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Introducing ethical sustainability dilemmas in nuclear engineering education

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Abstract

Nuclear engineering is a technical branch where many questions of ethical and sustainable character are actively debated in politics, media and science. Both advocates and opponents of nuclear power use arguments that are normative and taken from ethical and/or sustainability theory to reinforce their standpoints. We believe that analysing and discussing these arguments in the safe context of higher education, is important for educating nuclear engineers with a critical mindset and for teaching them to go beyond mere opinions.

The Bachelor of Science Programme in Nuclear Engineering at Uppsala University, Sweden, is a one-year programme with the aim of equipping students with an engineering approach to the nuclear technology field, and to make them well-prepared for a professional career in the nuclear industry. The programme contains physics and engineering courses in fields such as reactor physics, thermohydraulics, power engineering and nuclear safety, as well as an independent thesis work.

In this paper we describe a project aimed at integrating ethics and sustainability, specifically in the context of nuclear power, into the programme. We discuss how to teach and assess these topics effectively. We demonstrate how to introduce the United Nations Agenda 2030 (UN, 2025) and its 17 sustainability goals, and suggest some exercises. We then describe how ethical theories such as utilitarianism, virtue ethics and deontological ethics can be presented and applied to engineering problems, and how ethical decision making can be applied to sustainability dilemmas. Finally, we give examples on some topics where ethical sustainability dilemmas exist in relation to nuclear power and discuss how student assignments (both written and oral) can be designed to stimulate student discussion and learning. The findings are supported by student evaluation reports from the sessions. As an outlook for further development of the programme, we offer suggestions on how to further strengthen the topic of ethics and sustainability throughout the programme by identifying ways to integrate and build upon these themes in later courses.

1 Introduction

The Bachelor of Science Programme in Nuclear Engineering at Uppsala University (Swedish abbreviation is KKI), is a one-year programme that admits students with at least two full study years from another engineering programme with specialisation in e.g. mechanical, electrical, construction or energy engineering. During their previous studies, the students have gained basic knowledge in mathematics, physics, and engineering, although the exact courses students have taken vary. While this programme is quite unique, the context and the challenges are not completely different from those of traditional masters' programmes. The main difference is that our students are not required to hold a completed degree upon admission; instead, they combine their earlier studies with the KKI year to achieve the Bachelor of Science

degree in Nuclear Engineering. Worth noting is however, that many of the admitted students have more than two years of previous studies, and a large fraction already have engineering degrees. The Swedish Higher Education Ordinance (UHR, 2025) allows them to achieve a new 180 credit Bachelor of Nuclear Engineering by “reusing” 120 credits from their previous engineering programmes. In this way, students can for instance earn two 3-year degrees after 4 years of studies.

The KKI programme has a maximum capacity of 30 students, but it has never reached full enrolment. It has been quite challenging to attract students, probably due to the unusual construction of the programme as an extra year, but also due to the uncertainty of nuclear energy as a long-term energy source and career opportunity in Sweden. Lately, however, the program has seen an increase in student interest, see Figure 1.

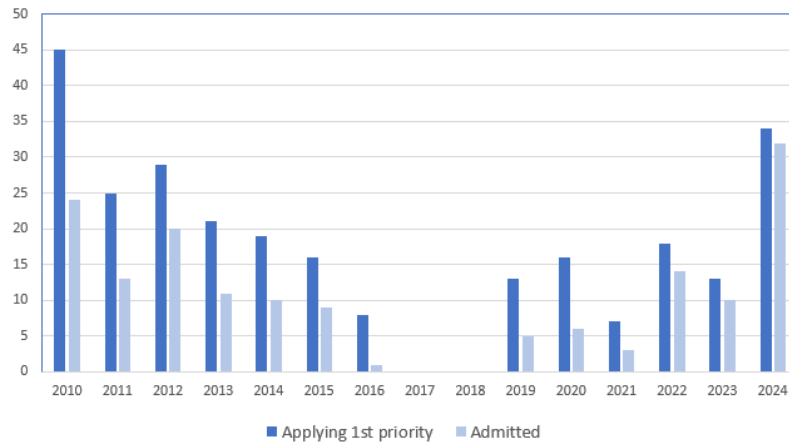


Figure 1: Number of applying and admitted students to the Bachelor of Science Programme in Nuclear Engineering at programme. Students applying as their 1st priority choice are included.

In the Higher Education Ordinance (UHR, 2025), the requirements for the degree of Bachelor of Science in Engineering specifies goals regarding ethics and sustainability:

For a Degree of Bachelor of Science in Engineering the student shall:

- *demonstrate the ability to design and manage products, processes and systems while taking into account the circumstances and needs of individuals and the goals for economically, socially and ecologically sustainable development set by the community*
- *demonstrate the ability to make assessments informed by relevant disciplinary, social and ethical aspects*
- *demonstrate insight into the possibilities and limitations of technology, its role in society and the responsibility of the individual for how it is used, including social and economic aspects as well as environmental and occupational health and safety aspects*

We cannot assume that students have received training related to these goals in their previous studies, so to ensure that sustainability and ethics has been taught and assessed, this has been included in the KKI syllabus. The KKI-programme is taught entirely in Swedish; hence, in this paper, text and formulations from both teaching activities and student responses have been translated to English.

2 Teaching sustainability in relation to nuclear power

The UN:s Agenda 2030 with the 17 goals for sustainable development (UN, 2025) was used as a suitable starting point for discussing sustainability. Students are generally already familiar with these goals, not only from university, but from secondary school and even primary school. They are also often aware of criticism of the goals or of the concepts of sustainable development itself. Some of the critical points raised are the fear of the goals being too broad and too bland to make any difference, and the question of what development means (economic?). Other concerns are the inherent acceptance of a capitalist system in the model, the strong focus on human needs as opposed to the needs of other species, the difficulty to measure progress of sustainability and several others. Opening an initial discussion on these issues was found to be a successful way of engaging students in further constructive discussions on sustainability.

2.1 Exercises on sustainability and nuclear power

In the classroom, students were given two short exercises:

Which of the Agenda 2030 goals have a connection to nuclear power?

The students were asked to first think individually and then work in small groups to identify all connections between a goal and nuclear power, considering both how it supports and conflicts the goal.

Examine and discuss rhetorics from environmental organizations pro and against nuclear power.

Several environmental organizations have taken a stance either for or against nuclear power, and short texts from their uploaded material were read and discussed in groups. The organizations were Greenpeace (Greenpeace, 2025), The Swedish Society for Nature Conservation (Naturskyddsföreningen, 2025), Friends of the Environment for Nuclear Power (Miljövänner för kärnkraft, 2025) and Finland's Green Party (De Gröna, 2025).

3 Teaching ethics and ethical decision making

The previous experience of working with ethics varies among the students. No prior knowledge is required; but it is also desirable to avoid unnecessarily repetition of concepts and training already covered in previous programmes and courses. The ethics session, therefore, begins by asking the students about their experiences of ethics in earlier courses.

An easy and commonly used introduction to ethics is the trolley problem (Thomson, 1976), which is also used in the present course. The setup of the trolley problem is a situation in which a trolley is heading for a group of five people and will kill them if nothing is done. A student is faced with the question whether they would intervene by pulling a lever which will alter the route of the trolley towards a single person. Initially, many students find it obvious that pulling the lever is the right thing to do (causing one fatality instead of five).

Starting from the simplest version of the trolley problem, we subsequently problematize it by varying the input parameters and making the problem more complex, e.g. by replacing the single person with a family member, a friend, a child, or a criminal etc. To give some ethics theory to support solving the trolley problem; utilitarianism, virtue ethics and deontological ethics are introduced, and the students are encouraged to discuss how to solve the problem if applying these theories. In addition, time was also spent

to analyse technical questions from the various ethical frame works, e.g. how to programme the behaviour of self-driving cars. Furthermore, the question of whether people who live today have a responsibility for future generations, was raised. This question is closely linked to sustainability.

3.1 Models for ethical decision making

To concretize and exemplify ethical decision making, students were presented with a simple model for ethical decision making, adapted from (Lennerfors, 2019). This model is depicted in Figure 2.

	Alternative 1	Alternative 2	Alternative 3
Consequences for me			
Consequences for others			
Duties/rights			
Virtue			
Other			
Summary of pros and cons			
Decision			

Figure 2. A simple model for ethical decision making. Adapted from (Lennerfors, 2019).

The students were instructed to use this model, or some other structured model, in their future dilemma exercise to avoid solving their dilemmas by means of e.g. gut feeling, wishful thinking or confirmation bias.

4 Combining ethics and sustainability – the dilemma exercise

After the students had been introduced to and worked with, sustainability and ethical theories, the main exercise: Ethical sustainability dilemmas related to nuclear power, was introduced. Six dilemmas were presented to the students:

1. One of the fastest ways to generate more electricity is to build large-scale wind power. Some people think this is a good idea because wind power is a renewable energy source. Others believe it is unsightly, creates noise, and harms wildlife (birds, reindeer, etc.). What decision do you think should be made regarding wind power? Related Agenda 2030 Sustainable Development (SD) goals: 7, 11, 13, 15
2. In your town, a new deep repository for spent nuclear fuel is planned to be built. It will create many jobs, and many people will move to the area. At the same time, the radioactive material will remain

hazardous to humans and the environment for thousands of years. What responsibility do we have today for future generations who will have to deal with this issue? SD goals 3, 7, 8, 13

3. There are far fewer women than men studying nuclear power technology, and some surveys show that women tend to be more negative toward nuclear power. It can also be challenging to work as a woman in a male-dominated industry, which might lead many to choose other paths. However, some people believe that women are "naturally" less interested in science and should pursue something that suits them better. What do you think? SD goals: 4, 5, 8, 10.
4. The development of small modular reactors (SMRs) could provide electricity and opportunities for development in many developing countries, such as those in southern Africa. To help these countries avoid relying on fossil fuels and achieve economic prosperity more quickly, wealthy nations should fund such SMRs in vulnerable countries. Do you agree? SD goals: 1, 2, 7, 8
5. Sweden's bedrock is among the most uranium-rich in the world. Yet, we do not mine any uranium but instead import a large portion of our uranium within the EU from countries such as Kazakhstan, Russia, and Niger. Is this justified, ethically? SD goals: 3, 7, 8, 9, 13
6. Many peace organizations oppose nuclear power due to its technical proximity to nuclear weapons and the possibility of using fissile material and nuclear facilities for weapons production. Do you agree with them that we should abstain from nuclear power in favour of a more peaceful and secure world? SD goals: 7, 13, 16

Each dilemma is related to nuclear power, the first dilemma not obviously so, but it addresses the conflict that has arisen between proponents of nuclear power and wind power. The other dilemmas address handling of radioactive waste, gender imbalance in the nuclear industry, access to electricity in developing countries, mining of uranium and the technical relation between nuclear power and nuclear weapons. All these questions are of relevance in the nuclear industry sector and are also related to sustainable development; note that a suggestion of associated Agenda 2030 goal is given for each dilemma.

The task given to the students is to choose one dilemma and write a short reflection on the problem and an analysis considering both sustainability goals and ethical theories. For each dilemma there is a concrete question to be answered, i.e. a decision to be made. The reflections were written individually and submitted to the teacher. In a following seminar, students were divided into groups of 4-6 students and presented their work to each other, followed by a discussion moderated by the teacher.

5 Results; outcomes and student perceptions

5.1 Sustainability and ethics exercises

The introductory exercises on sustainability showed that the students identified that all the Agenda 2030 goals can be addressed in nuclear power applications, in one way or the other. This outcome was to some extent anticipated by the teachers, and the intended learning objective was for students to realize that sustainability and nuclear power are more closely connected than they might initially perceive.

The survey of texts from environmental organizations, advocates and opponents of nuclear power gave the students the insight that the same arguments are often used both for and against nuclear power. Examples

are related to economy and ecology, i.e. that nuclear power is too expensive/alternatives to nuclear power (for example when including costs of climate change) are too expensive or that nuclear power is necessary to provide a good environment for future generations/nuclear power is a danger to future generations. This exercise gave a natural motivation to learn more about ethics and how to make well-informed and ethical decisions.

Results from the question on whether students had ethics in previous courses can be seen in Figure 3. Less than half of the students answered that they have had ethics teaching before this course, making it sensible to include it.

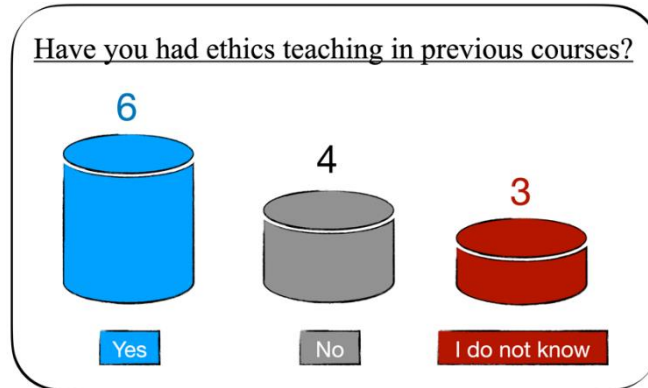


Figure 3. Question to the students: Have you had ethics teaching in previous courses?

Figure 4 is related to the trolley problem and shows the number of students who changed their decision because of the problem formulation being more complex. As can be seen, most students could not apply the same solution to the trolley problem when the input parameters changed. Note that the problem always included the same total number of people, meaning that other factors than a pure utilitarian bookkeeping of lives were considered.

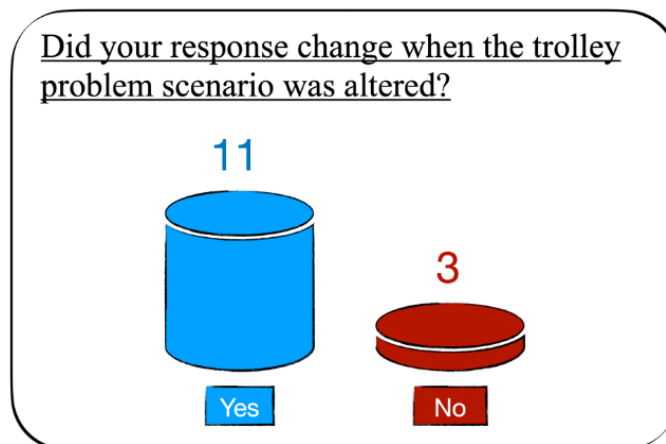


Figure 4. Question to the students: Did your response change when the trolley scenario was altered?

5.2 Main exercise: sustainability dilemmas

Twenty-one students participated in the dilemma exercise, selecting topics from those listed in Section 4 above. How they choose is shown in Table 1. Consequently, we can conclude that all topics were chosen, with “Large-scale wind power” and “Proximity to nuclear weapons” being the most popular.

Table 1: Number of students choosing to focus on which dilemma.

Dilemma	Number of students
Large-scale wind power	6
Deep repository in your town	1
Male-dominated line of work	1
SMR:s in development countries	4
Uranium mining in Sweden	3
Proximity to nuclear weapons	6

After the teacher reviewed the handed-in texts, the students were divided into six mixed-subject seminar groups for a follow up discussion with a teacher. In these seminars, each student first presented their reflections and conclusion, followed by a teacher-led discussion built on the points raised by the students. This procedure was chosen to 1) ensure that students could justify their texts, as AI-tools were permitted in their work, and 2) to deepen their understanding through discussion with peers.

During the discussions, some students noted that the solutions they eventually settled on in their chosen dilemma were not the ones they initially felt were the right decisions. For instance, among those who worked with the SMR (small modular reactors) in developing countries it was noted that while it initially seemed like a good idea, the more they studied the concept and learnt about it, the more concerns came up regarding safety and nuclear security. As more sustainability goals were considered, the complexity of the dilemma became clearer. Several students instead proposed the use of solar power in developing countries.

In the student course evaluation, one question addressed the dilemma exercise. However, only 6 out of 21 students responded. All 6 rated the exercise as fruitful or very fruitful, with an average score of 4,0 on a 5-point scale. The only free-text comment stated: “Very interesting”.

6 Conclusion and outlook

Nuclear power is a subject that can be highly controversial, often evoking strong opinions from both advocates and opponents. In this project, the aim was to educate students about sustainability in relation to nuclear power, and to give them tools to make ethical decisions, even in complex situations. It can be argued that such abilities are important for all engineers, and nuclear engineering is an excellent topic to train these abilities. The present sessions on sustainability and ethics, followed by the larger dilemma exercise, have been successfully implemented and the learning outcomes stated in the Higher Education Ordinance have been addressed. As a continuation of this work, other courses in the programme are being reviewed, to

investigate if topics of sustainability and ethics therein can be further strengthened. The main candidate for this work is a new course, towards the end of the year: Nuclear Waste Management and Decommissioning. This course already contains a large student group-project, focusing on different waste management and decommissioning scenarios, in which sustainability and ethics is incorporated.

References

De Gröna, Finland's Green Party. 2025. *Political programme*. <https://www.greens.fi/political-programme-of-the-greens-2023-2027/>

Greenpeace Sweden. 2025. *Sex skäl till varför kärnkraft inte är vägen till en grön och fredlig värld* <https://www.greenpeace.org/sweden/artiklar/energi/sex-skal-till-varfor-karnkraft-inte-ar-vagen-till-en-gron-och-fredlig-varld/>

Lennerfors, T. T. (2019). *Ethics in engineering*. Lund: Studentlitteratur AB, 2019

Miljövännen för kärnkraft, Friends of the Environment for Nuclear Power. 2025. *Frågor och svar*. <https://www.mfk.nu/fragor-och-svar/>

Naturskyddsföreningen, The Swedish Society for Nature Conservation. 2025. *Vanliga frågor om kärnkraft* <https://www.naturskyddsforeningen.se/artiklar/vanliga-fragor-om-karnkraft/>

Thomson, J. J. 1976. Killing, Letting Die, and the Trolley Problem, 59 *The Monist* 204-17.

UN, United Nations. 2025 *United nations goals for sustainable development, Agenda 2030*. <https://sdgs.un.org/>

UHR, Swedish Council for Higher Education. 2025, *The Swedish Higher Education Ordinance (1993:100)* <https://www.uhr.se/en/start/laws-and-regulations/Laws-and-regulations/The-Higher-Education-Ordinance/>