Propagating an Integral and Transdisciplinary Approach to Sustainability Education

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Abstract

Recent directions in engineering for sustainable development (EESD) (and in ESD more generally) have pointed towards an increasing realisation that in order to adequately begin to address respective meta-problems associated with global (un)sustainability, 'object world' disciplinary perspectives *alone* are insufficient. Instead, the required depth of knowledge that expert disciplinary knowledge can provide must be both complimented and built upon by other disciplinary as well as experiential knowledge. Integral and transdisciplinary approaches to learning can play a central role in helping achieve this.

When such approaches are applied, they facilitate the possibility of new and emergent knowledge and insights which can transcend disciplinary bounds, with the potential to reach places where no single disciplinary approach can; a classic case of 'whole greater than the sum of parts'. This however requires a degree of disciplinary humility and openness to other approaches and disciplinary norms, as well as a degree of trust, patience and time. Nevertheless, in the context of seeking authentic sustainability, it is necessary.

The classical engineering degree structure is not amenable to this approach. Engineering has traditionally seen itself as a 'problem solving profession only insofar as 'problems', including complex socio-technological ones (with ecological and economic import) can be neatly reduced to well-defined closed system decontextualized 'puzzles' which can then be algorithmically optimised. This is deeply problematic as it cannot map reality; specifically, complex contemporary 21st century reality, instead resulting in emergent 'unintended consequences'.

A key intervention point therefore in the development of a fit-for-purpose cohort of engineering graduates capable of addressing emergent twenty first century meta-problems is through their formative education. Here integral and transdisciplinary approaches to sustainability education/ESD offer a useful approach. But this requires not just the inclusion of 'sustainable development material', but a perpendicular reconceptualization of pedagogical approaches. This approach coheres with contemporary pedagogical best practice as it privileges relational and constructivist approaches to learning over the traditional atomistic approach, incorporating as it does, peer to peer and personal reflective learning opportunities.

This paper reflects on the experiences of a programme where undergraduate chemical engineering students undertaking a sustainability module collaborate with students on an analogous sociology module. It describes how this transdisciplinary collaboration takes an integral approach to sustainability learning, incorporating both subjective and objective perspectives as well as inter-subjective and inter-objective. The work reflects on how this initiative worked by drawing on student feedback and the authors' experiences.

1 Introduction

Disciplinary engineering knowledge is invaluable in addressing the inter-connected 'grand challenges' that are increasingly present through contemporary twenty first century society. These challenges, which incorporate nexus issues around energy, water, food, ecological degradation and climate change, as well as human societal issues around health, increasing inequality and ethics, may all be considered as emergent symptoms of 'unsustainability' across an increasingly global(ised) society (Ehrenfeld, 2009; Byrne, 2014; Fitzpatrick *at al.*, 2015)). When framed in this way, 'sustainability' can be characterised as an emergent property of a (flourishing) complex system (Ehrenfeld, 2009). The dominant contemporary paradigm, which is a paradigm of reduction and disjunction (separation) is by this conception considered unfit for purpose (Morin, 2008). This has deep implications for the self-perception the expert engineering professional and for their role in problem solving. The traditional conception of the engineer (that is, subject to a paradigm of separation, and hence silo-isation with respect to other disciplines) allows that all problems can be reduced (as per a paradigm of reduction) to linear decontextualized 'puzzles' capable of being 'solved' through suitable algorithmic means, invariably through some sort of technological intervention (Bucciarelli, 1994; Buch & Bucciarelli, 2013; Byrne & Mullally, 2014). However, irreducibly complex problems require a recognition of their complex and deeply interconnected nature. This means that the 'object world' of the expert professional, while being crucial in addressing any such problems, is at the same time, by itself, insufficient.

By this paradigm of reduction and separation, the issue of climate change for example can be considered as a problem from the perspective of the engineer which can ultimately be 'solved' primarily by the development and application of appropriate technological interventions (such as for example, technologies to harness renewable energy forms). However, by the same token, from the perspective of the lawyer equally it becomes a problem to be solved through a global legal framework. This same problem to the economist is one which can be resolved by appropriately incorporating economic externalities, while from the perspective of the political scientist it is a problem of political will or structure. A social scientist may see the problem in terms of how humans relate to each other through stories, myths or (meta-)narratives, or in terms of structure and agency and/or may recognise it as ultimately an issue of ethics and normativity. Each disciplinary perspective thus offers its own unique and privileged 'solution' to the same problem from their own disciplinary silo-ised 'object world' view of the world around them.

If we take an alternative worldview through the lens of a paradigm of complexity however, all the above respective perspectives are each envisaged to offer some truth and value in terms of both framing and addressing the issue(s) at hand, but such a paradigm also recognises that no one disciplinary perspective can offer a complete or definitive characterisation or response. Instead, the integration of all these perspectives, and *more*, is required. We say *more*, because such an integral and transdisciplinary perspective would also recognise the value that the experiential knowledge (knowledge in addition to that of the expert) can bring to the problem, for example, local, community and coalface experience, while for intricate complex problems like those of climate change, there is also a recognition that there is a deep interconnection between this symptomatic issue and other problems of unsustainability including food, energy, water, as well as those residing in broader environmental, economic, ethical, political and social domains (Byrne, 2014; Byrne et al., 2016).

2 Background and rationale

It is with this understanding that engineers not only require a toolbox which provides them with the expert disciplinary knowledge that will enable them to address emerging contemporary meta-problems

around unsustainability, but that they will also have to go beyond that by recognising that it is only through working with other disciplines as well as those with experiential and local knowledge that we can collectively begin to adequately both frame and address these issues. It is founded on the realisation that what may have been considered adequate in the training and practice of the professional engineer through its most recent manifestation through the latter part of the nineteenth century and through the twentieth century, is now no longer fit for purpose, if it ever was. Indeed, much of the real and perceived progress over this past century and a half, fuelled as it was by a splurge in (almost literally) free energy in the shape of a fossil fuelled bonanza, has been a perfect complement to a socio-economic model based on growth based consumption (and consumerism). This has had severe downsides, most obviously manifest in the ecological domain, but also in the social, economic and ethical domains. Put simply, it is the second law manifestation of the fact that there is no such thing as a free lunch; 'if there is a foundation on which all environmental degradation rests, it is entropy generated by the ever-increasing transformation of energy by humans' (Wessels, 2006, p.51).

This realisation that what is required is a 'new engineer' (Beder, 1999) or the conception of the engineering professional one who is 'committed to a social good and being structured (constrained in various ways, privileged in others) so as to achieve that social good. …In this conception of a profession, and only in this conception, can we understand engineering as a morally worthy enterprise, worthy, that is, of individual commitment and social recognition.' (Bucciarelli, 2008, citing Johnson 1989), entails that the self-perception of the engineer must be broadened beyond the narrow confines of the 'guns-for-hire' model, to one which incorporates and embraces the reality of socio-economic and macro-ethical dimensions in professional training and practice (Conlon & Zandvoort, 2014).

The implication of this, to the authors, as academics grappling with issues around (un)sustainability and how these might be reflected in the disciplinary education of our respective students was pretty clear. If we demanded that engineers have a broader conception of their role while recognising the inherent complexity and interconnectedness when faced with contemporary meta-problems, then their formative educational experience would need to go *beyond* the (absolutely necessary disciplinary) requirement for development of the technical and disciplinary basics which facilitates the solving of well-defined decontextualized unique solution technical problems. If we are to expect contemporary engineers to work with *other* disciplines and *integrate* respective knowledges in the generation of requisite new knowledge and perspectives to frame and address contemporary meta-problems, then we couldn't really expect them to achieve these aims by merely 'talking the talk' and then hoping that they would do so post-graduation, all the while educating them in a parallel formative education system.

This was the motivation behind the initiative between the co-authors of this paper, as academics respectively in engineering and sociology, who taught on respective third year modules to our students on 'Sustainability in Process Engineering' and on 'Sociology of the Environment'. The result was a part bringing together of these modules for a common group assignment whereby students were tasked with identifying one aspect of 'sustainability' which interested them and which they were then asked to both frame and characterise, while also offering their perspectives through a coherent group presentation followed by a short individual reflection piece.

The motivation here was to, in a spirit of transdisciplinarity to open the possibility (and legitimacy) for undergraduate students of both engineering and sociology (the latter module was taken by students taking both sociology and government degrees) to frame and seek potential useful intervention points with respect to aspects of societal (un)sustainability. Furthermore, it was also intended to do this by applying an integral approach to learning, as one which seemed ideal for facilitating productive reflective learning in particular around complexity and associated wicked problems.

3 An Integral Approach for Sustainability Education

3.1 Assignment Description

A common assignment was designed for two third modules which ran concurrently at University College Cork: PE3011 Sustainability in Process Engineering (taken by students in the third year of a four year Bachelor of Engineering degree in Chemical Engineering) and SC3029 Sociology of the Environment (a module taken by third year students of the Bachelor of Arts degree, majoring in sociology and other humanities subjects as well as a BSc in Government). A number of international visiting students also took the module (from the European mainland, the USA and Brazil). The assignment, which is worth 15 percent of the overall module grade for both modules (10 percent for the group presentation plus five percent for the individual reflection), has run successfully since 2014 (Byrne & Mullally, 2016). The work associated with this paper is drawn from the 2015-16 iteration when a total of 42 students undertook the module including 26 from the engineering module. The students were divided into ten groups of four or five each, split between the two modules, and each group were tasked with choosing a topic or aspect of their choosing relating to some aspect of 'sustainability'. The following represents part of the task description presented to the students:

> *The task involves transdisciplinary teams of four or five working together to consider some aspect of sustainability. This will be done through the context of your own respective modules as well as bringing to bear your own object world disciplinary (and personal) perspectives and backgrounds. The resultant product may involve contrasting perspectives, framings or angles on the topic at hand or it may result in an emergent creative fusion of differing object worlds and disciplinary norms. Any aspect may be chosen by the group that relates to 'sustainability' to research and then reflect upon. The group reflection is open ended and can be directed as you best see fit. For example, you might like to consider what this aspect or topic means (to yourselves or to society), how it has the* ***potential to change the way we/you do things****, consider* ***how it can or might be achieved****, what are its* ***potential consequences****,* ***difficulties*** *or* ***problematic issues****, why or how it is so powerful a* ***concept****, and so on.*

Once groups had settled on a common theme, they were required to discuss it with a member of the lecturing team, who provided feedback and suggestions to the respective teams. The lecturing team during 2015-16 included the authors of this paper, plus a colleague on the sociology module Dr Kieran Damery.

3.2 Application of an integral model

During the 2015-16 iteration, an integral model was purposely chosen in structuring and delivering the joint sustainability assignment. Integral approaches cohere well with both transdisciplinary and sustainability imperatives as they recognise different levels of realities within the whole while rejecting a totalizing unity in favour of what might be called *'unitas multiplex'* (Morin, 2008) or 'unity amidst diversity and diversity through the unity' (Klein, 2004). This model was developed following integral approaches to education (Esbjèorn-Hargens *et al.*, 2010), in particular as described in the application of mathematics for teaching by Renert & Davis (2010). This model is a four quadrant model which incorporates in turn the following domains:

- Subjective (personal understandings of reality as filtered through/constructed by personal lens of each individual)
- Objective domain (the material, facts, meanings and disciplinary interpretations, meanings and norms)
- Inter-Subjective (emergent collective/cultural understandings, including socio-cultural norms)

- Inter-Objective (structural framework/nature of the module/assignment, including clas times/duration, location(s), assessment, delivery mode(s), number and make up of participants, lecturer(s))

The ongoing development and incorporation of its associated sessions were informed by this model, as outlined in Table 1.

Table 1 Incorporation of an integral approach to learning/teaching for sustainability assignment

Domain:	How it was facilitated:
Subjective	Post module personal reflection by each student highlighting personal learning gained from the exercise.
Objective	In-class content, including viewing of a documentary looking at conceptions of progress in contemporary globalised society, including the examination of environmental, social, economic and ethical dimensions. Material on assignment description, as well as complimentary module material (handouts, slides, required reading, etc.).
Inter-Subjective	Collective in-class discussions stimulated and structured by lecturing team, both after documentary (acting as stimulus and 'ice-breaker') and around the group exercise.
Inter-Objective	Structural context, including a designated 1 hour session over 5 consecutive weeks in a designated room as well as assignment (requirements, grades) and delivery structure (designed to facilitate each of the other domains).

Taking the integral model as a lens for considering the assignment and its delivery, the following key aspects were considered as key in helping to address all four domains of the model respectively;

The structure of the assignment (**inter-objective**): This was an important aspect of the joint assignment which the authors had to consider as it needed to facilitate the addressing of each of the other three domains. There were also structural constraints relating to timetabling (student and staff), and type and availability of room. The sessions were carried out over one hour during five consecutive weeks followed by a presentation session where each of the ten groups made a presentation to their peers and the lecturing team on their chosen aspect of sustainability. It was decided to incorporate a kick-off documentary over the first two weeks [objective] in order to stimulate discussion around a common focal point. These were characterised as initial 'Workshop and Group Brainstorming/Preparation Sessions'. This in turn fed/led into the prescribed group assignment where groups were charged with agreeing to consider/research/frame/propose interventions on some aspect of sustainability about which they would develop and deliver their respective presentations [objective]. Apart from the documentary, the remaining session time was heavily skewed towards the facilitation of in-class group discussions [inter-subjective]. Finally, individual participants were required as part of the assessment the deliver a short reflection after the delivery of the group presentations [subjective].

The 'priming' documentary (**objective**): The documentary was shown in two parts over the first two sessions and was the principal piece of material in this collaboration (module specific material was delivered separately as part of each of the respective modules). It was followed during each session by a group discussion which considered a broad question (e.g. on what participants considered as the relationship between progress and sustainability). The documentary thus acted as a useful common focal point for all participants doing this exercise, while it was broad enough to address sustainability aspects under all principal domains, including ecological, socio-technical, economic and ethical. It also proved

to be a useful learning experience for participants, while the shared experience helped to make it act as an ice-breaker for participants with different disciplinary 'languages' (and cultural) backgrounds who also did not know each other heretofore.

The in-class group discussions (**inter-subjective**): These provided an opportunity for students to converse across each other's respective disciplinary languages, and to help students better appreciate the different 'object worldviews' that students from other disciplines held, and indeed more fundamentally, to appreciate that students from different disciplines legitimately held different 'object worldviews'. This could raise potentially difficult challenges for the students, even in terms of framing a problem with respect to some commonly chosen aspect of sustainability. It thus played a critical role in the assignment and the students' associated learning (as evidenced by student feedback, see later).

The reflective piece (**subjective**): students were required to each write a short reflection (of 400-600 words) on how they thought the transdisciplinary assignment worked and what they felt they learned from the exercise after the completion of the group exercises.

3.3 Student output

The groups appeared to work very well together, and came up with a range of topics related to sustainability, which they presented at the final session. These are listed in Table 2.

Table 2: Sustainability related topics chosen by groups for presentation

Group	Chosen 'sustainability' topic	Group	Chosen 'sustainability' topic
A	Sustainability and Ethics	F	Globalization and Inequality
B	Waste	G	Homogeneity & Diversity
C	Industry and Sustainability	H	Defining Progress
D	Inaction and Sustainability	I	Awareness & Behaviour
E	Entropy	J	Consumption & Consumerism

The presentations were each of eight minutes duration and were given by all members of the group, followed by a short question and answer session. While the presentations worked well, it was the personal reflections of the engineering students which appeared to demonstrate most ably how they had learned from and developed their thinking around sustainability challenges as a result of their experience of the assignment, while it also revealed some of the more difficult issues around the exercise. One student's reflective assessment is indicative:

> *As an assignment I felt it was interesting to engage with a different discipline than engineering; something we did not have an opportunity to do for the first three years of the degree. The main benefit of this was the different viewpoints and experiences that the sociology students were able to bring to the conversation. The Erasmus exchange student was able to provide insights into how the topic of sustainability is evolving in Denmark; something we could only speculate about. Their cultural attitude was also evident as they seemed to value environmental conservation at a level greater than that of the Irish. However, there were a number of drawbacks to this joint assignment; in particular, the government student failed to properly engage with the subject of sustainability. Instead he opted for a business as usual approach where he suggested that we should continue to research into the subject. The lack of a sense of urgency in his approach was frustrating and seemed more like a means of maintaining the current global paradigm. Therein lays the problem however; that sustainability means different things to individuals and may be the reason why real change is so difficult to implement.*

4 Student feedback

Student feedback was collated through a bespoke survey that the authors put together which aimed to see specifically how the integral approach to module pedagogy worked through a series of questions which mapped each of the four quadrants of the integral model onto aspects of the assignment. 32 out of a possible 42 students completed at least part of this survey (a 76% response rate) including at least 22 (out of a possible 26) PE3011 students (85%) (three did not indicate which module they were taking). The results are presented in Table 3 with cumulative average (Avg) and standard deviations (S.D.) included. In terms of the integral model, questions 1 and 2 were designed to elicit feedback on subjective aspects of the assignment, while the remaining questions were aimed at determining how students' conceived that the inter-objective, inter-subjective and objective domains worked respectively. Feedback was pretty unanimously positive across all domains, in particular (and encouragingly for the authors) with respect to the inter-subjective domain of peer-to-peer and group engagement, where over 90% of respondents awarded either a four or a five.

Table 3 Aggregated quantitative student feedback on joint sustainability modules

In relation to both ***your module (PE3011/SC3029) and the accompanying assignments:***	**Worst**				**Best**	**Avg**	**S.D.**
	1	**2**	**3**	**4**	**5**		
1. How did they help you ***personally*** engage with and reflect on issues around sustainability?	-	1	6	13	12	4.13	0.83
2. How did they help ***you*** develop a ***deeper understanding*** of issues around sustainability?	-	1	5	14	12	4.16	0.81
3. How well was the module ***structured*** in a way (lectures, delivery, videos, interactive sessions, etc.) that facilitated engagement and learning around the relevant issues?	-	-	10	12	10	4.00	0.80
4. How well did the module facilitate ***peer to peer*** and ***group*** engagement and learning?	-	-	3	18	11	4.24	0.62
5. How well did the ***material*** presented (notes, slides, videos, etc.) facilitate engagement and learning around the relevant issues?	-	1	6	12	12	4.13	0.85

The positive response was borne out by the responses to an additional two qualitative open ended questions which dealt with what students felt were 'particularly useful' aspects of the exercise and how it 'might be improved' respectively. The responses here cohered with the positive feedback generally; on the improvement question only structural issues (inter-objective) came to the fore e.g. the tiered room used was not most conducive to good group interaction, the duration of the presentations could be longer and there could be a better balance between student numbers from respective module. In terms of particularly useful aspects, quite a number of students mentioned the documentary as being a useful lead in focal point/stimulus (objective), while the remaining comments dwelt principally on the value of the group/discussion components (inter-subjective) as well to a lesser extent the opportunity to personally reflect on (and hence re-imagine) sustainability conceptions (subjective). Selected indicative responses reflecting these latter domains are displayed in Table 4.

Table 4 Qualitative student feedback on joint sustainability modules

Can you highlight any aspects of the module or its delivery that you found ***particularly useful?***
Hearing others opinions and further discussing them [Inter-Subjective]
It was very good to discuss the topics amongst the class. It feeds more 'real' to open a dialogue rather than be fed research done by others. [Inter-Subjective]
Helps give a deeper understanding by giving different perspectives and looking at topics from different points of view. [Inter-Subjective]
Allowing students to give their opinion – debating [Inter-Subjective]
The aspect I found most useful was the greater understanding I obtained of "true" sustainability'. Not the sustainability model that has been marketed to us of continued consumption but in a greener way. This module clearly outlined the problem with this model of growth and has made me more conscious. [Subjective]

5 Conclusion

A four quadrant integral model was imposed upon and used to assist in the development of a transdisciplinary exercise around exploring meta-problems around sustainability for engineering students working with on a joint exercise social sciences students. From the perspective of the authors, the application of this model proved appear to be particularly useful in informing the teaching of sustainability, though ultimately the exercise appeared to work very well in stimulating productive dialogue and shared understandings across disciplinary boundaries. Moreover, formal student feedback showed the student learning experience to be overwhelmingly positive. While it highlighted some (relatively fixable) shortcomings in structural delivery (inter-objective), students felt that other domains of the integral model were very well covered, in particular the inter-subjective domain which was addressed through designed opportunities for peer-to-peer, lecturer-student and intra-class dialogue and discussion.

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