Challenging energy engineering undergraduates with diverse perspectives on nuclear power (EESD2020)

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Abstract

As part of an introductory energy engineering undergraduate module at University College Cork, student presentations on a zero-carbon energy plan for Ireland have shown a high preference for nuclear energy, despite a complete absence of nuclear energy from the same module curriculum. Nuclear power has never been built or generated in Ireland, is currently illegal, and faces high levels of public opposition. The origins of a high preference for nuclear energy among undergraduate student engineers is therefore unclear. In response to this high preference for, but critically unengaged view of nuclear power, the authors developed a participatory learning activity for first year undergraduate engineering students to engage with a range of maximally different perspectives on nuclear power. Four different perspectives on whether Ireland needs nuclear power were presented to this year's class: *definitely yes; definitely no; maybe yes; maybe no*. These perspectives involved a number of different framings of nuclear power and ranged across a spectrum from techno-economic to socio-technical. They emphasised to a greater or lesser degree issues around risk, cost, system impacts, timing, social acceptability, and sustainability. The activity took place in a room divided into four quadrants with each quadrant representing one of the four different perspectives on nuclear power. At the start of activity, students were invited to go to the quadrant that best represented their initial views. Each perspective on nuclear power was then delivered in a short expert presentation by one of the co-authors. Throughout these presentations, students were invited to remain in or move from their quadrant as they were persuaded or not by the arguments advanced. At the start of the activity, an overwhelming majority (96%) of the students indicated a *yes* preference with the majority of these being *maybe yes* (79%); at the end of the debate the total *yes* share had significantly decreased (to 54%), with the largest share of the lost vote moving to the *maybe no* category which finished at 36% (having started at 0%). Overall, there was a greater distribution of students across all four categories than at the start. Evaluations on the activity format were largely positive. Student reasons for changing their views were mostly socio-technical points specific to Ireland that included the electricity system, overall energy needs, costs and expert availability. Closing reflections introduced the idea of a wicked problem and highlighted the importance of values to questions such as "Should Ireland Go Nuclear", i.e. avoiding an exclusively narrow scientific framing.

1 Introduction

1.1 Background

In University College Cork (UCC), there are four undergraduate engineering degree courses: civil, structural and environmental engineering; electrical and electronic engineering; process and chemical engineering; and energy engineering. The first year of all these degree courses is a common year with identical subjects and modules being taken by all students; it is only at the end of their first year that students nominate their preferred stream of engineering, which they subsequently embark on in second year. The modules the students take in their first year are a range of foundational engineering subjects (physics, chemistry, thermodynamics, mathematics, etc.) and an introductory course to each stream of engineering.

As part of the introductory undergraduate module to energy engineering, students are introduced to a range of energy engineering related topics (fossil fuels, renewable energy, energy efficiency, electricity systems, climate change, etc.) and undertake a group project as part of their course work. For a number of years, the main group project was to develop an "Energy Plan for Ireland" using a similar format to the "Five energy plans for Britain"[1] devised by David McKay in his book *Sustainable Energy - without the hot air* (McKay, 2009). The "Energy Plan for Ireland" exercise required students to outline a low carbon energy plan for Ireland that balanced the supply of low carbon energy with the demand for energy (in the form of heat, electricity and transport).

While teaching and evaluating this module in 2018, two authors of this paper noted the very high preference for nuclear energy, despite a complete absence of nuclear energy from the same module curriculum. Nuclear power has never been built or generated in Ireland, is currently illegal, and faces high levels of public opposition (Red C Research & Marketing, 2011). The origins of a high preference for nuclear energy among undergraduate student engineers is therefore unclear. Although nuclear energy engineering is taught on the energy engineering curriculum, it is not until second year. For the authors it seemed important to engage with the students' preference for nuclear energy but also to engage with the fact that it's an energy source with a lack of popular support, despite not being built in Ireland.

1.2 Engineering Ethics

While a significant part of the engineering curriculum in UCC is technology and scientific focused problem-solving, as part of the accreditation provided by the professional body of engineers (Engineers Ireland), there is a requirement for tuition that introduces the ideas and practices of engineering ethics. Additional tuition includes the topics of complexity, uncertainty and wicked problems. Accommodating these topics within the existing engineering curriculum in UCC has involved a number of different approaches (Byrne and Mullally, 2014), some relatively standalone, others more integrative.

1.3 Interactive Learning

In response to the high preference for, but critically unengaged view of nuclear power, the authors developed and organised a participatory learning exercise for undergraduate engineering students to engage with a range of maximally different perspectives on nuclear power. The activity was designed to teach

[1] https://www.withouthotair.com/c27/page_203.shtml (accessed Feb 13th 2020)

students about nuclear power, its complexity, the context in which it must operate (and by extension, the importance of context), and to do so in an engaging, open and stimulating format.

2 Methodology

2.1 Four-way debate

The authors devised a four-way debate built around the question, "Should Ireland Go Nuclear?"; four maximally different answers or perspectives were prepared: *definitely yes; definitely no; maybe yes; maybe no*. Each of these perspectives involved a number of different framings of nuclear power and ranged across a spectrum from techno-economic to socio-technical. The arguments emphasised to a greater or lesser degree issues around energy density, risk, cost, system impacts, institutional capacity, social acceptability, and sustainability. The main points are summarised in Table 1.

Table 1: Arguments

Page	*Definitely Yes*	*Definitely No*	*Maybe Yes*	*Maybe No*
Energy Supply	10000 years of uranium supplies exist			
Energy Density	Nuclear superior to all fuels			
Electricity System	Nuclear can balance intermittent renewables	Significant amounts of nuclear waste generated	Nuclear SMRs could be a good fit for Ireland's small system	
Consequences of an accident		Examples of Chernobyl & Fukushima		
Energy Security		Uranium an import dependency	Backup required for all power stations, not just nuclear	
Social Acceptability		Processes are challenging for Ireland		Protracted process highly likely
Cost		Cost escalation more likely		Nuclear costs are rising; RE costs are falling
Institutional Capacity		Poor capacity to deliver; training & expertise absent	SMRs built abroad so training needs not an issue	Ability to deliver large infrastructure projects weak
Public Trust				Low levels of trust in gov make nuclear challenging

The room in which the activity took place was a mostly open empty space (a bespoke university innovation space, located within the library) with four corners each representing one of the four different perspectives. A number of chairs were positioned in each corner. The sequence of stages of the activity was as follows:

1. Students arrived; were introduced to the event; before any presentations took place, the students were invited to go to the corner that best represented their views on "Should Ireland Go Nuclear?"
2. An expert speaker gave a 5-minute speech arguing the *definitely yes* perspective; afterwards students were invited to move to a different corner if they had changed their minds
3. An expert speaker gave a 5-minute speech arguing the *definitely no* perspective; afterwards students were invited to move to a different corner if they had changed their minds
4. An expert speaker gave a 5-minute speech arguing the *maybe yes* perspective; afterwards students were invited to move to a different corner if they had changed their minds
5. An expert speaker gave a 5-minute speech arguing the *maybe no* perspective; afterwards students were invited to move to a different corner if they had changed their minds

At all but one of the stages, there was traffic of students moving from one corner to another. It was clear to all participants that the distribution of preferences was different at the end than at the start. After the last stage, there was a show-of-hands for how many students had changed their views once, twice, or more than twice. Then, students were encouraged to ask any questions, raise any comments, and to offer their reflections on the results as they could see them (i.e. the changed distribution of preferences across the four categories). Then, each of the four expert speakers was invited to give their 'real' view, whether influenced or not by the presentations of the other expert speakers. Finally, there were some reflections from one of the co-authors on complexity, uncertainty and engineering ethics. At the end of the activity, students were asked to fill out a short activity evaluation form.

3 Results

3.1 Four-way debate - changing views

28 students participated in the activity. At the start, when the students were asked their pre-presentation perspectives, an overwhelming majority (96%) were in either of the *yes* categories (*definitely yes*, 18% or *maybe yes,* 79%); see Table 2 for all results. At each subsequent stage (2-5), the shared total of *yes* declined until it reached a combined share of 54% at the end. While it could be said that *maybe yes* "won" the debate (i.e. it ended with the largest share) this was largely because it started with the largest share. *Maybe yes* never increased its share throughout and in all but one stage it decreased in size; of all the categories, it lost the most votes. Overall, there was a greater distribution of perspectives across all categories at the end of the debate than at the start: at the start, two categories were <5%; at the end, all categories were >10%. The relative share of *definitely* and *maybe* changed less throughout the debate. At the first stage it had a 79% combined share, throughout the stages it declined to 68% and 61%, then at the last stage it returned to 79%.

Table 2: Share of participants in each category at each stage

	Share of Participants			
Page	*Definitely Yes*	*Definitely No*	*Maybe Yes*	*Maybe No*
Stage 1	18%	4%	79%	0%
Stage 2	29%	4%	68%	0%
Stage 3	29%	11%	54%	7%
Stage 4	29%	11%	54%	7%
Stage 5	11%	11%	43%	36%

3.2 Reasons for changing their views

A majority of the participants (54%) changed their views throughout the debate; most of these changed their minds once (43%); the remaining changed their minds twice (11%). The numbers of who changed their views are shown in
Table 3.

Table 3: Number of participants who changed their views

	Number of Participants			
	Didn't Change	Changed Once	Changed Twice	Change > Twice
Count	13	12	3	0

The student evaluations revealed some of the reasons the students changed their views. A majority who changed their views indicated it was because they concluded Ireland didn't need nuclear energy:

- *"I changed my views as Ireland does not need huge energy supply as the country is small [...]"*
- *"It was due to the fact that we may not need nuclear energy"*
- *"Because nuclear might not be needed, better to import it"*
- *"While nuclear might be needed worldwide, might not suit Ireland"*
- *"Yes nuclear is needed on a global scale but is it really needed for Ireland? The money could be used to improve more renewable energy"*

Others indicated that nuclear energy mightn't be a good fit for the existing electricity system in Ireland:

- *"Doesn't seem to suit Ireland as a country"*
- *"Load levels and the fact it doesn't fit in our grid"*

Other factors cited for changing their minds included cost, lack of expertise, risk, and affordability:

- *"There were many facts which were brought up that I had never considered before such as costs and facilities and training"*
- *"Risk of nuclear is still not 0%. Ireland does not [...] have the resources to maintain a nuclear plant"*

Although 46% of the participants didn't change their views, only two out of these thirteen indicated why:
- *"Nuclear energy could happen, but it's being delayed by the severity of risks and costs. But at the same time, every other renewable resource has come with risks. At the day in age, we need all the energy we can get"*
- *"Political will never be there for nuclear in Ireland"*

3.3 Event format feedback

Students were also asked their perspectives on the format of the event. Most were positive while one had a suggestion for more participation during the voting stages (rather than just at the end)

- *"Very good. Involved. Made you think"*
- *"Very well presented arguments, made me unsure on where I stood on nuclear energy"*
- *"Done well"*
- *"Questions should have been allowed to be asked after each point"*

4 Discussion

4.1 Student engagement

From the student evaluations and talking to the participants, the overall response to the format of the debate was positive. The event was designed to encourage and facilitate participants to consider different viewpoints and to make it easy to change their minds. At a deeper level, the aim was to encourage students, through active engagement and participation to think critically (in this case in the context of considering nuclear power). This was to be achieved by demonstrating the complexity that permeate socio-technical projects and domains, and hence the requirement for engineers to be wary of seeking hard and fast reductive or technologically (alone) based 'right answers'. The fact that a majority did in fact change their minds (54%), and for them the significant information seemed to be energy system context (Ireland's need for growing amounts of energy), electricity system properties (minimum size of plant, security of electricity supply), socio-technical factors (expertise and training), and political factors (trust in government). The importance of being open to changing one's mind was emphasized near the end of the event when each of the expert speakers was asked their 'real' view: only one out of the four speakers 'agreed with themselves', with three of the other four citing arguments or points made by other speakers or students as being persuasive.

While some students clearly learned new information that changed their minds, for the students that didn't change their minds it is unclear if the information they received was new or not new and whether it was sufficient or insufficient to confirm or strengthen their pre-existing views. Interestingly, the most positive event evaluation comment (*"Very good. More please"*) was from the student who started and remained in the *definitely no* category throughout. On the other hand, two participant evaluations from those who started and remained *definitely yes* throughout, both critiqued aspects of the debate format, *"Questions should have been allowed to be asked after each point"* and debate content *"Nuclear waste has solutions"*, the latter contradicting a point made during an expert-presentation and raised during the student questions at the end.

4.2 Interactive learning

Participant feedback on the format of event was largely positive, e.g. "*Very good. Involved. Made you think*". The event duration was one hour and due to the participants regularly moving around, there were no sustained periods of sitting, which seemed to contribute to the high levels of attention throughout. In addition, because the participants had to respond to the short expert presentations with a decision (i.e. move corners or not), this also seemed to encourage high attention levels. Finally, due to the layout of the room with the expert-speakers standing in the middle while encircled by the four categories, there was no traditional "front" of the room where a lecturer would stand and "back" of the room where students would congregate something which in the personal experience of the authors had led to diminished classroom engagement.

4.3 Engineering complexity and ethics

While the students came to the event expecting a series of arguments for and against nuclear, and this is largely what they got, the cumulative effective of the different arguments and perspectives advanced was that the nuclear energy issue was presented and perceived as complex. It has many dimensions. In some closing reflections by one of the authors, this point was highlighted and extended to introduce the concept of the wicked problem. If engineers sometimes look for easy solutions or 'right' or simple answers, the many facets of nuclear energy show this isn't always appropriate. While this may seem a self-evident point, our experience of undergraduate engineers, in particular with first years demonstrates that they find this a challenge. From a teaching perspective it was easy to make the observation about multiple dimensions to a problem due to the format of the event which was structured around different perspectives on a single question. This particular format also facilitated an opportunity for students to better develop a necessary appreciation of socio-technical complexity by actively engaging with the topic at hand.

During the closing reflection, a further point raised was observations about the role of science and values. It was pointed out to the students that questions such "Should Ireland Go Nuclear?" can't always be answered with recourse to "mere science" alone, i.e. values are an important part of the debate too. From an engineering ethics perspective, it is also vital that students and engineering professionals understand this point, as failure to do so has (too) often resulted in well-designed projects from a technical perspective facing unexpected public opposition. This results in engineers often resorting to speculation that this can be resolved by better (scientifically and technologically) educated publics, when in fact opposition often comes from highly educated persons who are objecting on the basis of values-based grounds. This is because such projects go beyond the merely technological domain and into economic, ecological, social, legal and ethical domains. Such a post normal scientific environment can thus facilitate inherently normative projects (and concepts such as the precautionary principle, among others), whereby science alone cannot provide definitive direction. Recognition of this results in engineers who are more comfortable in embracing complexity and successfully engaging with multi-level socio-technical systems, such as associated with the provision of nuclear power The authors believed the students were more receptive to this point after themselves finding it difficult to find an easy answer to the question posed, "*Very well presented arguments, made me unsure on where I stood on nuclear energy*".

5 Conclusions & Recommendations

5.1 Conclusions

The question "Should Ireland Go Nuclear?" is a complex one with many dimensions and viewpoints. Experts do not necessarily agree, and more information does not necessarily bring more certainty. This was borne out by the contents and outcomes of the four arguments that were advanced. The four-way debate, with participant voting and speaker reflections, was an effective way of introducing the wicked problem concept and of demonstrating how nuclear power is an exemplar of this. The four-way debate was an engaging exercise for the students, who via the activity evaluations forms gave a largely positive verdict.

5.2 Recommendations - Future Activities

The event format could be readily adapted to any issue, in particular complex socio-technical issues where there exist strong viewpoints for and against. Parts of the event format could also be adapted to include questions between rounds (as per a student suggestion). The event format could also be redesigned into a student assignment in which students themselves develop the presentations and deliver the arguments; these students could come from the same class or could come from a subsequent year (i.e. second, third or fourth year) of energy engineering. Near the end of the round of arguments, the event chair highlight that each of the expert speakers had emphasised different points rather than directly contradicting each other; i.e. their arguments had consisted of what they said but also what they didn't say. The exercise could be a springboard for a critical thinking skills class, i.e. how do I evaluate contradictory expert arguments?

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