along side students participating in Formula Student, also working as volunteers to complete the car ready for the competition in mid July.

Given the good experience of the 2009-10 project, VFRA was offered again and this time 15 students took this up. Students were split into 3 groups to work on particular parts of the vehicle as follows:

Group A – Engine and controls

- Set up engine and get it working; predict vehicle performance from engine characteristics
- Design and set up controls – kick start, clutch, throttle, gear change
- Design means for testing performance at the drive wheels in the lab

Group B – Transmission

- Check mounting of wheels
- Connect drive and test
- Design drive to give second option of having only one wheel driven
- Set up and test performance of brakes
- Design for reverse gear

Group C – Chassis and steering

- Design and set up pivot arrangement between rear and front chassis; consider effects of operating on rough roads and what degree of freedom is needed in the pivot
- Design and set up steering including analysis of steering forces
- Check suspension stiffness; estimate level of impact loading on chassis; is chassis strong enough?

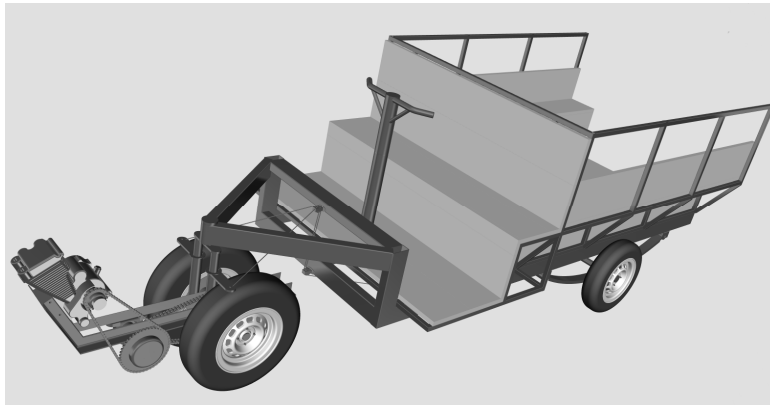


Figure 5. Design of the Vehicle for Rural Africa (VFRA) 2010

Students were consulted on the division of work and the list as given above and this was important for them to feel part of a team and not simply doing work under instruction. Up to the point of writing of this article, students have not completed their work but in the most recent discussion students confirmed that there were still very pleased to be working on this project and were highly motivated. Marks for students were not always good given the work often showed up major weaknesses in their understanding of engineering analysis and quality of design drawings. Given their strong desire to learn and improve, students were encouraged to correct their mistakes. Corrections could be done which fed into later pieces of coursework by the nature of the coursework format shown in Table 1 to ensure credit was given to this effort as much as possible.

5 CONCLUSION

The new mechanism to support engineering design education in the context of providing useful artefacts for the developing world has been created by means of a partnership between the UK charity Developing Technologies and the two universities of City University London and Imperial College London. At both institutions, existing teaching modules have been adapted and developed to accommodate this initiative which has been growing since starting in 2002. From the review by Kahn and Pullen [5] in 2007, this activity was found to create high levels of motivation amongst engineering design students and encouraged deep interaction between the students and professionals, not limited only to practicing engineers. Since then, the concept has been expanded at City University London and, in particular, incorporated in to a formal design module.

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