Staff and student perspectives on embedding sustainability into the engineering curriculum.

Roger Penlington, Jenna Tudor and Noel Perera

Department of Mechanical and Construction Engineering,
Northumbria University, NE1 8ST.

r.penlington@northumbria.ac.uk

Abstract

Recognising that sustainability is an important concept within engineering this paper describes a project run by a team of academics which sought to investigate how engineering students viewed sustainability, what role they perceived it to hold in their work, and how they felt it should be incorporated into their education.

Students and academics acted as equal stakeholders in the project with the students coming from a range of backgrounds including undergraduate and postgraduate programmes in Mechanical Engineering, Product Design, Electrical Power Engineering and Multidisciplinary Design Innovation.

The investigation sought to understand student and staff perceptions of how the university approached the concept of engineering education for sustainable development into the curricula. An additional aim of the research and activities of the project was to contribute to influencing how sustainability may contribute to engineering curriculum change within UK higher education.

The activities conducted by the project team demonstrated that students and staff currently have an awareness, yet a limited understanding, of sustainability. Students strongly felt that sustainability was a key part of an engineer's role and responsibilities. The findings recognized scope for concepts of sustainability to be more effectively included it in the curriculum for engineers adding many opportunities for imaginative pedagogies.

It is proposed that students should also be encouraged to generate their own conceptions of sustainability and globalization and participate in discussions around these to ensure personal engagement with them. The project outcome generated valuable material which could support communication and dialogue about sustainability to support the education of global engineers.

1 Introduction

The need for the addition of sustainability within the curriculum of student engineers has been long established and some approaches to teaching openly discussed but fundamental change of the engineering curriculum has yet to happen despite several calls, such as those of national engineering bodies.

This paper will describe the initial investigation within the engineering discipline of student and staff views of sustainability it will then relate these to opportunities for change within the

engineering curriculum which may support the overall enhancement of graduate skills within a global engineering community.

2 The initial investigation

The initial stage of this work sought to investigate how engineering students viewed sustainability and engineering within a global context, what role they perceived it held in their work, and how they felt it should be incorporated into their education. A three stage method was employed to gather initial views by an 'answers on a postcard' exercise, exploration of these ideas by an online questionnaire and then generation of ideas of approaches to teaching by the use of focus groups.

As the first stage of the project the team invited 'answers on a postcard' where both academics and students were invited to add comments to pre-printed postcards which could then be left in a box.

Despite differences in age and experience, many common themes and ideas emerged from the student and staff postcards.

Analysing the data using an emergent approach, the team found that three key themes emerged:

- A global engineer should have interdisciplinary knowledge.
- A global engineer should be multi-literate.
- A global engineer should be able to cross borders and boundaries e.g .language, cultures.

Some of the responses to the question 'How can we change courses to make them more global/ethical/sustainable?' were:

- Talk to each other more / increase use of group discussions
- Look at models of study in different cultures
- Have courses linked between 2 Universities (1 UK, 1 international)
- Cover more global issues
- Incorporation of ethics and sustainability in course syllabuses
- Changing assessment tasks and criteria, make assessment focus on these issues

In response to the question 'How could university engineering courses prepare students to become global engineers?' responses included:

- Get tutors to lead by example, innovating and leading the way
- In depth learning of all aspects of engineering
- It should include communication, drawing ...
- Confidence, awareness of different working cultures.

Staff and students believed there was a clear link between global engineering and interdisciplinary learning. They saw this as having two elements: the need for engineers to be able to work and learn across different engineering disciplines (as engineering itself is multi-disciplinary); and the need for engineers to have a broader knowledge of other disciplines beyond engineering itself. Students took the initiative and made suggestions about the type of subjects that might be valuable for engineers as additional fields of study, and also suggested a

number of activities and attitudes which would allow engineers to work across boundaries and borders.

The idea that the global engineer should be multi-literate and have a wide portfolio of skills and competences came out very strongly from the postcard data both from students and staff. First year students in particular emphasised that subject literacy was important which may indicate the early stage of their learning. Some students also made the point that it was not the skill set but the ability to apply it to other contexts that was important.

Staff suggested that students needed a whole variety of skills besides the basic engineering skills including emotional intelligence, compassion and social responsibility. This reflected students' comments that there are a range of more generic professional skills which are crucial for the global engineer. Suggestions from students included: creativity, innovation and communication skills, as well as being organised, enterprising and showing originality.

Students also felt that engineering curricula should have a stronger emphasis on practical skills and experience. Students said it needed to "have more practical 'real life' situations" and should include "a couple of modules which include making small practical projects such as small wind turbines or using energy from the sun". Students also called for more real experiences and a link with the 'real' world, suggesting "trips and projects from around the world" that would "cover more real life engineering problems and experiments".

A key theme which emerged was that a global engineer should be able to cross borders and the boundaries between different contexts. Here the main border crossings mentioned were from academic contexts, crossing from the university into the 'real' world and from theory to practice. It was also suggested that the divide between theory and practice needed to be bridged, ensuring university curricula "relate problems in class to real life engineering problems". It was felt that this boundary crossing would help students to "start seeing the big picture".

3 The second stage of the investigation

The second stage of the project sought to find out more about students' views on sustainability, so they were asked to complete an online questionnaire. Students from all four years of undergraduate study completed the questionnaire which included a variety of questions about sustainability, and the answers received could be divided into three main concepts.

- We should definitely consider sustainability as part of the world;
- As engineers and employers, we should look for sustainability; and
- Sustainability is the role of the engineer.

We were interested to understand student perceptions of sustainability and also how this may be influenced by external factors. Students were asked to consider what sustainability means to them. Answers ranged from a wide global perspective to engineering-specific ideas with some combining the two. Students suggested sustainability was about:

- Considered use of natural resources to prolong their availability
- Use of renewable energy
- Improving the lifecycle of products/producing less waste
- Consideration of the three Rs – reducing, recycling and reusing materials
- Consideration for human life and the environment.

Students identified the importance of a long-term perspective on sustainability, recognising that the work they do now will impact on future generations. They felt it was very important to make the appropriate choice of materials and resources, taking into account availability and the level of those resources. Sources of renewable energy were also identified, including solar, wind, tidal and students included nuclear energy. Students said: *"We need to start to use more renewable energy resources and not use up everything we have now."* As well as thinking about renewable energy sources, students also felt that improving the lifecycle of products and, therefore, creating less waste, would support sustainability. They considered: *"designing quality items that can be passed between users instead of thrown away after a few months."* This was also reflected when talking about the three Rs and students felt it was important that as well as considering the use of the product, it also conformed to the three Rs. Students also considered the impact on human life and the environment and how sustainability could improve the quality of human life. Examples included lowering emissions and protecting the environment for future generations.

As well as thinking about examples of sustainability, students were also asked to identify areas where sustainability is not used in engineering, although it should be. Students gave a variety of answers, ranging from ones which could be implemented within the university to global answers. Students felt the university could model more sustainable behaviour, by asking students to submit reports electronically, rather than as printed copies. Other responses included nuclear and power production, and the building of new homes. It was suggested that: *"Large housing projects... should include a far higher standard of insulation and renewable energy sources."* Students also felt sustainability could be used in teaching schemes and the technology market, as well as in the automobile sector of developing countries, where *"manufacturers overlook sustainability criteria just to meet the customer demands not foreseeing the adverse effect in the future"*. As well as the use of oil in industry generally, students also mentioned industry moving to other countries and *"the massive pollution because production techniques are simply cheaper"*.

Students were able to associate broad ideas within their concept of sustainability which suggests a constructive use of wider influences expressing that sustainability should include themes such as; increasing the life span of products, collecting resources without causing any damage, to prolong the Earth's resources, maximising the potential of a resource and ethics.

A large majority of students (95.2%) felt it was necessary to learn about sustainability in an engineering course. They said they felt it formed a major part of life for everyone and had become more important in recent years following the reduction in numbers of natural resources.

One student said: *"Our current consumption of natural resources is not viable, for ourselves and future generations, so it is our duty to learn about renewable resources and use this information in the future."*

Students seem to believe that sustainability will increasingly become part of the role of the engineer in future, with more and more companies introducing their own guidelines. They also felt that producing a sustainable product is starting to have a positive impact on consumers.

When asked how students felt sustainability could best be incorporated into the curriculum, they suggested specific projects, and that a percentage of marks could also be allocated based on whether the project meets sustainability guidelines which could be set by the University or the individual programme. Some students felt it should be included as a module but others suggested the idea should be introduced across their curriculum.

4 The third stage of the investigation

Once ideas of sustainability and globalisation had been discussed, thoughts turned to how this could be taught in the future. The project team held focus groups with the students to generate ideas for the inclusion of sustainability in future, the collection of more extensive views during a day-long event allowed the student conversations to develop well beyond headlines and to question how engineering may be taught.

It was suggested that the university's approach to this could be two-pronged, reflecting sustainability in the material taught and also in the way it conducts itself. Where sustainability could be taught within modules aspects such as material usage, energy usage and manufacturing impact should be covered.

It was felt there needed to be a change of attitude towards sustainability, and that raising awareness of the issue formed a key part of the learning. The teaching could begin in school, culminating in inclusion in the curriculum at university.

It was suggested that there could be a recognition for studying sustainability, perhaps in the form of accreditation or a qualification, but that the subject should also be integrated into learning at a younger age, perhaps starting with schools.

The curriculum could include lectures, placements and design modules, perhaps drawing on experiences from other countries where they may have a better system. Exercises, talking and discussion are all important, not only to generate ideas, but also to develop some of the inherent principles of sustainability that students identified, such as crossing boundaries.

Core themes could be developed by a continued narrative throughout the course with interaction, making it personal for the student in relation to their views and interests. It is also important to show students that their views and feedback on such issues are valued, for example through the use of an 'ideas box' for students, which would help make the engagement with the concept a more tangible experience.

As the conversations within focus groups developed into a deeper consideration of approaches to teaching and learning the role and structure of a university programme are questioned, modularisation may challenge integration of holistic approaches to learning of overarching concepts such as sustainability.

5 Discussion

In this investigation we sought to investigate how engineering students viewed sustainability, what role they perceived it to hold in their work, and how they felt it should be incorporated into their education. With attention moving towards the role of the graduate engineer, programme content and learning experiences may be questioned. What are the fundamental understanding and skills that may be offered by an engineering graduate in the 21st Century?

It was clear that sustainability was viewed as an important and integral part of an engineering curriculum for the 21st Century, even if some aspects required further clarification. What was also evident was that many opportunities exist for enhancing engineering pedagogies which in turn was supported by calls for more sustainability awareness and development from faculty.

In this discussion we propose that engineering pedagogies may be developed through the constructive application of sustainable development and global thinking to a holistic

engineering curriculum with a particular suggestion that assessment practices offer many opportunities to develop student thinking without adding content to the core curriculum.

A foundation of this approach is to consider what are key characteristics of the an undergraduate honours or taught masters degree;

> "*An Honours graduate will have developed an understanding of a complex body of knowledge, some of it at the current boundaries of an academic discipline..... The graduate will be able to evaluate evidence, arguments and assumptions, to reach sound judgements, and to communicate effectively.*
>
> *An Honours graduate should have the qualities needed for employment in situations requiring the exercise of personal responsibility, and decision-making in complex and unpredictable circumstances. "*
>
> *"…...Students [at Masters level] will have shown originality in the application of knowledge, and they will understand how the boundaries of knowledge are advanced through research. They will be able to deal with complex issues both systematically and creatively, and they will show originality in tackling and solving problems.*
>
> *They will have the qualities needed for employment in circumstances requiring sound judgement, personal responsibility and initiative, in complex and unpredictable professional environments."*

In reading these statements with 'education for sustainable development' as ones aim, countless opportunities arise, for example how better to take the student to the "current boundaries of the academic subject" or to "evaluate evidence, arguments and assumptions" even before any recourse to demonstration of "personal responsibility" is made.

Through dialogue with students we have evidenced the motivational power of incorporating engineering for sustainable development within the curriculum and suggest that when this is combined with approaches to learning which may be termed as authentic and engaging students in assessment tasks which mimic the situation of an engineering practitioner. Through the structured use of tasks incorporating wicked problems. and industrial focussed projects real engagement with learning will be fostered as well as allowing the graduate attributes requested by employers may be practiced and assessed.

For many years the trend within engineering curricula has been to focus on the acquisition of a comprehensive body of knowledge which may then be applied to the solution of technical problems through the approach of taught solutions, termed worked examples and case studies. Often design projects, or more recently forays into problem and project based learning, have been used to give context to the application of technical knowledge with an additional hope that characteristically difficult aspects such as innovation and creativity will be displayed. Yet the broader results of such approaches are often delicately balanced as not all learners develop sufficient confidence in the underlying engineering science to be free and open in their thinking to enable innovative application and creative problem solving, often the result is an outcome which mimics the examples given by the tutor.

The technological developments of recent years have not been universally applied across the Globe and as engineers we are well aware of, and are able to measure, the results of the decisions of our predecessors and colleagues, such as expanding energy demands, scarcity of

certain material resources, contamination of ground water and transport congestion. Therefore our current ability to apply knowledge is failing us, and more knowledge will not overcome this deficiency. The students contributing to this study clearly stated that they expect us to give them the tools to enable them to consider the holistic application of their engineering knowledge in a way that is wholly sustainable and not just through short term and local solutions.

Therefore it may be asked; how can we introduce sustainable development and global competencies holistically as additional complex and ill defined challenges within this curriculum?

So what is needed to transform engineering pedagogies? If it is the approach being taken to the application of knowledge which is leading to unsustainable application of technology within the World then this is the aspect which must change. To enable this room must be found within the engineering curriculum and for transformation to be achieved we need to step back and consider 'what matters' within engineering learning? Consideration of this leads to questions of what student engineers need to know verses what student engineers need to be able to do (going beyond telling us what they know to telling us what it means).

The availability, quantity and ease with which engineering knowledge may be accessed has undergone an explosive expansion in recent years (as a result of digital technologies), often it is now not the lack of information which baffles our students but rather the volume, variety and questions of quality which are troublesome. For this reason the basic objectives of engineering programmes need to reconsider the nature of personal development fostered by educational programmes and in particular through traditional assessment practices.

It is suggested here that it is assessment (as identified in the student questionnaire) which may be the real key to demonstrating the fundamental opportunities of placing engineering for sustainable development and global thinking within the curriculum.

The approach proposed here is that sustainable development and global competencies are not seen as additional aspects of the curriculum but are instead seen as core facets of engineering and can be considered as foundations of engineering applications. Without application knowledge is abstract science and not engineering, and without consideration of all aspects, locations and stakeholders of application the engineering may be considered as potentially flawed. *"When we practice our profession of engineering, it is important that we view humanity and the ecosystem as part of an undivisible whole"* (Baillie and Catalano 2009).

It is proposed that the evidence of the motivation and also the suggestions that students make are strong indicators that deep integration of the themes of sustainable development and global awareness within the engineering curriculum should be pursued. Consideration of how assessment may be used constructively within the curriculum provides many opportunities for faculty to create situations where an understanding of discipline specific knowledge may be assessed through its application within the context of sustainable development. The many facets of assessment which are available, and the extent to which they may be developed can be illustrated as in Table 1.

Regardless of the specific curriculum area the progress of the challenge of assessment task structure will be broadly similar, moving from well defined through to ill defined and complex.

Table 1: Development of complexity and uncertainty within assessment task grade

Task grade	Approach to problem solving	Single or multidisciplinary	Complexity of knowledge required	Clarity of context	Definition of outcome
a	simple	basic single	basic	well defined	well defined
b	less simple but defined	single discipline	basic	well defined	well defined
c	less simple and undefined	single discipline	basic	well defined	well defined
d	less simple and undefined	multi-disciplinary	defined	well defined	well defined
e	undefined	multi-disciplinary	defined	less well defined	defined
f	undefined	multi-disciplinary	undefined	defined	defined
g	undefined	multi-disciplinary	undefined	undefined	defined
h	complex and undefined	multi-disciplinary	undefined	undefined	undefined

As a final statement which may support this proposed approach to developing an engineering pedagogy with less focus on the acquisition of knowledge and more focus on developing experience of critical thinking and creatively applying knowledge we give the following extract from the foreword to UK-SPEC which states "*Professional engineering is not just a job – it is a mindset and sometimes a way of life. Engineers use their judgement and experience to solve problems when the limits of scientific knowledge or mathematics are evident.*" (Engineering Council 2013)

References

Baillie, C., & Catalano, G. 2009. *Engineering and Society: working towards social justice*. Morgan and Claypool.

Engineering Council. 2013. *UK Standard for Professional Engineering Competence.* http://www.engc.org.uk/ecukdocuments/internet/document%20library/UK-SPEC.pdf

Quality Assurance Agency. 2008. *The Framework for Higher Education Qualifications in England, Wales and Northern Ireland.* http://www.qaa.ac.uk/Publications/InformationAndGuidance/Pages/The-framework-for-higher-education-qualifications-in-England-Wales-and-Northern-Ireland.aspx.

The data in this paper was taken from a Higher Education Academy Engineering Subject Centre funded project entitled 'Educating the global engineer: staff and student perspectives on embedding sustainable development practices into the engineering curriculum.' The project team was Catherine Montgomery, Roger Penlington, Jenna Tudor, Noel Perera and Angelina Wilson.