Civil engineering education for sustainability: faculty perceptions and result of an Australian course audit

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***Abstract**: Reorganization of an Australian academic unit offered opportunities to strengthen inter-disciplinary delivery of sustainability content in the undergraduate civil engineering curricula. Data assessing whether current topic coverage meets that objective was collected by auditing course content, followed by a survey of course coordinators. Lecturers have dimensionally simple views on the meaning of sustainability. However, integration of compartmentalised definitions generates a holistic perspective: "responsible, low-impact use of natural resource with attention to achieving a balance of long-term objectives, in a way that is accountable to the community." Slightly more than half of civil engineering courses address sustainability, with 99 unique topics generated. These were categorized using 21 proposed concepts that constitute 'sustainability literacy.' Civil engineering courses at this institution appear to be particularly strong in addressing the economic concepts of eco-efficiency, production-consumption links, and product life cycle, as well as social dimensions of democratic participation, quality-of-life through career management and gender equity, and ethics.*

Introduction

The School of Natural and Built Environments (NBE) commenced in January 2004 at the University of South Australia (UniSA). The unit was developed to encompass the real-world synergies that lie between the natural and built environment and offers the opportunity to demonstrate disciplinary exchange leading to increased understanding and application of sustainability. The Strategic Plan 2007-2009 for NBE states "Our vision … is to be recognised nationally and internationally for creative and effective teaching and research in sustainability." Given the challenge of defining the blurry boundary of sustainability, competing discourses and a burgeoning literature, evaluation of progress and accomplishment can be complex. As a first step, this investigation outlines academic staff perceptions regarding the implementation of a sustainability curriculum, and assesses the extent of current sustainability-related teaching within the civil engineering degree by mapping sustainability content in current courses.

UniSA has taken steps to move toward incorporating environmental issues and sustainability into all aspects of the university. This whole-of-systems-approach as it links educational content in courses, research direction, campus operations and facilities management, administrative policies, and community outreach supports a climate of change (Koester et al. 2006, Cortese 2003). UniSA has focused to date on sustainability research and greening campus operations, including hire of an institution-wide Environmental Manager in 2009. The establishment of an Institute for Sustainable

Systems Technologies with NBE membership complements the long-standing work in social sustainability by the Hawke Institute for Sustainable Societies. Within NBE, there are ongoing research programs in alternative construction materials, sustainable cities, water-sensitive urban design, green transport, cycling, nature-based tourism, and landscape restoration. On the operational side, NBE governance structure until recently included a Sustainability Committee on par with teaching/learning and research committees, and there has been a Sustainability Plan prepared for the Mawson Lakes campus. Presuming that universities should play multiple roles in the 'promotion' of sustainability and that mutually reinforcing activities spur change, this research analyses current sustainability programming in civil engineering. UniSA's approach is consistent with Lozano's (2006) notion that sustainability should be integrated into the policies, approaches and learning of all academic members, professors and the students. as well as academic directors.

Conceptual Framework

Support for teaching in sustainability has grown out of changing societal beliefs, as Fien (2001) expresses: "Educational systems should affirm the role of education in building civil society in all educational institutions supported by whole-of government commitment to sustainable development, promotion of new educational policies, programs and practice, and transformation of curriculum support systems." Even traditional professions such as engineering exhibit increasing expectations that engineers should learn to go beyond a narrow technical focus and take a positive role in practice when working with communities to solve problems in ways that recognise concerns about social, economic and environmental sustainability (Bryce et al. 2004). These calls for enhanced sustainability skills and career acculturation have become much more sophisticated in the decade since professional bodies such as The Institution of Engineers Australia called it imperative that engineering practitioners learn to integrate development and the environment given the prominence of their professional role in shaping the common future (Harding 1998). Yet we have no definitive understanding of what is currently being taught under the umbrella of sustainability, or whether teaching in an interdisciplinary context such as the relatively new school at UniSA enhances academic integration of sustainability concepts.

Fien has been a leading Australian thinker in articulating what constitutes sustainability literacy, to the point of developing curriculum for the United Nations Decade of Education for Sustainable Development 2005-2014. In a classic paper outlining the fundamental working knowledge an engaged 21st century citizenry needs, Fein (2001) organised 21 sustainability concepts into environmental, economic, and social themes. The environmental stream incorporates the concepts of interdependence of living and human systems, biodiversity, ecological footprint, ecospace, carrying capacity, the 5 R's (reduce, reuse, renew, recycle, rethink), and inter-species equity. The steady state economy, sustainable production and consumption, eco-efficiency, product life cycle and triple bottom-line accounting constitute the economic realm. The sociocultural and political sphere necessitate analytic skills in understanding inter-generation equity, human rights and democracy, basic human needs, local-global links, the precautionary principle, community quality-of-life, ethics and media literacy.

In order to array this package of concepts against private sector conceptions of sustainability, Fien's framework was compared against the 'Sustainable Values Framework' promulgated by Hart (2007). Hart identified 37 multidimensional sustainability concepts linked to firm performance and shareholder value. He sorts these concepts into 4 quadrants based on the concept's application along an x-axis corresponding to nurturing internal capabilities versus engaging external constituencies, and on a y-axis dependent on whether it is focused on managing current business or building future opportunity (Figure 1). Bypassing the issue of Hart's omission of purely environmental concepts, there is a parallel for all of his more detailed concepts embedded in Fien's framework. Therefore, Fien's principles were used to provide a starting point for assessing the skill base attained by UniSA civil engineering program graduates.

The Study Setting

The School of NBE was created from the amalgamation of three Schools: Geoscience, Minerals and Civil Engineering, Environmental and Recreation Management, and Geoinfomatics, Planning and

Figure 1. Hart's (2007) Sustainable Value Framework

Building. At present NBE offers undergraduate bachelor degrees in civil and water engineering, construction management and economics, urban planning, and environmental management and sustainability, with associated advanced degrees. In addition to the Bachelor of Civil Engineering undergraduate program, the previous double-degree programs have transitioned to offer a specialisation in environmental management which articulates to a related master's degree. Overall, there are 50 permanent academic staff members. The school serves 1,125 undergraduate students this year, and has approximately 200 graduates annually. 2009 will see 48 graduates from the civil engineering program.

Methodology

Data was collected by auditing course content through study of class handbooks and internet pages, followed by a survey of course coordinators/lecturers. The targeted courses were core to the Bachelor of Civil Engineering undergraduate program, and the two associated double-degree programs at the time. There was coverage of 52 undergraduate courses with 39 different coordinators/lecturers representing regular, adjunct and sessional academic staff. An 81% response rate was achieved, with representation of 42 courses from 30 individuals. Representation by disciplinary area follows: 9 in civil engineering, 8 in management/commerce, 6 in biodiversity/planning; and 4 in statistics/ mathematics. The research support from top administrators was invaluable in influencing faculty to invest scarce time in response to the study, and preparatory alert emails and formal non-response reminders increased the completion rate. Non-response bias is not perceived to be significant. The nine courses "missed" were evenly split between engineering, environment, and management.

The survey was pre-tested and estimated to take 20 minutes for completion. The 10-question instrument asked course coordinators to provide a personal definition of sustainability, explain the source of their sustainability expertise (if any), indicate levels of support (Likert scales) for various sustainability-related teaching issues, and articulate barriers to integration of sustainability in the curriculum. The <u>core</u> question dealt with inventory of sustainability concepts currently taught in each course, further categorized by Fien's delineation of 21 topics necessary for scholarship and literacy in sustainability. The resulting matrix was quite complex and thus, given staff time constraints, the survey entailed a two-step process. Solely for that single question, one researcher filled in preliminary responses based on their review of course content in the course information book and course webpage material. Then the respondent, in every case, added to or refined the categorizations and specifications. For example, if the external audit showed that "use of recycled materials in construction" was covered in the class, the topic would be placed under "product life cycle analysis" (Fien 2001; definitions of each concept were provided) in the matrix sent to the lecturer. S/he then moved, added to or eliminated the teaching topic from the completed survey.

Results

Understanding of Sustainability

Teaching staff were asked to indicate their professional understanding of the concept of sustainability on a scale from 1 (none) to 7 (acknowledged expert). The mean was 4.4, corresponding to a verbal description of "slightly above average." Self-assessment scores, however, vary by discipline with biodiversity lecturers exhibiting the highest mean (5.8), followed by civil engineering staff (4.5), management faculty (4.0), and mathematics/ statistics (3.8).

Another open-ended question asked respondents to give their professional definition of sustainability. From content analysis of term usage, it is demonstrated that while individual course coordinators have specific views on the meaning of sustainability, they tend to be individualistic and compartmentalised. Most respondents only listed one or two dimensions of sustainability, especially a future-oriented time frame, and minimising environmental impact. However, when the individual components are combined, the integrated definition put together is holistic and very meaningful. According to school academic staff, sustainability is "low-impact human activity that balances economic sufficiency with stable environmental health and equitable community quality-of-life in the long-term." Following some refinement through a consultation process, this definition could be promulgated as the comprehensive approach to sustainability to which the School aspires. At a minimum, in terms of workability, it certain improves on the widely known definition from the Brundtland Report, "development that meets the needs of present generations without comprising the ability of future generations to meet their own needs."

Sustainability Concepts

Fifty-five percent of courses have sustainability content: 12 courses taught by biodiversity/planning faculty, 9 out of the civil engineering program, and 2 commerce courses dealing with strategic management and international best practices. Whereas all biodiversity/planning courses contain sustainability topics, 11 civil engineering and 8 management classes do not provide issue coverage.

When one arrays the Fien (2001) concepts by the course content topics (the complex matrix can be obtained from the authors), the first finding noted is broad coverage of some aspects of sustainability out of the engineering courses. One would expect biophysical aspects of sustainability to be strongly emergent from the environmental program, but there were a priori questions about the contributions of engineering content. Fifteen engineering courses contribute 57 sustainability concepts or topics as defined by the respondent/course coordinator, whereas 5 environment courses add a further 42 concepts or topics. In terms of theme coverage as proposed by Fien (2001), engineering courses appear to be particularly strong in addressing the economic concept of eco-efficiency. As one respondent pencilled in the survey, "engineering is all about sustainability if we use less material at a lower cost option, and it lasts." Alternatively, core environmental courses provide a solid grounding in important biodiversity topics, including the natural services provided by the ecosystem and conservation. There is much attention given to inter-connections in the core courses, but in different ways by the respective disciplines. Engineering looks at how project components connect and how the community is affected, whereas environmental content focuses on relations between ecosystem components and how humans impact the cycles. The two approaches would appear to be of value in their complementarity. Similarly, both fields address biodiversity but with divergent approaches; the environmental lecturers provide a conceptual framework for operation of natural systems, whereas as the engineering perspective is of an applied nature. The biodiversity topic is where the School's strong program in water management and heavy geology staffing also become evident.

Ecological footprint is variously addressed as an impact management issue (engineering), or actual estimation of resource consumption patterns (environment). Eco-space and carrying capacity appear to be disciplinary-specific language, with engineering educators utilizing the former, and environmental lecturers using the latter to both discuss the way human activity negatively alters the biosphere. The strong contribution of the School's building and construction degree is evident in the emphasis on recycling and re-use, and product life cycle.

The civil engineering program appears to devote more content to economic considerations, with two important contributions from the environmental field. Whereas engineering accepts consumption as a given and seeks to optimize materials selection, design and planning, working in human dimensions aspects of natural resources use involves understanding the personal values that underlie consumption and lifestyle choices. In addition, the environmental discipline has subfields of inquiry that deal with advanced accounting methodologies that incorporate environmental externalities or seek to create economic systems that mirror natural processes. It is known that the triple bottom-line accounting topic receives only superficial coverage in the current degree, whereas the topic receives widespread attention in cutting edge thinking.

Civil engineers get a moderate level of content dealing with community, social and political considerations, mostly from engineering courses. It is assumed that other environmental courses cover social issues, but that they are not part of the core curricula. The environmental program appears to cover a gap, however, with an internationalization that emphasizes the developing world, poverty and international development. Inter-generational equity issues in resource use come up in both programs through the pollution topic, as current use of hazardous substances burdens future generations with health risks and clean-up costs. One would expect ethics and professional practice standards to emerge as part of a professional education, but the strong coverage of life-career balance issues comes primarily from the research agenda of one engineering staff member who studies gender issues in civil engineering.

Several cornerstone courses provide the bulk of sustainability content. Over half (52%) of concepts come out of one course on human dimensions of environment, taught by environmental lecturers. It is a 1st year overview course that has broad coverage to introduce a multiplicity of issues, with little depth unless students complete a team project on a narrower subject. The course is also core in the environmental, planning, and GIS degrees offered by the School, and occurs in part because of the synergy of co-location and thus the ability for content to be customized to meet the needs of each profession. A course on engineering geology provides the second largest cluster of content (8 concepts/topics). Sustainability content is spread much more evenly across courses. Environmental engineering and a civil engineering design project account for the greatest number of sustainability topics, but together only provide slightly over one-quarter (29%) of emergent topics. Sustainability appears to fit in most engineering courses, albeit very narrowly defined.

Barriers and Constraints

Respondents provided open-ended answers about barriers and constraints that operate to limit sustainability teaching coverage (Table 1). As expected, course coordinators reply that time available is a major constraint, suggesting that they have planned content for a 13-week semester and added sustainability content is weighed against other topic needs. It helps to interpret this most common response category in light of the less frequently mentioned comment that sustainability content should be determined in the context of overall multi-year curriculum choices, rather than isolated course decisions. It appears there would be some receptivity to further staff training or mentoring in sustainability in order to boost competence, and there are also individual calls for teaching sustainability early in the program rather than heavy concentrations in the final year (n=1), and for earmarking teaching resources to develop sustainability content (n=1). Only two response categories, lack of relevance and the less common ‘lack of interest’ (n=1), demonstrate outright rejection of enhanced sustainability content.

Table 1. Common Barriers and Constraints to Increasing Sustainability Content

Barrier/Constraint	Number of responses
Teaching time available / no room in course	16
Not relevant to course	10
Personal understanding of sustainability	4
Believe sustainability should be embodied in broader education	4
N = 30	

Conclusion

The co-location of the natural and built disciplines in the School appears to provide some tangible advantages and informal serendipity that improves sustainability content. The sustainability content range exceeds the authors' pre-study expectations, and in combination offers, at least anecdotally, above-average exposure to sustainability principles. NBE's planning and vision documents, the seminar series, all-staff governance and planning meetings, and informal hallway discussions enabled by physical arrangements are posited to have created a climate where sustainability content has been enhanced. Admittedly, several core courses, especially human dimensions of environment and environmental engineering, provide the cornerstone for sustainability content. These broad conceptual courses are supplemented by narrowly defined add-ons where the lecturer decides there is a niche for sustainability content as related to a narrower engineering theme. The reality is that sustainability is top-of-mind because the School's mandate is about teaching that incorporates environmental, economic, and community goals, and daily dialogue reinforces this paradigm.

Academic staff were emphatic that sustainability not be covered in one (or two) targeted sustainability courses; no one wants a shorthand reference to "***the*** sustainability class." In terms of investing in staff capacity and enhancing an open climate that could lead to making broader sustainability-related curriculum content changes, there appear to be targeted opportunities. First, the school's (draft) collective sustainability definition is an operational improvement on the problematic Brundtland definition, and is valuable in signifying the interdependence of the various disciplines. As such, it offers a centrepiece for the formal sustainability training requested by a small minority of staff. But informal means, i.e. a course-by-course basis rather than a single broad-scale initiative, are more likely to characterize the adoption process by which individual staff move toward increased integration of sustainability. The axiom "success breeds success" is likely to apply as staff amenable to the tenets of sustainability expand their teaching content, demonstrating the accomplishments to late adopters. Mentoring was not suggested but partnering faculty who share commonalities in how they approach sustainability might be useful to generate creative synergy and momentum.

Findings suggest broader staff discussion and formal strategic directive might, however, be appropriate in two areas: assignment and projects within the civil engineering curriculum, and development of a plan for how and when sustainability content will be integrated across several years of a program. In the first case, several staff highlighted assignments and design projects that they believe provide a strong grounding in sustainability or complemented the lectures in terms of demonstrating applications. First-year orientation and final year complex advanced projects might also be modified to build student competencies related to sustainability. It is also imperative to plan how sustainability can be integrated across all courses, as the principle itself implies by definition. This strategy could take the form of phased introduction of sustainability concepts at set times across several years, building blocks repeated and reiterated over an entire program, or articulation of the role of each course in contributing overall to fundamental understanding.

UniSA's evolution as a leader in sustainability education is an evolving work in progress, but staff members have entered into a long-term interdisciplinary dialogue that is enabled by non-traditional location of related but disparate academic fields within the same school.

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