Co-educating Social Scientists and Engineers through International Service Learning

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***Abstract*—*Engineering and Social Sciences each have a distinct language and set of principles. However, both are essential for impactful intervention in international development and most spheres of Engineering irrespective of location and socio-economic factors. The new Sustainable Engineering Management in International Development MSc at Swansea University, UK developed in association with the Prince's Foundation, enrolls Social Science and Engineering graduates to work in-country (sub-Saharan Africa in this inaugural year) with various stake-holders, including an NGO for their MSc research. The students had responsibility to manage the relationship with their NGO partner and identify how best to use their skill sets to deliver benefit to the host community. A key aim is to develop engineers who can understand and articulate the social context and impact of their work, and social scientists who can relate to and appreciate the design method that lies behind engineering interventions. This paper explores the first year of delivery. It was evident that the use of critical reflection was central to transforming the students' perspective of their role in development. We also discuss solution vs needs-based approach and co-operation between students and the partner organisations and local communities.*

Keywords—Development Engineering; International Service Learning; Multi-disciplinary education; sub-Saharan Africa; Project-based learning

I. Introduction

There has long been a recognition that the traditional engineering curriculum, focused on development and communication of technical content, is failing to produce engineers who are prepared for the complexity and impact of their work in the world outside academia. This appears to manifest itself as an inability of students to function sensitively in foreign cultures [1], a lack of awareness of the influential role that engineers can have in affecting society [2] and developing and acting on the whole-problem definition, mindful of not only the technical issue but the surrounding social and economic context [3]. Mulder [4] reviewed the incorporation of sustainability into curricula, concluded that engineering education should train students beyond considering the technical intervention, to being able to facilitate the process of addressing sustainability problems and move towards trans-disciplinary learning.

Swansea University, supported by the Prince's Foundation in the UK [5] have developed a cross-disciplinary MSc for both social scientists and engineers through a 12 month-long project-based learning (PBL) approach [6]. Project-based learning, also commonly termed problem-based learning, is a pedagogical approach where students engage with a real-world problem alongside their studies, and engage in structured learning to support their ability to address the issue. PBL was adopted early on in the medical profession. It is now making significant in-roads into engineering education, as Higher Education Institutes respond to the de-coupling of professional practice from higher education. This has been driven in part by the global research-intensive agenda, which it has been has been argued has led to an impoverished student experience and lack of tuition by practising engineers who appreciate real-world complexity [7]. Key aspects of PBL are that the problem to be solved is authentic and not theoretical, it is challenging, has an open-ended outcome and requires cooperative learning between students. PBL is rooted in the pedagogy of experiential learning proposed by Kolb [8] which proposes that effective learning takes place when spaces of experience and learning are co-dependent and reinforce each other. A PBL approach has been shown to develop leadership, communication, flexible thinking and respect [9].

As an educational programme that addresses the social (and other) dimensions of engineering, this course may be linked to themes including global learning [10], Humanistic engineering [11] and human-centred design (HCD) [12]. These characterisations are concerned with promoting awareness of socio-economic and environmental context of design activities, and the benefit of critical thinking and reflection as a learning outcome.

This course aligns most closely with the literature on International Service Learning (ISL), a variant of Service Learning (SL), which links PBL and Global Learning as a pedagogical approach integrating course content with placement experience where students use their skills to work with a community and gain learning outcomes from the experience.

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ISL aims to deliver benefit to both the students and the partner community, however, managing the expectations between these all stakeholders (student, staff, partner organisation & community) is not straightforward ([13] ,[14], [15]) .

While there are many examples of individual courses or sessions for SL or ISL ([1],[15],[16],[17]), there are fewer examples of a full post-graduate, multi-disciplinary course that is built around the concept of ISL specifically related to engineering interventions in development.

This paper introduces the course stakeholders and structure, and discusses the challenges faced and lessons learning based on staff observations. These include the challenge of multi-disciplinary teaching, how to balance student autonomy and opportunities for learning with the needs of other stakeholders.

II. Course Stakeholders

A. Students and Faculty

The MSc course enrols students with both engineering and social science backgrounds. In the pilot year, a total of eight students were enrolled, six engineers (two Civil, two Mechanical, one Product Design, one Chemical) and two social scientists (both with first degrees in International Relations). Two of these students were international (Gambian and Brazilian) and six were UK domiciled students. The gender ratio was 50:50. These students worked in two groups, each with one or two partner organisations. Three staff from the College of Engineering and one staff member from the department of Political and Cultural Studies mentor the students. This high student-staff ratio was designed in to mitigate risk in the first year of operation.

B. Partner Organisations and Local Communities

The course is supported by the Prince's Foundation, an organisation created by HRH The Prince of Wales to support community development. The Prince's Foundation provided the links to two of the partner organisations, and staff from the Prince's Foundation arrange the Community Engagement module.

1) Team 1: Sierra Leone:

Community Cooker Foundation, Kenya are a stakeholder NGO. Established in Kenya, the Community Cooker is an integrated waste management system. The cooker burns municipal waste at high temperatures to produce emissions that conform to WHO standards, generating heat that can be used for cooking. The waste heat has additional potential for baking, hot showers and energy generation.

Homeleone [18], Sierra Leone, is the second stakeholder NGO, together with the surrounding host communities of Newton and sub-districts of Firenke and Ma Brown. Homeleone are relocating people from informal settlements in the capital, Freetown to Destiny Village in Newton, a new community with affordable housing, utilities, health facilitates and opportunities for training. Homeleone had secured a grant to build the first Community Cooker in West Africa and requested technical assistance with this.

In addition to the Community Cooker, The students worked on projects including low cost filtration systems, structural upgrades to footbridges to make them motorbike accessible and a review of the capacity building strategy of Homeleone.

2) Team 2: Zambia

Siavonga Nutrition Group [19] is a non-profit organisation aiming to improve nutritional conditions and food security for areas around Siavonga, Zambia. Swansea University has had a long standing relationship with the Siavonga Nutrition Group, facilitated by yearly service trips of undergraduate students through the Discovery SVS charity and College of Engineering Student Experience trips [20]. SNG were interested in creating facilities to teach children with Special Educational Needs (SEN) and were looking for technical advice with the proposed design of a new classroom.

The students researched building performance in sub-Saharan Africa, sustainable procurement, the use of VR in development engineering (for the purposes of remote monitoring and communications) and a review of the role in ISL in engineering development.

III. Course Structure

A. Overview

The course was run in three consecutive semesters over 12 months. All taught content was covered in the first two semesters, with the final semester focused on the dissertation period. The students were assigned groups at the beginning of the course, with faculty selecting the individuals for each group. The aim was to achieve good representation of both disciplines within each sub-group, being mindful of the technical expertise that was required by each partner. The students within each group would work on complementary research questions to the central 'problem'. The students were encouraged to make early contact with their partner organisations to introduce themselves and start to define their contribution to the needs of their partner. Throughout the year the relationship with the partner was managed by students with faculty oversight.

Over the course of the year they engaged with taught courses that cover the theoretical background to development studies and sustainability. They also had two modules within the taught period within which to research their individual topic of research. Many of the modules developed key project elements in their assessment, which were often salient to the in-country deployments, such as leadership & team development, risk assessment and project management.

B. International Trips

An initial week-long trip to the partner organisation in sub-Saharan Africa was carried out halfway through the year, and a

longer 2-3 week trip was carried out during the final dissertation period. The initial trip was designed as a 'fact-finding' trip, designed to give the students a chance to engage with the stakeholders before starting work on designing their intervention for the second trip.

C. PBL Assessment Strategy

The taught content [21] was delivered as a series of two- to four-week consecutive modules, including: *Development Studies*, *Circular Economy, Impact Monitoring & Evaluation, Risk & Resilience* and *Community Engagement*. This block-taught format allowed the students to engage intensively with each topic. Following the principles of PBL, the majority of assessment was linked to the activity with their partner, e.g. In *Leadership, Team Development etc*., the students were required to analyse each other's competencies and determine their respective roles within their project team, and determine the nature of their interaction with their partner organisation. In *Complexity, Uncertainty, Risk & Failure*, the students were required to define project and personal risks and produce a risk assessment for their scoping visit to be held in January.

The students managed the process, with staff mentors to oversee the activity to ensure compliance with cost, health & safety and ethical standards. The students managed a budget, booked flights, accommodation and developed their itinerary, and had the freedom to design the terms of engagement and scope of activity with the partner organization. This high degree of autonomy was intended to give the students the experience of responsibility, closely simulating the job of managing a project.

For the engineering faculty involved in the course, consideration of impactful teaching and assessment required a reimagining of learning outcomes to measure learning gain in the 'softer' skills of leadership communication, collaboration, development of perspective and cultural sensitation etc. that the course is designed to enhance. Critical reflections were adopted as an important component of assessment, helping the students to link the experience gained through working on the project back to the taught content. Critical reflection has been recognised as a valuable teaching method in Management pedagogy as it requires the reflector to engage with the wider social impact of actions [22]. This is particularly useful for the engineers on the course, who are used to quite closely bound solutions

IV. Faculty Observations and Reflections on Pilot Year

A. Student tendency to revert to undergraduate stereotype

Given the course was established to bridge the divide between the social sciences and engineering and the project-based and applied nature of learning and assessment, it was surprising how entrenched the technical solution-orientated approach was in the engineering students. Despite putting the students through an intensive social-science education, when it came to on-the-ground action, the engineering students consistently put much less emphasis on the social science aspects, preferring to start work on a technical intervention before fully realising the need and determining whether the intervention was appropriate by carrying out research with the stakeholders. This may be because of the change in project topic that many students experienced, resulting in much of their coursework to date not being relevant to the specific problem being investigated.

All the engineering students arrived in the field for the second trip without having prepared questions for interviews or focus groups. They had only given pre-cursory thoughts to sustainability and longevity of their interventions. Their focus appeared to be on delivering a technical solution, and they appeared to consider that the 'other' aspects would be dealt with if time allowed. A similar case occurred with the social scientists on the course, but in this case directly opposed to the engineers approach, as these students found it hard to bring in the 'engineering' into their dissertation as they were drawn to focus on and organisational and social structures at play.

By the end of the course, and clearly facilitated by critical reflection, the majority of students had started to engage more fully with the multiple dimensions of their project work. However, this point came much later than initially anticipated by faculty.

From our viewpoint, this was initially disappointing as we had tried to develop a course that would equip students to not make the mistakes that a traditional engineering education might encourage, e.g. push a solution forward without taking time to understand if the solution was the most valid approach.

Although it was positive that the students were active and making genuine, if small, contributions, we had concerns about the viability and longevity of the interventions, and thus we decided to review whether we had a flaw in the program and could re-design assessment to improve the integration of engineering with social science and review whether the programme was effectively linking theory with practice, with enough feedback to assist them during the transition away from 'traditional engineer' approach.

Ensuring the students had a consistent project topic would have helped, but we also considered whether it was too ambitious to expect the students to make the connections from the social science content to the engineering intervention themselves, particularly when under the time-pressure of a short time in country. It should not have been a surprise, as much of undergraduate engineering education is focused on problems that are simply bounded with a few variables, and sustainability, social impacts etc. are often treated as secondary foci of investigation. These students were not used to considering the technical dimension on a par with environmental, social and economic considerations of the need. For our students, while they had been taught, e.g. appropriate community engagement, assessed on their understanding of it, and developed a communications plan,it was only during the concept design and project stagesthe theory and application oftopics were integrated together and the students had to manage the technical and social aspects simultaneously. It may be that the scaffolding required for learning in their zone of proximal development [23] was not structured or supportive enough for them to reach the stage of integrating both the engineering and social science dimensions into their understanding until approaching the end of their

study. On reflection, we could have been more explicit about the place of engineering design and need characterization within the broader design process, as done by Ranger & Mantzai (2017), instead of asking the students to infer this from their studies. This could be done through introduction of a competency-based assessment criteria such the Global Learning Matrix [10], or linking assessment to a Design Thinking approach more fully [17]. This could have reaped benefits in demonstrating to the students the value of an open-ended 'ideate' stage as a precursor to attempting technical design.

As a result of this, in the second year of delivery, the students will not be pre-allocated project topics. Instead, a range of options will be discussed with the stakeholder organisations in advance, and the first trip will become an immersion trip, an opportunity to meet the stakeholders, discuss the issues and identify how their skills align with need. Faculty will take a closer role in helping students to be aware of the assumptions they may be making during this process. The focus will move from providing a project definition to an assessment of need and available resource as a starting point in the design process.

B. Project vs Problem

By arranging the projects in advance with the stakeholders we had taken away the need for the students to fully engage with the 'why' behind their individual project, and when they did they sometimes struggled with the suitability of the proposed project they had inherited. This was partly overcome in the Sierra Leone team where, due to concerns the Community Cooker plans would not be made available in time, three of the four students were encouraged to pursue their own projects. Even with this opportunity the engineering students remained predominantly focused on traditional engineering criteria. This may because their applied coursework on e.g. Monitoring and Evaluation had to date been focused on the Cooker design. They were now moving to a different topic, therefore they were moving away from the PBL approach, with their project no longer aligning with the assessment they had produced. As an example on the first trip, one student started to develop filters to clean wastewater so it could be used for irrigation. A prototype was made within a few days of arriving. However, consideration as to the training and maintenance of these filters, the alternatives available, considerations about the financing and whether the design was scalable and roll-outable, were not addressed by the student until much later, instead of being integrated from the beginning of the design process.

During the first trip to Zambia, to survey the site of a new school (for which the team were going to adapt the current Ministry of Education generic school building plans for disabled access), some of the Zambia team began to question the value of the proposed new school building against other uses of the funds available to them. They were picking up a legacy project from the undergraduate student service learning trips, that had been decided as a suitable project with the technical requirements needed for MSc level study. The students were not in agreement about whether the school was an appropriate use of funds, questioning the benefit it would bring to the wider community and not just the school. Fundamentally, the problem came down to a failure to set up appropriate Terms of Engagement, as described in the following section.

C. Working with a partner and Terms of Engagement – Service to whom?

Both groups initially expressed reservations about their partner organisations (although these reservations were generally ameliorated by the end of the year). This negative reaction is likely to be partly the 'distress' phase of culture shock, and partly a reasonable critical reaction to the operational reality of a resource-stretched organisation working in one of the poorest areas of the world.

Both groups managed to complete the organisational logistics for each trip and communicated with their partner about the planned interventions. However, even at the time of the second trip, neither group were able to clearly articulate the terms of engagement with which they worked with the project partner. We had asked the students to establish terms of reference with the partners (to give them the raw experience of having to define their contribution), but possibly as they had not had experience in establishing terms of reference, there was no appreciation of the value of a clear set of terms. In addition, this was not linked to assessment, and therefore lacked a tangible incentive for the students to engage with it. This caused problems throughout the year as the students were unsure if they were meant to take the role of employees, consultants or equal stakeholders with their partner organisation and/or the host community where the partner was based. Each of these different roles embodies different priorities. As some student projects drifted away from activity that would directly benefit the partner to more general research, this led to the students having to navigate some difficult conversations with their project partners, made harder by the fact the students and the partner had different views on what the project work should entail. When students identified possible conflicts between the aims of their project partner and the host community, this became more fraught.

This reflects the difficulty of adopting the conflicting dual role that student-practitioners in ISL undertake [14]. The role of a practitioner is to apply knowledge to form a solution. The role of a student necessitates learning, and the freedom to make decisions within a PBL approach comes with it the risk of failure. The space to experience and reflect on failure to learn or failure to apply knowledge can be a powerful learning opportunity for students [24], particularly when this brings a moment of dilemma or crisis. This type of experience in the context of SL has been shown to lead to transformation of understanding and perspective ([25]; [26], [13]).

While from a pedagogic viewpoint, failure and crisis can be useful opportunity to learn, the existence of the partner community as a stakeholder in this process raises ethical considerations about how acceptable it is to allow failure to occur for the purposes of learning. Crabtree [14] explores this conflict between service and education, since there are concerns that the benefits to the partner organisation may not be clear and there may be no lasting impact [25].

Putting the students through this difficult process was admittedly intentional. It was intended they should appreciate the need for clear terms of engagement, and having the experience of define this from scratch was intended to give them material for critical reflections.

V. Encouraging a Global Engineering Outlook

It is remarkable and humbling to witness how much the operational perspective of the students had shifted by the end of the course.

The global learning VALUE rubric is a competency-based assessment approach which requires students to become open-minded, understand how their actions impact others and address the world's most pressing needs [10], and is a useful lens through which to objectively assess the learning objectives of the course.

In giving the students first hand and unfiltered responsibility to manage complex issues, the students have had access to rich transformative learning opportunities that meet several of the VALUE rubric that are hard to achieve in the classroom.

- Through critical reflection, the *Global Self-Awareness* competency has been met, as the students are articulating their identity and their role in the wider global context, now cognizant of their abilities and the roles of other development professionals.
- Critical reflection has also enabled the students to engage with *Perspective Taking*, understanding how they are viewed and how power dictates relationships, this has developed most significantly for the engineers in the group.
- The field experience has allowed the students to develop their skills managing *Cultural Diversity*, in managing their ethical responsibility to their study participants and learning through doing how to build effective partnerships though building relationships based on shared responsibilities.
- *Personal & Social Responsibility* has been exercised by the students as they research interventions for site-specific application, managing a budget and determining impact, justifying to themselves and in assessment their financing decisions

VI. Conclusion

The challenge to any educational program is balancing teaching and assessment, learning and doing to deliver learning outcomes of value to students. Managing the balance of autonomy for the purposes of learning and structure to guide students has been a challenge on this course.

The students need enough freedom to engage in activity that would allow them to develop their management skills, but in the end required closer supervision than anticipated to ensure they made the link between the social science and engineering content of the course.

The balance of taught content and applied project learning also required managing. Since learning and experience inform each other in a cyclical relationship [8], it is unclear whether it is more beneficial to lead with a scoping visit or taught content in ISL. It is clear that the ideate stage of the design thinking process cannot begin until the student is in the field, and that in this first year of delivery the first trip was held too late. In asking the students to begin the design process prior to their first trip, redundant research was carried out, and the students progressed too quickly towards a solution before engaging with the partner organisation or the host community in the project location.

It is clear the students were experiencing 'Chameleon complex' [25], the sense of disconnect students experience when they are faced with translating their knowledge to action, particularly when subject to the inevitable time constraints of ISL. This is further complicated by the desire to perform a valid service to the partner community while mindful of being able to conduct research that is worthy of an MSc dissertation. The students were not aware of the need for terms of engagement to outline their role and responsibilities in the partnership. Without this, the students were at times considering their partner as their client, and at others they were considering the local community as their primary stakeholder, resulting in conflicting views of the best way to proceed.

As a harsh eye opener to the complexities of international development, the course has been successful. The transformation of the student's understanding of achieving impact in development is evident from the evolution captured in their reflective assignments, where they display the ability to shift perspective and consider situations and decisions from multiple viewpoints, and question implicit assumptions [22]. This has often come as the result of crisis, e.g. team disagreement, or a realization that the initial project proposed was not possible and a complete re-think was needed, necessitating abandoning a considerable amount of background research.

At the same time, one of the original intended projects, the new disabled access classroom for Siavonga, was not delivered, and the construction of the Community Cooker at Homeleone is yet to be completed. However, we are relaxed about this. B. Amadei expresses it as not only doing the project right, but also making sure it is the right project, saying "*Doing the right project is equally, if not more, important because it focuses more on whether the project is in balance with the societal, economic, and environmental systems with which it is interacting*" [27]. When the students felt the aims of the project were incompatible with the theory they had been engaging with, some spoke up and managed a difficult situation with the project partner themselves to refocus the study. They managed to move to

what, for them, was the 'right project', carrying out need analyses with the view to laying groundwork for future cohorts of the course to engage in a wider range of beneficial activities.

This experience was mirrored in the Sierra Leone team. The students had the resource to e.g. build a bridge, install water filters across the community etc.. However, they came to the realization that for their impact to be long-lasting, it was essential to understand e.g. the existing community financing models for footbridge building; the power structures and decision makers in the community. Thus, many of the students scaled back their ambitions for a deliverable, and instead moved to a multi-year viewpoint, focused on understanding the context well and handing over to the next student cohort to continue.

Throughout this process, the position of our development partners in this process has been a concern and one which we still need to consider how best to manage. We are aware that as the partnerships develop and the partner and local communities get used to yearly cohorts working with them, the nature of involvement may change. The way that new students will engage with the communities (some of whom have had limited contact with researchers and students from the Global North prior to this year), may adapt, due to changing expectations.

The experience of the partner organisations and host communities involved is often the voice missing in the ISL literature, and we hope to utilize future cohorts to start to explore this in greater depth.

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