Using wicked problems in teaching for sustainability

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***Abstract*— Societal challenges are often complex and multifaceted, with solutions that are not simply "right or wrong", but rather "better or worse". These can often be presented as wicked problems and addressing them requires critical thinking, ethical reasoning, and the ability to navigate uncertainty and conflicting interests. Future engineers will need to evaluate the broad sustainability implications of new technologies that are being developed or applied in new ways. We designed and implemented wicked problems as exercises within the new interdisciplinary LTH course *Air, Particles and Health.* Each problem started from an engaging, real-world issue and incorporated diverse stakeholder perspectives to highlight conflicting interests. Each student chose a stakeholder to represent. At the sessions, students first met in homogeneous stakeholder groups to develop their arguments. After that, students assembled into mixed groups with one representative per stakeholder —to discuss and seek common ground and solutions. Each group then presented their conclusions in the full class. A brief written evaluation was carried out after the exercise session and free text answers in CEQ were analysed. The student´s feedback was that the wicked problem sessions were an important complement to other learning activities in the course. Several good suggestions were received from the students to further develop the wicked problems sessions.**

***Index Terms*— Wicked Problems, Sustainability, CEQ**

I. Introduction

THE engineers educated at LTH will develop and apply the technologies of the future. In the transition towards sustainability, they need to be equipped to tackle increasingly complex problems that require considering multiple perspectives and weighing various factors before determining what is truly right or effective. Traditional engineering education often deal with "tame" problems (Rittel and Webber, 1973) that can be taught with traditional methods. However, today's societal challenges and problems differ substantially, and the solutions are often not "right or wrong" but "better or worse", making traditional educational approaches less effective. These types of problems can be considered "wicked" problems (Rittel and Webber, 1973) and addressing them requires critical thinking, ethical reasoning, and the ability to navigate uncertainty and conflicting interests.

Using wicked problems in teaching and learning presents challenges due to their complex, interconnected nature and lack of clear-cut solutions. According to Conklin (2006), wicked problems are inherently different from ordinary problems because they have no definitive formulation and no true stopping rule. Therefore, in our opinion, using wicked problems in teaching as a basis for discussions presents an interesting tool to emphasize the complexity of real-world sustainability challenges.

To cite Laurence J. Peter "Some problems are so complex that you have to be highly intelligent and well informed just to be undecided about them". However, criticism has arisen regarding the treatment of complex problems as 'wicked,' as it can lead to the notion that 'all is relative,' resulting in indecision. This, in turn, often neglects the practical aspects for those who need to address and act on these complex issues (Noordegraaf et al., 2019).

Societal challenges are typically addressed by different groups (stakeholders) from different, often conflicting, viewpoints. Hence, possible solutions require compromises and trade-offs. Wicked problems and training in representing different stakeholder perspectives was introduced at LTH through a student-led project in the course Sustainable Development in Nano-Perspectives (Lönngren et al. 2010). The concept has been further developed and implemented at other universities (Lönngren 2017).

Strategies to teaching and learning that can be effectively applied to wicked problems were described by Sharp et al. (2021). The observations were as follows: 1. Students engage better and learn more effectively when they are active participants, and agents of, their own learning. 2. Learning environments need to be sites of inclusive and equitable learning for effective teaching to take place. 3. In teaching wicked problems it is often better to start slow, simple and local and then build in complexity and scale.

Some challenges with using wicked problems in teaching have also been described for example frustration from students who expect to be given a straightforward answer or solution to a problem (Lönngren and van Poeck 2020). However, being aware of this challenge will help teachers to prepare well, dedicate time to explain, and give successful examples of how wicked air pollution problems from the past were solved e.g. acidification, or tobacco smoking.

Lönngren (2021) describes design principles to formulate wicked problems for engineering and natural science education. Her recommendation is to start with a problem that *engages* the students and choose interest groups and stakeholders that makes it possible to discuss the problem from *different perspectives* and indicate *conflicts of interest* between the groups.

The aim of this work was to design and implement as a pilot wicked problems within aerosol education and to evaluate how they contributed to the student´s learning.

II. Design of Wicked Problems for Aerosol Education

We designed wicked problems for engineering education within aerosol science following the principles given by Lönngren (2021). The topics included:

1. Is use of portable indoor air cleaners justified in Sweden?
2. Transport Emissions: How should Clean Air Zones be designed and regulated?
3. Circular Materials – Secondary Use of Waste Streams and Safety
4. Climate vs Health Impacts of Air Pollution.

Each problem started from an engaging, real-world issue and incorporated diverse stakeholder perspectives to highlight conflicting interests. Several of the problems discussed topics that appeared in the national news at the time of the course (for example the introduction of Clean Air Zone in central Stockholm).

Each problem was described in 400-500 Words. Tentative stakeholders were listed, for example Manufacturers associations, Swedish EPA, Labour Unions, tenants, parents whose children suffer from respiratory diseases and NGO´s.

III. Pilot Test of Wicked Problems in the Course Air, Particles and Health

We implemented three of these problems as exercises in the new interdisciplinary LTH course *Air, Particles, and Health* (co-read by second and third cycle students). Two of the problems were discussed during longer sessions (2 · 45 mins each). A third problem was implemented as a 20 min discussion segment embedded in one of the regular lectures. The general concept of wicked problems and how they can be addressed from different stakeholder perspectives was introduced in the beginning of the first session. The description of the wicked problem was sent out to the students a few days before the longer sessions. The students signed up and choose a stakeholder to represent before the session within Canvas. A few spots were available where students could define their own stakeholder to the problem.

Each session began with an introduction of the specific problem and related stakeholder perspectives. The students first met in homogeneous stakeholder groups (10 mins discussion) to develop their arguments. After that, students assembled into mixed groups (~5 students per group, 25 mins discussion) with one representative per stakeholder — to discuss and seek common ground and solutions to the formulated problem. At end of the session each group presented their conclusions in the full class, and the session ended with a teacher-led summary of the key arguments shared across the class. The wicked problem sessions were not mandatory and not part of the examination of the course. However, the course written examination at the end of the course included one question formulated as a wicked problem following the same structures as the exercises.

A brief written evaluation was carried out after the first exercise session, followed up by a discussion with the whole class about the experience of the wicked problem exercise. The free text answers in the Course Experience Questionnaire (CEQ) were analysed with a focus on the wicked problem exercises. Ten students completed the CEQ for the course.

IV. Results and Discussion

The CEQ-results for the course as a whole was positive (Good Teaching: +66, Appropriate Assessment: + 73, Overall satisfaction: + 80). Several students reported the wicked problem sessions were an important complement to other learning activities in the course (lectures, written project and lab sessions).

In the written feedback from the students and informal discussions about wicked problem sessions the following were main messages:

- All students were positive to introducing the sessions,
- The majority of the students reported that the sessions helped them to process, reflect and apply knowledge gained in the course,
- Several student´s reported that the exercises helped them to see a problem from different perspectives and to discuss different opinions.
- Some students pointed out that so far throughout their education they learned to argument for the environmental consequences, but it was one of the first times when they had to consider economic, political, social, and private emotionally loaded perspectives. They considered it thought-provoking and valuable.
- A few students mentioned it was hard the first exercise but worked really well the second time

Several good suggestions and reflections were received from the students to further develop the wicked problem sessions:

- It was found to be too easy to find a common ground and agree on solutions. Wicked problem and stakeholders could include more conflicting terms, or stakeholder could be described in a more non-flexible way)
- More time is needed for the main discussion and the follow-up in the full class.

Reflections and suggestions from the teachers include:

The exercises will be made mandatory and the students will be instructed to be better prepared before the exercise by independently formulating arguments for their chosen stakeholder. The students will be asked to submit a brief written reflection after each exercise.

The answers to the exam question that was formulated as a wicked problem demonstrated that most students had achieved an ability to see air pollution problems from different angels and to apply their theoretical knowledge to societal challenges and to start to develop arguments to create policy.

V. Conclusions

Teaching for sustainability using wicked problems is a useful tool in engineering education. It helps in attaining deeper understanding of the complexity of problems and multifaceted consequences of implementing new or alternative technologies. It also helps in developing critical thinking, formulating arguments in discussions where ethical aspects, uncertainty, conflicting and emotionally loaded interests are discussed. Hence for students, it both enhances the learning process and prepares for future professional roles.

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