

Engineering Education towards Social and Environmental Justice

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***Abstract:** The impact of the engineering industry on communities and the natural environment can be considerable, both positively and negatively. Recognising this, this impact is a key motivator for developing professional engineers who are equipped to critically examine their role, and who can ensure their actions are in the best interests of the community. The required theme of social and environmental justice goes beyond the standard definitions of ethical professional conduct, to where engineering solutions are implemented with community outcomes at their core.*

Educating engineers with the embedded skills and mindset to consider these issues is a challenge for academics and educators. This paper discusses a project on this topic being undertaken for the Australian Learning and Teaching Council on the topic of Engineering Education for Social and Environmental Justice. This program is being led by researchers at the University of Western Australia and involving academics at five institutions in Australia and the United States. This project involves developing, delivering and evaluating courses that have been designed to provide exposure to, and increase understanding of, social justice issues amongst engineering students. This paper is in two parts and includes preliminary outcomes from a pilot study into the student experience within one such course, using threshold concept theory to determine barriers to learning. The second part of this paper outlines future research within this project.

Project Overview

This paper describes research being conducted as part of an Australian Learning and Teaching Council (ALTC) project – *Engineering Education for Social and Environmental Justice* (EESEJ). This project involves academics from the University of Western Australia (UWA) working in conjunction with participating researchers from Murdoch University, University of Sydney, Rensselaer Polytechnic Institute (United States of America) and Engineers Without Borders Australia (EWB).

In this context, the definition of social justice is well defined by Marullo & Edwards (2000, pp. 899) who write, “when one’s goal is social justice, one attempts to alter the structural, or institutional practices that produce excessive or unjustified inequalities among individuals or that treat people unfairly – for example, discriminating among people on the basis of race, sex, social class, religion, nationality, ethnicity, sexual orientation, or disability status.”

The EESEJ project covers two core areas, Engineering Curriculum and Engineering Pedagogy. The Engineering Curriculum portion of the project involves developing knowledge maps with a view to create a curriculum in which justice is valued. The Engineering Pedagogy portion of the project is exploring and analysing the courses that apply and deliver this content.

This research detailed in this paper aligns with the Engineering Pedagogy side of the EESEJ project and explores how themes related to social justice including equality, poverty, gender, globalisation,

and environmental impact can be included within university engineering courses. This is an emerging research area and one that is being recognised for the importance in developing engineers that will work in a globalised world characterised by increasing inequality between communities and nations, as well as ecological and financial instability.

Preliminary Results – Pilot Study

Overview

The pilot study for this research has been undertaken on the Introduction to Professional Engineering (Global Challenges in Engineering) Course at UWA. The course is a first year introductory engineering course for engineering students of all disciplines. The course structure includes two distinct sessions: (1) an information session in which theoretical topics relating to engineering, society and the environment are explored; and (2) a practical session where students worked in teams on a waste project for communities in India, Argentina or Western Australia. The course was tutored by ‘information tutors’ who were not engineers but were expert in social sciences and education and ‘practical tutors’ who were engineers.

Research Direction

The purpose of this research was to analyse the effectiveness of the course on developing students’ understanding of social justice issues. The two research questions which framed this initial research were (1) How effective was the Global Challenges in Engineering Course at improving understanding of social justice? (2) Which themes and topics acted as barriers to learning and could be considered threshold concepts?

Methodology

For this research, a qualitative approach was applied, using threshold concept theory. Threshold concept theory is a methodology that aims to determine topics which act as ‘portals’ that lead to a previously inaccessible way of thinking about something and which may be troublesome to learn (Meyer and Land, 2005). Once this threshold has been crossed that knowledge is now accessible and the learner can move to the next level of understanding. To perform this analysis, student feedback is provided, generally through interviews, although this can be supplemented by qualitative written responses. In this context, it is worth mentioning that threshold concepts could be both theoretical topics, as well as the approach that the course takes to address them.

Data Collection

In this preliminary study, a qualitative approach was utilised, drawn from focus group interviews and student surveys. Volunteer students participated in interviews involving between one and four students simultaneously; lasting around an hour. The questions used in these interviews were open ended and aimed to provide students with the opportunity to reflect on their experience. Probing questions were used to gain further information and clarification. Six focus groups sessions were undertaken with 11 students participating. These interviews were transcribed to enable more detailed analysis. The total cohort undertaking this course was 440 students. Further to the interviews, surveys were completed with students being able to comment on their experiences, which were returned by 336 students.

Analysis

The written responses and transcribed interviews were analysed to determine recurring troublesome areas and to better understand the collective experience of the course. Perkins (1999) and Meyer and Land (2005) identified a series of barriers to understanding, and areas of troublesome knowledge. These are as follows: conceptually difficult knowledge; ritual knowledge; tacit knowledge; inert knowledge; foreign or alien knowledge; troublesome language; and ways of thinking and practice. This provided a good framework to analyse student responses to the social justice themes within the course.

Conceptually Difficult Knowledge – As acknowledged by Perkins (1999), all areas of scholarship have conceptually difficult areas of knowledge. Within engineering, with its emphasis on science and

mathematics, these topics are commonplace. During the focus group interviews, students were directly asked what areas of the course they found challenging or troublesome. While the following areas of troublesome knowledge demonstrate that there were areas which were barriers to understanding, students responded that they didn't believe the course contained subject matter that was difficult. Further questions later revealed that there were barriers to understanding, but these did not emerge from this direct question. Noting that students were likely to be comparing the content matter to their other technical subjects, it is perhaps unsurprising that they did not consider the course conceptually difficult. Whilst course tutors were clear that many students lagged in their comprehension of key points, the students did not in fact understand that they did not understand. A representative response to this question is as follows.

"None of it was really that difficult because I thought the information packages were quite straightforward. All those topics you can understand. It wasn't really abstract concepts."

Some students, however were able to clarify what they did not understand and it was common to hear students consider things as 'vague', in a derogatory way, when they didn't grasp the complexity of the issue.

"I found the concept of globalisation confusing as it has pros & cons about it for eg. It influences quality of services & is economically beneficial but confronts us with morality & ethics."

Tacit Knowledge – Meyer and Land (2005) build on the definitions by Perkins (1999) to define this area of knowledge as that which is often hidden or unstated. This can be an issue when "assumed knowledge" is not shared with those new to the field. As this knowledge is not directly revealed, it can be difficult for the novice learner to develop, and cause a barrier for a more complete understanding. There were many basic assumptions being made by the non-engineering social science tutors in introducing certain topics to first year engineers, which they may not share.

The link between poor people and rich people. How does our economic system increase the gap between the rich and poor?

Why (can't) the local government find better ways to solve the problems of living conditions?

Troublesome Language – Difficulties in understanding jargon can make the learning process more challenging especially when there are commonplace definitions as well as multiply correct technical ones.

"If a random definition came up like 'sustainability', or something like that the class didn't 100% understand, I think some of [the other students], sort of, just didn't participate. I think there were a couple of different definitions, here and there, that they didn't quite grasp. But I think it's just that they didn't bother to read it, because a lot of the kids thought, "oh, information session, easy way to waste time," so they didn't even bother reading the information."

Alien and Foreign Knowledge – When a topic is entirely new, it stands to reason that individuals might have a harder time in understanding the topics. For example, one student responded that globalisation was a topic that they hadn't encountered in the past.

"I researched globalisation. I'd heard about it, here and there, but it's not exactly a conversation you have everyday... When they spoke about how to impact a culture, how people actually losing their culture because everyone kind of just merging to one super group of people. I realised that I'd been thinking about for a while how people have

actually lost their cultures. I'd also thought how that doesn't seem quite right, but I never put a word to it, until now. Now, I sort of broaden my idea, of it."

Ways of Thinking and Practice – Beyond the content, the ways of thinking and implementing the learned topics can also be a barrier for understanding the content. This was a recurring area that students identified as challenging. As part of the course, students were asked to reflect on their feelings in response to readings and videos; something many students found this challenging. The task was foreign to most engineering students where course matter is generally of a technical nature. Also new to many students was working in teams within practical session and the challenges associated with group dynamics.

"My group was not very willing to work. We didn't allocate roles, but I've sort of taken the role of maybe, team leader. They just didn't do any work, and if I asked them, could they please do this and they'd never do it. That would be the biggest challenge. So, you might get a good mark at the end of it, and they just were so set on "Well, I don't really care." Like, "If I pass, that's the main thing." ... That was one of the hardest things that I found."

The project was not graded on the technical solution provided, but rather the design process and applying course content and developing a culturally and environmentally appropriate solution. For students accustomed to being graded on their technical output, this was a challenging adjustment.

Outcomes and Conclusions

This pilot research provided some preliminary results that provide insight into the topics, and delivery techniques that are challenging for students. Most notable in content were related to globalisation and neo-liberalism. These were foreign topics that students had little to no exposure with. Interestingly, these were topics that split the respondents in how they engaged with them. Some students expressed a strong interest and went beyond the course involvement to explore them further, while others opted not to engage, and completed the course with only little further understanding.

This course deliberately emphasised social themes, and downplayed the technical design portions of engineering. Without engineering mathematics and design providing conceptually difficult aspects, some students had the attitude that the course was not worth as much time and effort as other courses. Almost universally acknowledged was the fact that the topics covered in this course were not covered elsewhere and that the topics covered in this course filled a gap.

The way this course was delivered presented challenges for some students. With a strong team focus some students found group dynamics challenging. An important part of engineering, this was an important part of the course design. Furthermore, the project part of the course (deliberately) had less well-defined aims and outcomes, which some students found challenging. With this aspects being an important part of the engineering profession (teamwork and problem definition), it is believed that these lessons are of value for students.

Broader Research Project

Overview

As part of the ALTC project, there are seven courses that have been created, or significantly updated, to include themes of social and environmental justice. These courses are as follow (1) Introduction to Professional Engineering (Global Challenges in Engineering), UWA, First Year Course; (2) Engineering for Social Justice, UWA, Third Year Course; (3) Environmental Engineering Design and Management, UWA, Third / Final Year Course; (4) Design Concepts in Science and Engineering, Murdoch University, First Year Course; (5) Professional Engineering, University of Sydney, First Year Course; (6) Rensselaer Polytechnic Institute (USA), Course to be Finalised; and (7) Humanitarian Engineering Research Program, EWB, Multiple Universities, Final Year Research Program.

These courses are varied in their approach to social and environmental justice issues, with some being explicit and predominantly focussed on this area, where others include these content as a smaller aspect within a broader course. This paper describes outcomes from preliminary research, conducted on a number of these courses.

Method and Methodology

Two theoretical frameworks will be drawn upon for future research: phenomenography and threshold concept theory. Phenomenography is a research methodology that investigates a collective experience of an event, activity or other phenomenon. Throughout this research, the event in question will be the educational activity (course of research project). This research methodology is particularly effective at understanding and describing the participants' experiences during a particular event, in this case during the engineering courses (Daly et al, 2008). Threshold concept theory, as described in the pilot study, will continue to be used throughout the research.

The data collection associated with this research will be conducted by a range of methods. These include through student surveys; student reflective reports and analysis of student assignments.

For each of these courses, this data will be supplemented by focus groups and individual interviews to explore in greater detail students' perceptions to the course content and delivery. These interviews are recorded, transcribed and analysed for key themes and outcomes.

Future Research

The pilot study detailed some of the areas which can be identified as troublesome for students, and these will continue to be defined in the coming months. The research questions that remain outstanding include the following:

- What specific topics related to social justice are particularly challenging for students, and can be considered "threshold concepts"?
- In what ways do students who have been involved in humanitarian engineering research projects, as opposed to more traditional projects, approach topics such as international development, engineering for community and multi-disciplinary projects?
- What is the best practice in educating social justice for engineering in relation to the structure, content and delivery methods?

These questions will form the basis of the ongoing research as part of this project.

Conclusion

With engineers continuing to be involved in complex, multidisciplinary projects that cross international boundaries and cultures, it is crucial that they are able to effectively understand issues related to social and environmental justice. Educators have a key role in developing professional engineers with these skills and as the courses included in this research have shown, there is scope to include these topics within university programs.

This paper has documented preliminary research into a course that has included social and environmental justice topics and highlighted some of the troublesome areas that students encounter. As these topics are different from the technical courses that engineering students are accustomed to, the initial findings suggest that challenges that students face relate to delivery and approach, as well as foreign material. By increasing our understanding of these troublesome knowledge areas, we can improve teaching and ensure appropriate efforts are afforded to assist students pass through the threshold of understanding.

This paper has also outlined the focus for future research in the field of engineering education and social justice.

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