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AN INTERDISCIPLINARY APPROACH TO EMBEDDING THE GLOBAL DIMENSION INTO ENGINEERING DESIGN: EMPATHY, ENGAGEMENT AND CREATIVITY

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ABSTRACT
Education, and specifically engineering design, has a lot to offer in our efforts to promote and achieve sustainable human development (SHD). A focus on SHD can be enhanced by non-disciplinary and atypical learning environments that complement core engineering and engineering design studies. This paper presents a case study of an educational innovation resulting from a collaboration between an NGO and a university.

Keywords: Engineering design, global dimension, sustainable human development, engineering education.

1 INTRODUCTION

The 21st century has arguably brought some of the toughest and most threatening challenges to both the human species and the planet as a whole. The impacts of challenges such as climate change are bringing new levels of scrutiny to our interactions with the natural world. A paradigm shift will be required to move engineering design from a previous reality of infinite and plentiful resources to a world where in the face of increased demand, these resources are rapidly depleting, urbanisation is increasing the complexity of our society and there is more awareness of the interaction between the built and natural environment.

Sustainable Human Development (SHD) was established in the 1987 Brundtland Commission [1] as being a critical focus for the future of our environment and development. The concept centralizes the principle that any development activity should aim to meet the needs of the present, without compromising the ability of future generations to meet their own needs. However this ideology has failed to gain adequate ground-level traction in the engineering and development sector, with few engineers being exposed to the ideas of sustainable human development or the broader dimensions of sustainable engineering practice in a development setting during their university education or early industry-led career development. A renewed focus on sustainable human development (SHD) could re-orientate modern engineering design and allow engineers to work together for a sustainable global future. The education of engineers – in particular design engineers – needs to incorporate new skills, competencies and approaches to facilitate this shift.

The UK based charity EWB-UK (part of the wider Engineers Without Borders global movement) is attempting to tackle this issue within both the education and professional development of young engineers. EWB-UK wants to help develop a new generation of engineers with the ability to work in the complex setting of international development, bearing in mind the ideals of sustainable development. Building a working ethos and set of practices (which we will refer to in this paper as Sustainable Human Development or SHD) is a critical first step, and these have been termed the ‘global dimension’. This involves critical enquiry and a creative approach to the local context of each and every problem tackled, with engineers in particular focusing on the impact of the social, economic, environmental and cultural dimensions of their proposed interventions, and developing solutions in collaboration with local communities.

The EWB Challenge has been developed internationally and runs in the UK, Ireland, Australia, New Zealand and Malaysia. It aims to provide a tool for universities to expose their engineering and design undergraduates to complex real-world design problems. With the strategic aim of encouraging universities to embed the ideals of SHD within undergraduate and postgraduate curricula, the EWB-Challenge is a novel educational initiative that incorporates a high degree of flexibility in delivery, allowing lead academics at each institution to navigate the complexities of externally accredited curricula and of institutional politics.
This paper will present a case study of the launch of a dedicated SHD course at Imperial College London, detailing student engagement with the material, the development of the course structure and content over successive iterations (via a process of action research) and some reflection on the founding principles of the engineering profession and how these might shape the engagement of students with this initiative.

2 INTEGRATION OF THE CHALLENGE AT IMPERIAL COLLEGE, LONDON

Undergraduate disciplinary learning at Imperial College is supported by a cross-faculty programme of study called Imperial Horizons. This offers course modules in business, languages, humanities and sustainable human development (SHD). We offer a structured three year programme of SHD modules collectively called our 'Global Challenges' field of study. We have integrated the EWB Challenge into our second year SHD curriculum, which offers students the opportunity to undertake an extended real-world SHD design project in mixed discipline groups. We have designed these modules to be complementary to core degree studies at Imperial, so we integrate a number of non-standard methodologies and perspectives to challenge the students to think outside their disciplines and to help them tackle the complexity and uncertainty of a real-world situation. The students work in mixed disciplinary teams, drawing on their individual knowledge and experience, integrating methodologies from social sciences, design and business studies and reflecting on their own relationship with problematic situations to create considered and hopefully innovative solutions.

3 PEDAGOGICAL RATIONALE

The Global Challenges (SHD) curriculum within Imperial Horizons has been designed with a coherent curriculum across all three years of study that share the following common core aims for our students:

1. To foster an appreciation of the value of interdisciplinary learning
2. To develop confidence in their ability to learn independently
3. To develop a realistic and evidence-based approach to global challenges
4. To establish effective team working and collaborative practice
5. To explore communication practices and develop core skills

Some of these areas are explored more fully below.

3.1 Collaborative Learning

Within our course design, there are two levels at which collaborative learning occurs. Firstly and most explicitly, our students are working in multidisciplinary teams, where they are expected to individually contribute their own experience and disciplinary perspectives to the team work.
Secondly, the students self-enrol in different learning streams, where they focus on a unique topic or perspective within the broader learning landscape of each year of study. However, all students work in the same physical space, and by aligning the conceptual elements of the curriculum so that they are tackled simultaneously by all students, we are able to encourage collaboration across the learning streams. This has been a highly rated element of all our courses, with students citing this as the best feature of the course in formal feedback. It means that students working on a practical engineering design, might take inspiration or input from a team working on a business initiative to tackle poverty within the same community.

3.2 Partnership Curriculum

All the Global Challenges courses are built around a partnership curriculum [2], where the students make significant choices about both topic content and the scope of their study. Academic rigour and parity across the courses are maintained by the integration of a number of key concepts that can be tailored to the context of the students' individual choices. Contributing to the idea of true partnership in learning, we work with the model of the 'ignorant schoolmaster' [3]. The course leader has general

rather than specific development expertise, and the course tutors who support the student teams have no relevant development or engineering design experience. Instead, the tutors contribute their experience in independent working, motivation, research and project management. This arrangement means that staff and students are learning together, coming up against obstacles together and finding solutions together. We encourage a high degree of self reflection and reflexive practice of both the students and tutors, which in curricular terms is similar to the praxis curriculum described by Grundy [4] and the ideas of emancipation expressed by Habermas [5] and Rancière [3].

3.3 Interdisciplinary Methodologies

The use of interdisciplinary methodologies is critical to our course modules. We need to make sure that our modules offer material that is complementary but does not replicate any of the core content from any of the degree disciplines at Imperial (engineering, natural sciences or medicine). For this reason, drawing from social science and business methodologies provides the students with new perspectives and tools that they can use not only in this project, but back in the core disciplines and in their working lives beyond.

3.4 Developing Empathy

Goleman [6] describes three types of empathy- cognitive empathy, emotional empathy and empathic concern. Cognitive empathy relates to understanding another person's perspective and their mental model. We use a number of methods to begin to encourage our students to actively engage with an empathic approach to others. Students share their own experiences and actively reflect on the value of these experiences in their work. We use Peter Checkland's Soft Systems Methodology [7] as a tool for exploring the experience of an individual or group of individuals within a complex real world environment. The students create a series of 'rich pictures' – advanced mind maps that allow the students to quickly organize a lot of complicated and sometimes conflicting information – of the complex problematic situation. The students redraw this map as a series, each from the perspective of a different stakeholder within the community, imagining the 'worldviews' of the various community members. We also use 'empathy maps' to focus this exploration [8].

3.5 Enhancing Creativity

We encourage the students to use divergent thinking to enhance their creativity. It sometimes appears that the students are quite focused within their 'disciplinary channels', and they find free form creative activity quite tricky. As elucidated by Vosburg [9], divergent thinking is hampered by a negative approach. We have noticed that students find the idea of creativity quite intimidating and often believe that they will not be able to be creative. We provide the students with a range of creativity tools that they can try out, and encourage the students to keep a paper sketchbook of all their ideas.

4 DESIGNING A COURSE MODULE TO SUPPORT THE EWB CHALLENGE

Within the Global Challenges programme there are four learning strands offered to our second year undergraduates. The EWB Challenge is embedded in Design for Sustainable Development, but we also have a strand called Design for Economic Development (the focus is on business innovation to target poverty within a deprived community), Design for Local Sustainability (considering whether 'development' is an issue for 'poor' countries, or whether there is valid development work to be done in our own communities) and Visualising Global Challenges (looking at communication practices and public views of development activity). Design for Sustainable Development has been run four times, and via a process of action research, this has been refined and evolved to its current iteration. Our main aim is to enable the students to gain a critical understanding of a complex real-world community; to think empathically about the experience of individuals within that community and those working to help the community; and to creatively design a potential solution to a hardship faced by that community. We want the students to draw on the individual disciplinary expertise within their teams, and integrate this with a holistic approach to considering and designing for the community. Specifically we want the students to consider the 'global dimension' to design engineering in their projects – they must reflect on the economic, social, cultural and environmental impact and sustainability of their design.

To inform the action research cycle of iteration and review we have observed the students working and critically reviewed their submitted work, and conducted informal student interviews at strategic points during the module delivery and after completion.
There is not enough space in this paper to detail all the changes that we have made over successive iterations, but we would like to review two of these in detail.

4.1 Allocation of design brief

Despite providing our students with a design brief encompassing many potential areas of focus, an issue that had repeatedly challenged us, has been the students' drive to pick areas of the design brief that they could address with the least effort and most speed – of note, nearly all students choose to work in the water and sanitation (WASH) area of the brief, mostly designing a water filter by the end of the first session. We have determined via interviews that there are a number of reasons that feed into this decision making, including the perceived effort of the task (students would like the most marks for the least effort), the need to anticipate success (students are often unwilling to begin a task if they are not guaranteed a successful outcome), the self-assessment that they do not have the ability to be creative, and the fact that many of them see development work in their disciplines as relating mainly to WASH.
Students report a strong self-image tied to the ideals of engineering – with 'mastery' being a key concept for them and metric of their progress. They believe that they should be able to 'master' nature, or problematic situations, and often this is expressed as the imposition of a 'perfect' solution on an 'imperfect' situation. Shifting this emphasis is key to effecting genuine engagement with the complexities of the real world. Recognizing that students are working from this fiercely defended position, means that we can begin to unpick some of this ideology and move students into new ways of working.
In trying to address these issues as reflected in the choice of design brief area and design solution, we unsuccessfully worked through a range of iterations. In our second iteration we tried allocating students blindly to different design areas. This resulted in students becoming uninspired and stuck in areas that they found challenging, and often resentment building for the students who had been 'lucky' enough to be allocated to WASH areas. In the third iteration, we asked student teams to pitch for their desired design area, and to present the most obvious solution. We then asked all the students to discard the presented solution and spend their time finding a better way to address the problem. This did result in some good innovative thinking, but students still clustered around the WASH area, and we had a number of versions of 'not-quite-water-filters'.
Finally we adopted the current method, where students do not form their teams or pick their design area until after a prolonged period of divergent thinking and conceptual design generation. The students fill design books with drawings, clippings and imaginings, with no care as to the structure or function of the idea. They then pick the best ideas that are most likely to translate to a practicable option and anonymously present them for peer review and allocation. This is detailed a little further in the next section as it is linked to our biggest educational innovation – merging the strands of study.

4.2 Merging strands of study

We have merged our four second year course options into a single course, with four learning strands. There have been two key benefits to this approach. As mentioned above, it can help students to break out of one pattern of thinking and to see their task in a new light. For the non-business oriented students, seeing the community as 'customers' as the business strand do has made them realize that they need to engage with them during the design process, and not impose their design on the community without any consideration or consultation. At a broader level, this introduces the second key benefit. This sharing of ideologies and approaches between the streams, has enabled us to develop a 'common core' of curriculum for these four courses, that introduces all these students to a variety of different ways of thinking about development, design and their own role as innovators.
The course is broadly structured as follows, with students in each strand working on aligned content that makes sharing ideas across the strands easy and beneficial:

- Weeks 1-5: introduction to sustainable human development and exploration of the community and design brief analysis – mixed strand student groups
- Weeks 6-10: conceptual design development – mixed strand student groups
- Weeks 11-15: technical specification/production of exhibits

- Weeks 16-20: preparation of implementation package and reflection on process

Each session begins with all students working together to discuss key concepts and share their progress so far. Students work in mixed groups for the first ten weeks, with students from each strand represented in each working group. This maximizes cross-fertilisation of ideas. At week ten, the students anonymously post five conceptual designs online for their strand, which are then voted on. The design groups which then pursue each idea in weeks 11-20 are made up of students from that course strand including the student that posted the idea, and other students that picked that idea as a priority choice. This means that when the students come together as a design team they already have a common focus that unites the team. This has effectively alleviated the issue of teams with very varied interests or ideas running into team working difficulty, and also the issue that we frequently encountered previously with some student groups remaining 'stuck' for the majority of the course with no good ideas to work with.

In summary, a student undertaking the Design for Sustainable Development strand might work through the following process.

1. Introduction to the idea of working in SHD using a deconstructed approach to critically consider the meaning of development, and how the discourse is dominated by notions of power and expertise
2. Engagement with a real-world case study in a sensitive and empathic manner, and discussion of the challenges of intersubjectivity in this problematic and contested field
3. Exploration of the selected community, taking time to generate a genuine understanding of the complex dynamics, needs and desires of the community using an adapted version of Soft Systems Methodology [7] to facilitate this; this phase represents the opening of a 'virtual dialogue' with the community and is supported in real terms by a moderated forum that allows the students to pose some questions to representatives of the community, but is largely down to the students empathically modelling the community's input; if successfully engaged with, the modelling techniques allows the students to identify opportunities for intervention within the community
4. With these opportunities in mind the students develop their design questions, which are interrogated using the SMART tool [10]
5. Conceptual design, where divergent thinking is explicitly encouraged
6. Peer review of conceptual designs
7. Refinement and technical specification
8. Creation of an implementation package that completes their 'dialogue' with the community

6 CONCLUSION

At Imperial College we have designed a cross-faculty engineering design module that runs alongside other design and SHD modules to allow free flow and sharing of ideas across traditional disciplinary and methodological boundaries. We are finding that over successive iterations of this course, modified by a process of action research, we are able to achieve deeper learning and engagement of the students with the ideals of the global dimension in engineering education. Furthermore, the students are taking the learning and impacts from this course back into their disciplinary study, where there are anecdotal reports of enhanced student performance.

Although we present here just one example of how the EWB Challenge may be embedded into undergraduate engineering curricula, the remit of the challenge allows institutions a large degree of flexibility in the way the Challenge is used and this variability is reflected in the national picture. As a mechanism for bringing the global dimension into engineering and technical curricula, the EWB Challenge is proving to be popular, with an increase in the number of universities and students participating on a year by year basis. The EWB Challenge is certainly effecting change to some extent in university curricula but to understand the degree to which this is occurring will take additional work that is scheduled for the 2015/16 academic year. In particular, EWB-UK is actively working to gather examples of best practice from a number of academics and institutional settings to better inform the integration of SHD into formal curricula and the development of the EWB Challenge itself. With additional resource in the forthcoming academic year we hope to be able to provide demonstrable evidence that the EWB Challenge is effecting change within university curricula. Indeed, the change in the UKSPEC in January 2014 [11] to include more of a focus on social context and conducting activities in an ethical way demonstrates engineering education moving towards values emphasised in the global dimension in engineering education.

Certainly at Imperial College, this learning opportunity is located as an optional module outside the core departmental and faculty teaching and although it may be counted towards the final degree award, it is not integrated into the standard curriculum for each student in any meaningful way. International recognition of this module, via a European Best Practice award from the Global Dimension in Engineering Education EU-funded project has been helpful in engaging the wider college community with the value of this course, and it will be interesting to see how the module continues to evolve over the next few years.

Clearly, this paper is based on anecdotal evidence gathered via action research in one institutional setting, with a relatively small student cohort. Further investigation of student attitudes to the global dimension in engineering design and the value of cross-disciplinary learning would be desirable.

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