

Transformative Change in Engineering Education

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Introduction

There is a growing opinion amongst some parties that traditional engineering undergraduate degree courses are no longer providing the skills for the engineers of the future (Oskam, 2009). Many argue that a radical new approach to the curriculum is required. However, wholesale curriculum changes are difficult and take time. Although there has been much written around transforming pedagogies and methods of delivering engineering subjects there is still the dilemma of how to integrate the skills required of future engineers without compromising their technical foundation.

In this regard, some European Universities have been looking at ways to include 'breadth' papers in addition to the student's degree specialisation. A recent study by Alpay (2013) indicated that this approach was proving highly attractive to students. Furthermore, Miller (2010) reported that modern students are motivated to make a difference in the world and the lives of people, but do not see the narrow study of physics and mathematics to be the key to tackling these problems. Miller argues that students do not see the study of engineering, science and mathematics as being directly related to the problems they see and care about, and that engineering curricula needs rebalancing.

The irony of this situation is that, as the world becomes more complex, the Grand Challenges (Miller, 2010) we face involve human behaviour as much as they do technology. Thus, a transformation of engineering education, that requires students to engage with real world challenges, could help provide engineering graduates with the skills required for the future. One of the challenges in achieving this was highlighted by Holmegaard et al (2010), who looked at students' dissatisfaction with engineering degree programs. While the study referred in general to STEM subjects, it reports that students perceive STEM programmes to offer little opportunity to develop themselves, beyond a professional level.

It could be suggested that a more authentic engineering education has the potential to help students develop creative problem solving and innovation skills. Authentic learning typically relates to real world complex problems and their solutions, using role playing exercises, problem-based activities in real world or simulated communities of practice. (Herrington, Reeves, & Oliver, 2014). Herod (2003) described authentic learning as "learning materials and activities... framed around real-life contexts in which they would be used. The underlying assumption of this approach is that the material is meaningful to the students and therefore more motivating and more deeply processed". Supporting this assumption, Chang et al (2010) reported that students engaged in authentic learning activities cultivate 'portable' skills and develop the flexibility to work across discipline and cultural boundaries to generate innovative solutions. This view resonates with Miller's view that millennial students are best motivated to learn by involvement in real world problems.

Therefore, if we are able to provide our engineering students the opportunity to integrate a more humanitarian aspect into their subject studies we will be providing a learning environment that would better motivate students to study engineering subjects and provide the world with engineers better prepared to meet the 'Grand Challenges'. One means of achieving this would be through use of Transformative Learning Theory (Mezirow, 1997) which can broadly be defined as: "...a process of becoming critically aware of how and why our assumptions have come to constrain the way we perceive, understand, and feel about our world: changing these structures of habitual expectation to make possible a more inclusive, discriminating and

integrative perspective and finally making choices or otherwise acting upon these new understanding”

As such, this paper looked at the way Transformative Learning Theory (Mezirow, 1997) has been applied in several areas within Auckland University of Technology’s mechanical engineering programmes.

Background

Auckland University of Technology (AUT) offers a number of accredited degree options including 4-year Bachelor of Engineering (BE) degrees (aligned the Washington Accord) and 3-year Bachelor of Engineering Technology (BEngTech) degrees (in line with the Sydney Accord), across a range of disciplines, including mechanical, electrical and built environment engineering. In offering these programmes, AUT has framed itself as a contemporary university with a distinctive approach to teaching and learning. It has a vision of providing student-centred, innovative and responsive learning experiences.

Around six years ago AUT undertook a major curriculum development in line with this vision. In executing the vision, the new curriculum was built around an engineering design ‘spine’, thus providing a framework upon which to build technical, professional and humanitarian competencies. The aim of doing this was to deliver an enhanced understanding of the role a professional engineer plays in society.

Philosophically, the design spine of both mechanical engineering degrees (BE and BEngTech) provides the basis for more simulated authentic learning opportunities. Each year of both degrees include design projects that are based around loosely defined problems that require students, working in groups of four, to produce their solutions in the form of written reports and to also be able to present this work to their peers. In their first year we use the EWB challenge to involve our first-year students in real world problems and aim to develop effective communication skills in an engineering context. In second year, we use self-selecting groups in a ‘design office’ style context and in later years use a similar model with increasingly complex problems.

It is hypothesised that the implementation of this model provides a way of engaging and providing a deeper learning experience for students. Furthermore, with real or simulated assignments, it is believed that this will encourage students to grow into a more self-directed learning mode and become lifelong learners.

Case Studies

Engineers Without Borders (EWB) Design Challenge

In the first year of their degree, AUT uses the EWB challenge to involve students in real world problems. The EWB project forms the context for our Introduction to Engineering Design paper, which is a core paper for all first-year engineering students. This paper aims to develop effective communication skills in an engineering design context, using a variety of media. It further aims to develop an understanding of the role and responsibilities of an engineer in society.

The pedagogy used for this paper is different to that of traditional engineering subjects where students passively receive information from the lecturer. Overall the approach is one of active learning. The design element is essentially covered by students completing tutorial problems individually or in groups with the aid of a facilitator. The EWB Challenge could be considered either as an authentic problem-based learning or inquiry-based learning and represents an opportunity for students to learn about and understand different cultures and be involved in an exciting time of change for the region selected for that year’s challenge.

A previous challenge was based on rural hilltop communities in the Gorka District of Nepal. It presented an opportunity to learn not just about the challenges facing the communities, but

also about community development in general, and the role engineers and other technical professionals can play. EWB is working towards the goal of a transformed engineering sector so that every engineer has the skills, knowledge, experience and attitude to contribute towards a sustainable community development and poverty alleviation. The EWB Challenge programme aims to contribute to this broader goal by working with universities to create change within engineering curriculum and help to shape engineers of the future by achieving the following objectives.

At AUT, there were around 100 reports submitted for the Nepal project, all were of a good standard; some were exceptional for first year students. Some groups and individuals were extremely well motivated and developed research skills preparing them well for life-long learning. Most students achieved learning outcomes that included critical thinking, ability for independent inquiry and the responsibility for own learning and intellectual growth.

While no evidence proves that problem-based learning enhances academic achievement, as measured by examinations, there is evidence to suggest the problem-based learning 'works' for achieving other important learning outcomes. Several studies suggest that problem-based learning develops more positive student attitudes, fosters a deeper approach to learning, and helps students retain knowledge longer than traditional instruction. Further, just as cooperative learning provides a natural environment to promote interpersonal skills and provide a natural environment for developing life-long learning skills (Kolmos, Fink, & Krogh, 2004). This was supported, anecdotally, by students' feedback on the EWB challenge:

"I found the EWB Challenge a great way to open our minds to the way in which engineers are required to think. I believe that it gave me a good taste of how engineers should approach a problem and work with different people to provide a plausible solution. From this challenge I've not only learnt more about the world, but I've been able to hone in on (sic) all my skills such communication, problem solving etc. To improve this project, I would have liked for it to be possible to have some consultation with the community of interest, just to experience with compromising and re-evaluating possible solutions with the people who ultimately determine the outcome of the entire design." BE student

"I think the EWB design project was a great experience, working with other members to find a solution was challenging from this design project. I learnt a lot of skills such as communication, presentation and sourcing various things, it was a great experience." BEngTech student

From this it is apparent that the use of the EWB challenge within the curriculum has been successful in fostering an engagement in the learning process. Moreover, it appears to have instilled an interest in the human aspect of engineering in our students, as hope for, based on Transformative Learning Theory.

Authentic Design Based Learning Project: Vehicle of the future

In line with AUT's desire to use more authentic learning exercises, second year students were asked to consider the future of transportation within their community, i.e. Auckland. Here students were required to self-assign into groups of four, like what would be typical in a real-life design office. A workspace, like a design office, was made available to all students in order to simulate, as closely as possible, conditions that would be encountered outside of university. They were given a project brief that outlines a problem and leaves the students enough scope to be creative in developing possible solutions and then presenting these solutions in a detailed professional level report.

For this exercise, the brief read:

Your design consultancy has been tasked by Auckland Transport (AT) to produce a design concept for a new type of personal transport and parking facility that

solves some major infrastructure issues within the Super City. The issues are, but not limited to:

- 1. High traffic congestion on main arterial routes.*
- 2. High levels of traffic noise and air pollution.*
- 3. Insufficient parking space.*

Auckland City (AC) has also recently decided that it cannot keep expanding into new suburbs so all of the city dedicated car parking buildings must be demolished to make space for new apartment blocks. To compensate for this reduction in parking capacity AC have identified a vacant space along the city waterfront which could be used as a car park. There are however some issues with this location.

As part of a feasibility study, AT have ascertained that, based on current car dimensions of 50m x 100m this space can only hold 5% of the anticipated daily city commuter traffic that enters the city.

AC also desires that the parking space be 'future-proofed' for expansion in vehicle numbers.

There are protected historic buildings on either side of the car park and the last colony of a native and highly endangered Maui Seal is located on the rocky foreshore directly adjacent and beneath the cliff edge of the proposed car park.

The final design concept and supporting details presented by your design consultancy must be presented within a professional report written at an appropriate level for presentation to the AC. Supporting material is to be provided in your individual design logbooks which will also be part of the material submitted for assessment. Each design consultancy studying this paper is lobbying to be awarded the contract to further develop their design, so this is a competitive process. You are to work in your design groups, allocating specific tasks to each member as part of your strategic plan and all work undertaken by each individual member must be chronicled in their respective logbook. Specifically, you are required to develop and present within your report the unique features and attributes that characterize your concept design. Part of this exercise is time and project management. You are responsible for meeting the completion deadline and must show evidence of a time management plan.

From the brief, it is apparent that in addition to the technical aspects of this project, there are other professional and humanitarian skills being acquired. More specifically, the project requires an understanding of environmental, social, ethical and legal requirements that engineers face on a day-to-day basis. Furthermore, the requirement to work in a group promotes collaboration and communication skills that employers are currently looking for. As such, we believe this project illustrates well how a simulated authentic problem-based learning experience, viewed through a Transformative Learning Theory lens, can replace the traditional lecture/tutorial model.

Authentic Assignments: Smart Materials

Despite the emphasis AUT has placed on authentic experiences in the design, the use of this has also been implemented into other areas of the curriculum. The underlying aim is to demonstrate the various roles that engineers play.

In this instance the topic of SMART materials was covered in two separate final year courses, Advanced Manufacturing Processes and Advanced Materials by way of traditional lectures. Both courses were taught separately, and no effective link was made between the properties of these type of materials and how they could be manufactured in the future, environmental, sustainability issues and commercial possibilities. As such, students typically would try to remember only enough to 'get through' both papers.

To this end, an 'authentic' assignment was developed to engage students more deeply with the subject. The assignment places the student in the role of engineer who must investigate and report formally to their CEO:

"You are the Project Engineer of a fictitious Company. This Company can be based on an existing Company that has developed 'Smart Materials' into a product.

The CEO of your Company has heard something about these 'these so-called smart materials'. He has little understanding of what they are and how they might benefit your Company. [Choose an Industry or Company]

He has asked you to prepare a report that explains what they are and how they could be used in future products for your Company.

Give details of the material properties.

You are asked to detail the possible applications applicable to your Company or Industry and the benefits they could bring.

You are expected to detail materials and processes involved.

You are expected to consider 'design for sustainability issues'

You should make recommendations on possible development of 'Smart' materials in your particular Company.

This should be produced in report format and be no more than 2000 words.

Again, it can be seen that students are encouraged (i.e. expected) to think about the wider implications of engineering. In doing this they need to not only engage in issues of sustainability, but the broader expectations placed on engineers in the profession and society at large. Though evidence is still being gathered on the efficacy of this assignment, it is believed that it helped foster a greater engagement with self-directed learning and lifelong learning skills.

Capstone Project: Halal Slaughter Machine

Capstone or thesis projects are a cornerstone of all engineering degree programmes in Australia and New Zealand and are the pinnacle of achievement within these programmes. At AUT both BE and BEngTech students are required to complete a capstone project, wherever possible this is a real industry project.

The project referred to in this case resulted directly from the student seeking out a summer internship with a company prior to entering their final year. This project involved the design and development of a ritual slaughter machine to restrain animals during ritual slaughter of meat in a Halal/Kosher (Muslim/Jewish) manner. The machine was required to comply with all the rules and restrictions for the ceremonial killing for the meat to be edible/ acceptable by the respective community.

Although people had attempted to create devices of this nature, none of the previous machines were known to satisfy the slaughter process requirements to be able to qualify as Halal/Kosher. The student not only produced an excellent final year project, the design won a national prize and the student was subsequently offered a full-time position with the company. Because of the student's work the company are now successfully exporting these machines to the Middle East.

Although this is only one example of a student outcome, it does serve to illustrate how AUT's philosophy of authentic learning based around a design spine has been able to deliver the results Transformative Learning Theory targets.

Conclusion

Although it is too early to draw firm conclusions on the efficacy of AUT's application of Transformative Learning Theory and authentic assessments our experiences to date suggest that inclusion in our curricula of issues that modern students relate well to have improved their general level of motivation, attendance and contribution to their respective groups.

Some of our recent students have graduated and are now involved in humanitarian engineering projects. Some are working with EWB, others with construction companies on social projects, and one with the UN working on engineering projects.

Over the last few years we have been able to attract some students to our programmes who previously would have been lost to engineering. This is particularly true for female engineers. Just over ten years ago only 1% of our engineering students were female. It is now at around 18%. It could be that our approach of embedding humanitarian engineering and more authentic problem solving rather than traditional lectures throughout our degree is a major factor in this.

In our view our whole curriculum needs reviewing to be in line with what is needed for the education of future engineers but whole curriculum reviews are difficult and take time. In common with many other universities engineering faculties looking to add more 'breadth' papers and we are currently discussing this. Some would see these being standalone papers that would mean losing some core technical papers, however our experience would suggest that embedding these throughout the programme is a better solution as it contextualises their presence and delivers a more holistic view of what engineering is.

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