The impact of curriculum content in fostering inclusive engineering: data from a national evaluation of the use of EWB projects in first year engineering.

Lesley Jolly[1], Caroline Crosthwaite[1], Lyn Brodie[2], Lydia Kavanagh[1], Laurie Buys[3]

[1]Faculty of Engineering, Architecture and Information Technology, University of Queensland, Brisbane, Australia
l.jolly@uq.edu.au, c.crosthwaite@uq.edu.au, l.kavanagh@uq.edu.au

[2] Faculty of Engineering and surveying, University of Southern Queensland, Toowoomba, Australia
Lyn.brodie@usq.edu.au

[3]Faculty of Built Environment and Engineering, Queensland University of Technology, Brisbane, Australia
l.buys@qut.edu.au

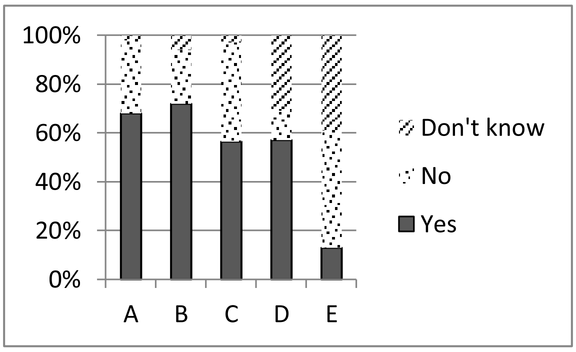
Abstract: *The year of Humanitarian Engineering draws our attention to the need to develop engineers who are not just technically competent but who can effectively address the needs of communities, maintain their ethical responsibilities, and take sustainability into consideration. This is what we understand by inclusive engineering. One approach to introducing such considerations into the curriculum has been the widespread use of Engineers Without Borders (EWB) projects in development settings as first year learning opportunities. We are evaluating different uses of these projects in 13 universities around Australia and New Zealand using a program logic data gathering methodology and a critical realist analytic approach to answer the research question "what works for whom under what circumstances?" In this paper we will concentrate mainly on one of these sites The University of Queensland. Data reveals that the EWB projects have great potential for raising issues of community involvement, ethics and sustainability but that the content of projects alone cannot guarantee that such objectives are addressed. Contextual factors, including: the focus of the course (e.g. professional development versus design), the attitudes of staff, and the pedagogy used all contribute to the successful pursuit of non-technical objectives. Projects with little obvious humanitarian or inclusive content such as one for long-wall supports in mining were found to foster context-sensitive approaches. In addition to project content, educators who are seeking to develop humanitarian and inclusive engineers need to pay attention to consistently expressed goals and values amongst the teaching team and the alignment of assessment (in style and weighting) with clearly stated learning goals.*

Content issues in educating for inclusive humanitarian engineering

Since 2008, Engineers Without Borders (EWB) offered a first year engineering student Challenge, requiring students to develop solutions for a selection of real problems experienced in one of their development project sites. Sites vary annually and have included communities in India, Cambodia and remote Australia, focusing on issues such as fresh water supply, basic infrastructure and housing as examples. Students work in teams to arrive at their solutions and may nominate to enter a national competition, judged by a panel of industry and community experts.

Universities quickly embraced the opportunities presented by Challenge. It is thought many academics saw the Challenge as providing an opportunity to move the first year curriculum away from abstract maths and physics to embracing activities aligned with practical engineering – solving real-world problems. Given the projects are team based, it also allowed universities to address graduate attributes around teamwork, communication and ethics. The content of the projects also allowed for attention to be focused on sustainability, appropriate technology and related issues within an engineering context and application model. There has also been resistance to the Challenge from those who question the value and outcomes of the projects, particularly in relation to engineering sub-disciplines (such as mining) who feel that the nature of the projects precludes their interests

Two years of earlier formal evaluation at the University of Queensland (Crosthwaite *et al*. 2009, Jolly *et al*. 2009, Jolly *et. al*. 2010), yielded mixed results as to the efficacy of the EWB projects. For instance, when asked whether the Challenge encouraged them to learn about sustainable development, 70% of the students agreed (Steer 2008), which meant that 300 students believed that it had no impact on them with respect to sustainability. Similar patchiness was evident with respect to other important aims of the course (Figure 1).



A: Was the reality of the project important?

B: Did the EWB project help you learn about sustainability?

C: Were your perceptions of engineering changed?

D: Did the EWB project add to your first year experience?

E: Would an invented scenario have worked better?

Figure1: 2008 student responses to EWB Challenge (Steer 2008)

However, given the extensive use of the Challenge, it was unclear whether these findings were unique to one university or more widely generalisable. Thus, in order to further explore our understanding of the bases of these various outcomes and to understand “what works for whom under what circumstances” (Pawson and Tilley 1997) the evaluation was expanded to include 13 universities across Australia and New Zealand, all of whom participate in some form of the Challenge. Our research aims to identify how differing application factors, for example course focus, produce different responses in student and how the range of student responses leads to the observed outcomes.

We argue that although projects such as those fostered through the EWB Challenge allow for the exploration of engineering in the service of society, they do not necessarily guarantee it. While some students are motivated by the idea of working for society, others are not. What and how engineers learn about working for society is directly affected by a host of contextual factors, such as instructor attitudes and course design, including assessment requirements. Content inputs are important to outcomes but they are not the only relevant considerations.

Theoretical framework

We began our research with program logic analyses which included mapping ‘how’ course controllers believed the use of EWB projects ought to work to produce the desired outcomes. This approach examined the adequacy of the ‘theory’ behind the implementation, that is, how participants expected their implementation to work and how likely it was that their expectations would be met (Brouselle *et al.* 2009). Naturally, those understandings and what was identified as desired outcomes varied across the sample as detailed in the section on Course and Institutional Context.

In the context of an increasing awareness that educational evaluation needs to treat educational interventions as social practices (Saunders *et al*. 2011), we chose the realist evaluative framework associated with Pawson and Tilley (1997) for its power to reveal “precise and substantive programme learning” (Blamey and Mackenzie 2007 p.451). It is also an approach whose realist epistemology, generative understanding of action, and focus on generalisable mechanisms for change could be expected to find a sympathetic audience in engineering’s similar discourses.

The approach starts from the position that aspects of **context**, including all of the activities that make up an intervention, provide the subjects of the intervention with a range of possible ways of responding to it. These responses are **mechanisms** that bring about the outcomes or changes (or learning). Mechanisms are not the activities that the intervention puts in place but the choices the subjects make about how they will respond, along with the capacities they bring with them to the task. Thus, if the intervention is the use of the EWB projects, context will include institutional factors, course design, instructor characteristics and so on, and the mechanisms will be the choices students make about what to do in response to the course. For instance, in a context where course design and instructor behaviours mean that student teams are left to fend for themselves, students might adopt any of a range of responses that we have previously labelled "in at the deep end", "mutual dependence" or "rugged individualist" (Jolly *et al.* 2009). The mechanisms which bring about change in this case are respectively, a development of teamwork strategies, a division of labour approach, or an understanding that teams don't work and one person always needs to intervene. Each of these mechanisms leads to different outcomes. This separation of activities from mechanisms is particularly useful in educational situations where there is a tendency for us to forget that the students are the sites of change and our actions as educators merely enable (or disable) that learning.

Methodology

Since data gathering and analysis at our various research partners is still going on, we will limit ourselves in this paper to discussing the Semester 1, 2011 implementation of the EWB projects at just one institution, The University of Queensland. The course under discussion had an enrolment of about 1000 students and was divided into four different projects: an EWB-based water purification project for chemical/ environmental engineers, a mechanical/ electrical/ software project to design a watercraft to remove post-flood debris, a civil/ materials project to design a deployable bridge, and a mining project to design long-wall supports. The students all attended the same set of lectures but each project had its own weekly 3-hour workshop session with discipline-specific tutors and project leaders. An important assessment item for all the projects was a public *Demo Day* where student teams were required to demonstrate their prototype designs. The idea of 'engineering in context' was understood by the course controller to be what united the subject and provided comparability across projects.

In this paper we draw on observational data collected in 21 hours of tutorials across all project areas and in 18 hours of *Demo Day* prototype demonstrations across all project areas. We also examined 200 pages from student workbooks and, at time of writing, have conducted formal interviews with three project leaders, as well as having had many casual conversations with project leaders and tutors. Further data was extracted from the student responses to an Exit Survey (Total N=812, 201 from UQ), as discussed below.

The course and institutional context

The initial results of the program logic analyses for all participating universities in Semester 1, 2011 and EWB, are tabulated in Table 1. It is immediately clear that there is a wide range of understandings of where the EWB projects should be situated in the curriculum with a tendency to use them in professional practice courses. This in itself has implications for how students will respond to the projects but that discussion and an extended description of the varieties of focus is beyond the scope of this paper. Instead we will concentrate on the first course in the table, "Introduction to Professional Practice". The course controller explained that the main objective of the course was "engineering in context".

This institution was one of the early adopters of the EWB projects but had struggled to make them relevant for all disciplines. In 2011, for the first time, the course was organised around the four different projects described above.

Table 1: First semester 2011 participants

Institution	Course Title	Nominated focus
Large research-led	Introduction to Professional Practice	Engineering in context
Medium sized research led	Discovering Engineering	Real projects for particular communities
Regional, online dominated	Introduction to Engineering Problem Solving	Problem solving
Non-Australian	Foundations of Engineering	Technical communication and design
Small technical	Sustainable Engineering Practice	Professional practice
Regional technical	Intro to Engineering and Design	Creativity in design
Remote regional	Design and Innovation	Communicating technology
Metropolitan technical	Sustainable Engineering	Professional development
Large metropolitan technical	Engineering and Sustainability	Intro to engineering
EWB	EWB Challenge in First Year Design	Sustainable development and appropriate technology

Project context and design constraints

EWB projects are embedded in their third-world contexts and the design brief reflected this in statements such as “EWB has invited you to collaborate on an engineering design project to address the need for a water purification device in the village.” The setting was consistently fore-grounded and related to design constraints at every opportunity. Unexpectedly, the mining project shared some of this approach with a design brief that emphasised the situation of workers in coal mines and their need for protection. Students paid consistent attention to mine conditions, and although this is not a social context in the same way as for the EWB sites, it is still a non-technical context. In contrast, the watercraft project was from the first about getting model craft to pick up ping-pong balls in a water tank. A scenario was presented of removing post-flood debris but this quickly faded from everyone’s consciousness. The civil project about a deployable bridge had the potential to invoke context and the brief began with discussion of Queensland’s recent floods. However, the brief went on to describe the task in commercial terms such “Your company is preparing a tender bid for the detailed engineering design for the 10 m span bridge.” and the need to produce a “client pitch”. This shift in context from community need to commercial practice was reflected in student workbooks which contained very little exploration of application contexts. On *Demo Day* we observed very few bridge designs that could be scaled up to real-world requirements, and this was also a problem with the watercraft projects. Teaching staff object to this interpretation since they saw successful completion of other assessment tasks which required students to pay attention to scalability. However, it is likely that only one or two members of a student team worked on this section of the report, thus all students may not have explored application contexts. What we can be sure about is what we saw students doing and saying in the watercraft and civil projects suggesting that context needs to be continually reinforced.

The use of a *Demo Day* where students’ prototypes could be demonstrated publically was exciting and motivating for tutors and students alike. One tutor remarked that “they are talking much more to each other and to us than they have done before”. However, the excitement of the build overshadowed the ultimate goal of designing something for a particular context in some cases. Students working on the watercraft were the most focussed on *Demo Day* conditions which included a circular water tub and ping-pong ball contaminants. Their designs were geared to recovering balls and therefore most of them were not suitable for scale up for recovery of debris of indeterminate sizes. The EWB projects, in contrast, were largely able to be deployed and paid more attention to the criterion requiring designs to reduce embodied energy. For most projects this was understood to pertain to the prototype only. So many watercraft were built of light weight foam but when asked about scaled up versions, students usually identified aluminium as the material of choice. One group told us “I suppose there are environmental issues but we don’t worry so much about that. It’s all on cost”. Staff in the course have already recognised the need to remove this tension between *Demo Day* requirements and assessment criteria and the goals of the course and are making changes for next year.

Finally the attitudes and classroom practices of the tutors and project leaders were important influences on how students responded to the projects. Some tutors were frank in their appraisal that it was all about *Demo Day* and getting marks. One tutor of the watercraft projects told one student group that he was worried about their design to pick up ping pong balls (researcher pauses in expectation of discussion about the difference between balls and real debris) but in the end he was glad they had gone with their design because they had ‘won’ - that is received top marks in this project category. As it happened, it was tutors in the EWB project groups who we observed to spend most time urging students to bring their ideas back to the context and it is likely that it was the content of the projects that also facilitated this. It is also possible that tutors self-selected for this project because of a pre-existing concern for engineering in context, although one tutor told us that he had previously been focussed on theoretical engineering but had found the EWB projects very motivating. He still tended to draw on his theoretical background, as others did their industry experience or their own work with EWB, but kept sight of the social and environmental context

Identifiable mechanisms

As we have seen, contextual factors have an influence on each other so we cannot say that any particular context will lead to a particular outcome. Here we consider the mechanisms provoked by the context - that is the choices students made about how they would respond - with reference to the desired outcome of an increased appreciation for an ability to engineer in context, taking account of social responsibilities and issues of sustainability. The two main categories of mechanism that we have room to discuss here are concern for context and concern for sustainability.

We have noted before (Jolly *et al*. 2009) that there is a strong altruistic streak in many engineering students (see also Steer 2008) and students continue to make statements such as “engineering can really do good in the world”. In the exit Survey, 79% of students from this institution agreed or strongly agreed that they were motivated by working on a project that could help people, with 10% undecided. Careful situation of projects can help provoke this altruistic response in susceptible students and we saw abundant evidence of students really worrying about how their designs would work in and impact on their settings. This was particularly evident in our observations of the EWB and mining projects.

However, for students the immediate context is a university course which they wish to pass so some element of mark hunting was also common. The clearest example of this dilemma for students comes from a group who were working on water purification. They worked hard to come up with a design that met all community constraints and answered local needs well - but the design was judged to be too slow to get maximum points on *Demo Day*. They therefore changed their design to make a faster, but less locally suitable prototype. Happily, they turned up at *Demo Day* with a third design which met all local requirements and worked well. Other groups were not so successful in negotiating the competing demands of community and assessment context.

As far as concern for sustainability went, it is clear that some students come to us with this in mind but this concern is not well fostered in courses. In the responses from students in all participating institutions to open ended questions on the Exit Survey (N=623), only two mentions of sustainability came up in response to “what were the positive aspects of your project”, while it was mentioned 7 or 8 times in response to “what was most challenging about your project”. One student noted “i think the content of what makes an idea sustainable was lacking in course content” and our observations in most sites bore that out. Some staff have indicated that they think sustainability cannot be taught to undergraduates (let alone first years) and these contextual factors reinforce pre-existing attitudes that sustainability is someone else’s problem.

Discussion

In what follows we consider the effect of certain context and mechanism factors on the learning outcomes most related to humanitarian or inclusive engineering. That is, those outcomes that relate to a student’s ability to pay attention to their ethical, social and environmental responsibilities. When we describe a context as enabling or disabling, it is with respect to those outcomes only. Similarly, some mechanisms are identified as supporting or inhibiting the development of those outcomes. It may be that these same factors may carry a different significance for other outcomes and this raises the question of how course and curriculum design can deal with competing aims. Unfortunately a more detailed discussion of this issue is beyond the scope of this paper.

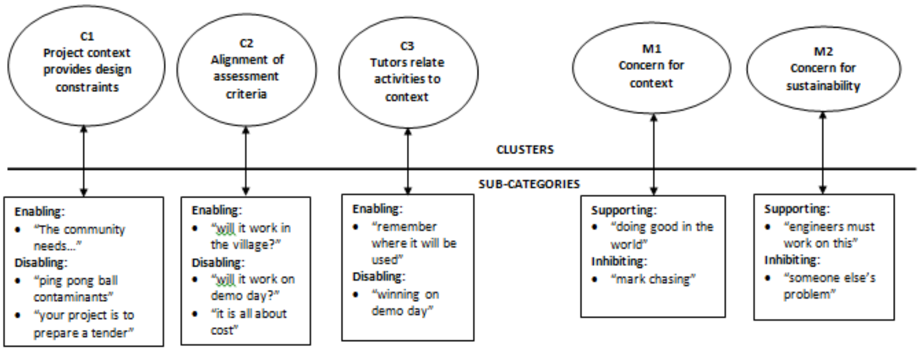


Figure 2: Realist model of factors influencing development of context-sensitive engineering.

C1, C2 and C3 in Figure 2 represent the contextual factors that were found to be most significant to the relevant learning outcomes in this case. C1, project context, enables the desired learning in cases where the emphasis is on user needs. While the EWB projects may be said to have made this easier because of their content, the mining project also used the need for protection of miners to stimulate context-relevant responses from students. The context of assessment (C2) was enabling where emphasis was placed on the real world context rather than the accomplishment of course requirements only, as the tension between *Demo Day* restraints and real world needs demonstrated. This was true of all projects regardless of content. Tutors' dedication to and promoting of the humanitarian objectives (C3) also made a significant difference to student responses. We saw this factor in operation most clearly in the EWB projects and it may be that the content of the projects encourages the required dedication.

There were two main kinds mechanism in operation as a result of these contextual factors. The first we have labelled "concern for context" (M1) and in context we include all of the environmental, social and ethical aspects of engineering. Where students were motivated by the desire to make a positive impact on the world they were likely to pay particular attention to project context. While this was superficially promoted by the content of the EWB projects, we observed some mark hunting and feeding the instructors a 'politically correct' line. On the other hand, there were instances of good attention to context in the other projects with less overt contextual emphasis, especially mining. The second mechanism was a concern for sustainability. It seems that some students come to us with their minds already made up on sustainability. While the content of the EWB projects ought to be ideal for raising the issue, it may be that they merely attract those who are already committed. The other projects also allowed for the possibility of paying attention to sustainability concerns but we saw little or no emphasis on it.

In conclusion, while the content of the EWB projects allows for the development of the target attributes, content alone cannot deliver them. Consistent attention needs to be paid to those attributes in the design of the course, including the assessment, and the message that instructor attitudes and behaviour sends. We should therefore beware of adopting any given curriculum content in the expectation that the content alone will deliver the desired outcomes.

References

Blamey, A., & MacKenzie, M. (2007). Theories of change and realistic evaluation: Peas in a pod or apples and oranges? *Evaluation, 13(4),* 439-455.

Brouselle, A., Contandriopoulos, D., Lemire, M. (2009). Using logic analysis to evaluate knowledge transfer initiatives: the case of the research collective on the organization of Primary Care Services. *Evaluation 15 (2*): 165-183.

Crosthwaite, C., Jolly, L., Brown, L. (2009) *A program logic approach to evaluating educational innovations.* Paper presented to 2009 International Research In Engineering Education Symposium (REES Cairns, July 2009)

Jolly, L., Crosthwaite, C., Brown, L. (2009) Building on strength, understanding weakness: realistic evaluation and program review. *Proceedings of 20th Annual Conference of the Australian Association for Engineering Education*: 911-917. Adelaide; AaeE.
Jolly, L., Crosthwaite C., Kavanagh, L. (2010) AN evaluation of the EWB Challenge – implications for future curriculum change *Proceedings of the 21st Annual Conference of the Australasian Association for Engineering Education*: Sydney: AaeE.
Pawson, R., Tilley N. (1997). *Realistic Evaluation*. London: Sage.
Saunders, M. Trowler, P. and Bamber, V.(Eds) (2011) *Reconceptualising Evaluative Practices in Higher Education: the practice turn.* London: Open University Press.
Steer, J.(2008) *Top Level Quantitative Analysis of Student Journals (2007 and 2008).* A report to the Faculty of Engineering Architecture and Information Technology, University of Queensland.

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