Educating engineers for changing a world full of ‘wicked problems’

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Sligo, August 16, 2022
Agenda

• Who am I?
• What is a ‘wicked problem’?
  • Examples
  • Theoretical descriptions
• Wicked problems in engineering education?
  • Current situation
  • Description of the ability to handle wicked problems
• Tools for teaching and assessment
  • Rubric
  • Design principles
  • Examples from practice

Help you find theories and example practices to use in your own professional development!
Examples of my experiences and interests

**Chemical engineering**
MSc 1991, PhD 1997

- 3-year university wide project on ESD (06-09)
  - Director Chalmers Learning Centre (09-14)
  - Hosted EESD conference (10)
  - Wrote Swedish textbook on Intro to SD (11)
  - Developed MSc program on ESD with GU (18)
  - Gave course on Sustainability for Engineers at UCB (19)

**Environmental systems analysis**
Prof, 2019

**Sustainability**

**Systems thinking**

**Supporting teaching and learning**

**Engineering education research**
Anthropocene... The great acceleration...


A perfect storm... Emergence...

Europe Braces for Extreme Heat as Power Infrastructure Wobbles
- Soaring temperatures boost cooling demand amid energy crisis
- Parts of Rhine already at risk of closing due to water level
  Source: Bloomberg

Democracy and human rights under threat

A world between orders...

China Says Taiwan Can Be Just Like Hong Kong. Huh?
"One Country, Two Systems" hasn't worked out as promised in Hong Kong. It isn't likely to change minds in Taipei.
Source: Bloomberg
Complicated AND complex makes ‘wicked’…

Methods for dealing with complex or complicated systems each have limitations that make them unsuitable for the other type.

Wicked problem characteristics (in social policy planning)

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true-or-false, but good or bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly.
6. Wicked problems do not have an enumerable set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered to be a symptom of another problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution.
10. The social planner has no right to be wrong (i.e., planners are liable for the consequences of the actions they generate).

Three sources of ’wickedness’

1. **Finitude**: related to the limits of cognitive ability and resources. However smart one is, or however powerful a computer is, there will always be a limit to what processes can be performed.

2. **Complexity**: described as a result of interactions between parts of systems, such as nested hierarchies, feedback and feedforward loops, or cascading effects in seemingly distant parts of a system.

3. **Normativity**: related to the importance of human norms and values for problem understanding and resolution. Conflicting norms and values are common between different agents, but even “within an agent’s normative commitments”

Real-world science and engineering problems are wicked problems!

Engineering students are trained to solve “story problems”

• Purely technical problems that are delivered in short, written stories.

• All necessary information about a problem is present in the story: “identify key words in the story, select the appropriate algorithm and sequence for solving the problem, and apply the algorithm”.

• Do not exhibit any of the three sources of wickedness identified by Farrell & Hooker.

• Resemble neither wicked problems, nor workplace engineering problems.

• Current gap in engineering education!!!

Four ways of dealing with wicked problems...

Phenomenographic study on ways that (nanotechnology) engineering students deal with the wicked problem of water shortage in Jordan:

<table>
<thead>
<tr>
<th>A: Simplify &amp; Avoid</th>
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<tr>
<td>B: Divide &amp; Conquer</td>
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<tr>
<td>C: Isolate &amp; Succumb</td>
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<tr>
<td>D: Integrate &amp; Balance</td>
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Students may feel **overwhelmed** if they lack appropriate tools for dealing with the **complexity, uncertainty, and value conflicts**. They may understand a problem as a complex system, but still expect to be able to solve it by dividing it into separate parts and solve each of these parts in isolation. They may then conclude that **nothing can be done**.

Lönnngren J, Ingerman Å, Svanström M (2016) Avoid, Control, Succumb, or Balance: Engineering students’ approaches to a wicked sustainability problem, *Research in Science Education*
What superpowers would the superhero engineer need in order to be able to handle wicked problems?

Examples of what emerges when I try to deconstruct this ability, now:

• Knowledge of the system and its properties
  • know current state, trends and unsustainabilities
  • use systems thinking, perspective shifting – zooming in and zooming out

• Envisioning of a ”better” situation
  • see possibilities
  • manage uncertainties and risks

• Changing the system
  • change agency; action competence
  • communication; empathy
  • moderate own behaviour

Shuri, Princess of Wakanda, master inventor and engineer

Spiderman, Peter Parker, designed and built all of his gear
Compare to: Key competences in sustainability

We developed and used a framework for addressing wicked problems

- Ten aspects – five structural and five referential
- Assessment rubric for each aspect
- Design principles for wicked problem descriptions
- Wicked problem descriptions
- Educational intervention – tested in computer engineering education
Ten aspects that need to be identified and reflected upon when addressing wicked problems

- Different **problem parts** that together make up the overall problem;
- Different **improvement measures** that could be used to address the overall problem and/or individual problem parts;
- Interaction between problem parts, such as feedback mechanisms, symbiosis, or conflict, through which one problem part could alleviate or aggravate other problem parts (**problem part interaction**);
- Interaction between improvement measures, such as feedback mechanisms, symbiosis or conflict, through which one improvement measure could facilitate or impede the successful implementation of other improvement measures (**improvement measure interaction**);
- Unintended, **secondary problems** that could be caused by improvement measures;
- **Stakeholders** and their interests in relation to the overall problem, individual problem parts, and/or improvement measures;
- **Spheres of influence** of different actors who could be involved in addressing the overall problem and/or individual problem parts;
- Lack of accessible information, i.e. information that is not currently available but could be obtained through directed research and information-gathering activities (**lack of information**);
- The importance of incomplete control and predictability for the outcome of improvement measures (**uncertainty**);
- The importance and influence of the local problem context for the outcome of different improvement measures (**local context**).
Wicked problem descriptions

• Water shortage in Jordan
• Literacy in Afghanistan
• Dengue fever in Sub-Saharan Africa

Design principles:
1. Ensure that the problem can be understood from many different perspectives
2. Ensure that conflicting values and interests cannot be ignored
3. Define an achievable ”result” that does not allow definitive answers or solutions to the problem
4. Ensure that students can make a connection between the problem and their educational program

Also design problem-specific support for students

Educational intervention

1. Student assignment: write a reflection on a wicked problem in relation to a given professional role; provides information for development of and work in subsequent workshops

2. Students attend two 2-hour workshops that address five aspects each; practical exercises where students alternate between working alone and in small groups – they use the assessment rubric

3. Student home exam: write a reflection on another wicked problem in relation to another professional role – they have access to assessment rubric; this is graded using the assessment rubric (F/3/4/5)
Workshop A – structural aspects

Main message: show the **structure of wicked problems** and how such problems can be managed by **shifting between a holistic view and details**

- Describe in your group the answer to the earlier assignment with a **mind map**
- Analyse the mind map with regard to the **five structural aspects**
- Discussion in whole class
- Assess individually an assignment response using the **assessment rubric**
- Compare results in your group
- Discussion in whole class
Workshop B – referential aspects

Main message: the importance of the situation around the problem – how the situation influences what can and cannot be done; the importance of different perspectives and value conflicts

• Reflect in your group around quotes from the assignment responses (7) – write down questions that have the purpose of clarifying and questioning underlying assumptions
• Analyse the assignment responses with regard to the five referential aspects
• Discuss in whole class
• Assess individually an assignment response using the assessment rubric
• Compare results in your group
• Discuss in whole class
Evaluation

• **Improvements from first assignment to home exam for all aspects**
  • Students found the **first assignment** overwhelming – frustration
  • Students were actively involved in the **workshops** – but were frustrated when they realised there was no “correct” solution, and when they realised that grading is subjective; stress – too little time, rushed through at the expense of deep engagement
  • Students found the **home exam** overwhelming and had difficulties to come up with IT-related measures. The rubric provided a ‘good’ structure that many followed slavishly
  • Students experienced negative emotions in the face of e.g. uncertainty and value conflicts
  • Too much cognitive support might tame the process... Reduce cognitive support and introduce emotional support?
Concluding remarks

• Think about the overall goal of education for sustainability as the development of an ability to handle ‘wicked problems’

• Try to understand what makes up this ability and what you can work with in your educational context

• Make sure you introduce more challenging and open-ended problems than story problems – tell students there are different kinds of problems which require different types of approaches. A wicked problem needs active exploration at different system levels, and in different system parts, and from different perspectives and approaches that integrate levels, parts and perspectives, as well as secondary problems.

• Evaluate and document what you do – share your experiences!

• Together we can find ways forward!