

Educating engineers for changing a world full of 'wicked problems'

Magdalena Svanström

Professor of Sustainability Studies

Division of Environmental Systems Analysis

Department of Technology Management and Economics

Chalmers University of Technology, Gothenburg, Sweden

magdalena.svanstrom@chalmers.se



CHALMERS

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

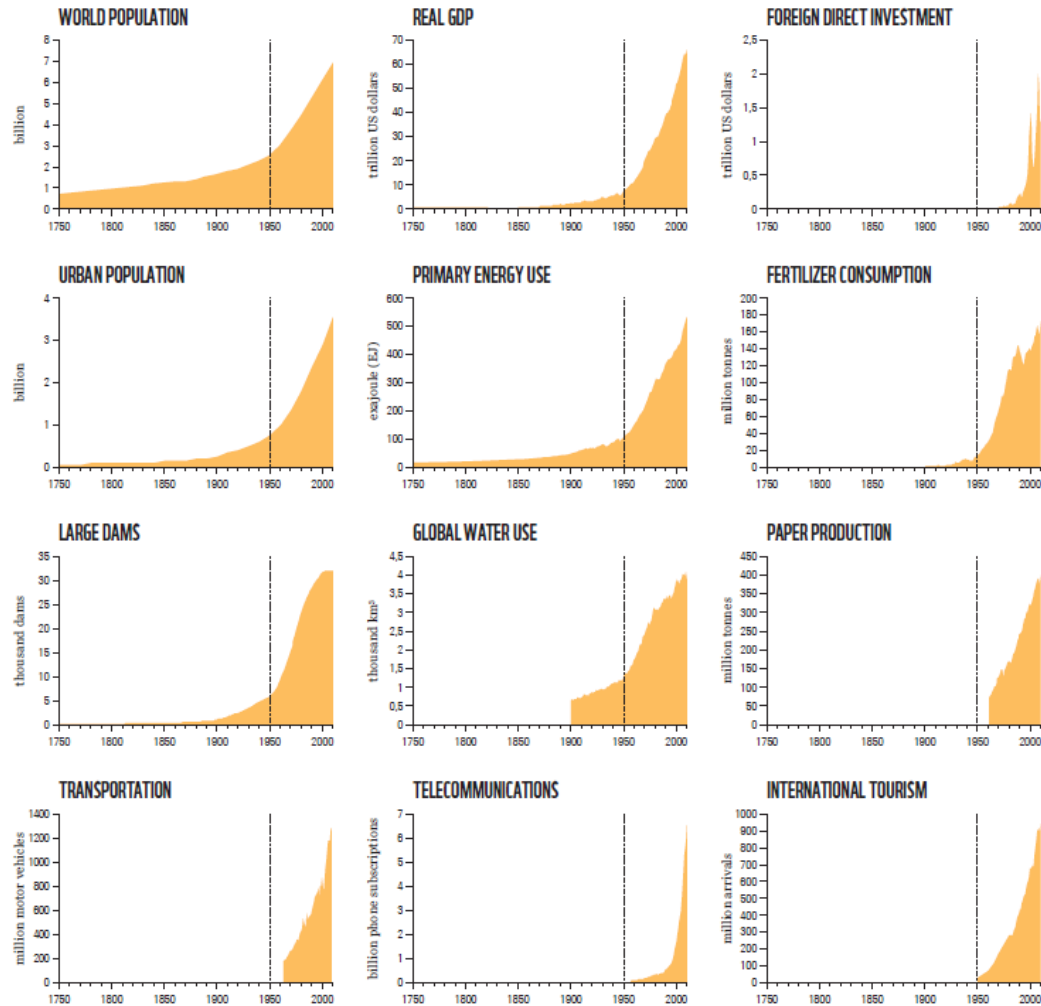
Systems thinking

Supporting teaching and learning

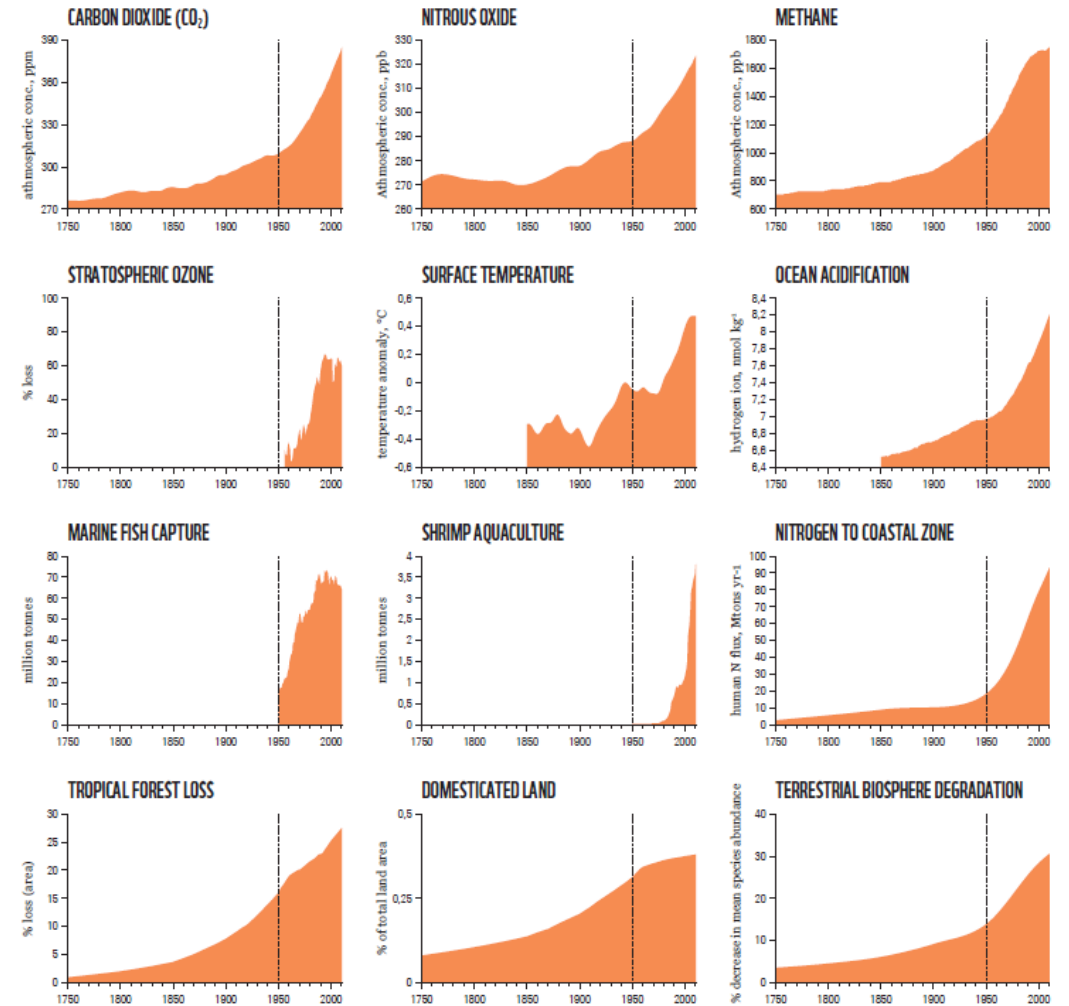
Engineering education research

Anthropocene... The great acceleration...

SOCIO-ECONOMIC TRENDS



EARTH SYSTEM TRENDS



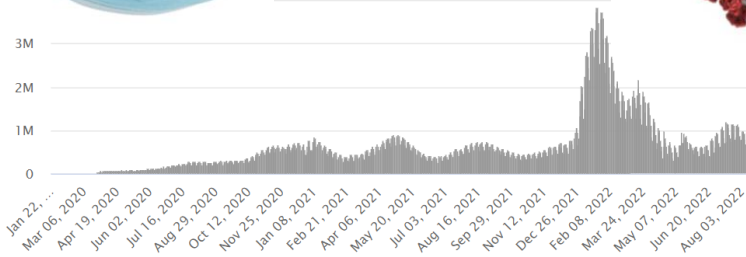
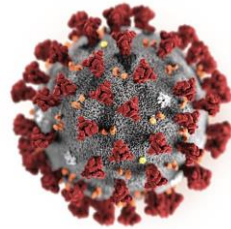
WWF. 2018. *Living Planet Report - 2018: Aiming Higher*. Grooten, M. and Almond, R.E.A.(Eds). WWF, Gland, Switzerland. Based on Steffen, W., et al. 2015. The trajectory of the Anthropocene: The Great Acceleration. *The Anthropocene Review*.

A perfect storm... Emergence...

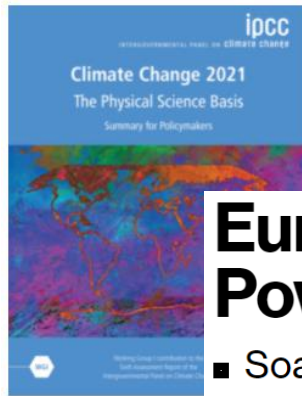


Daily New Cases

Cases per Day
Data as of 0:00 GMT+0



Source: Worldometer



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

CONSPIRACY THEORIES

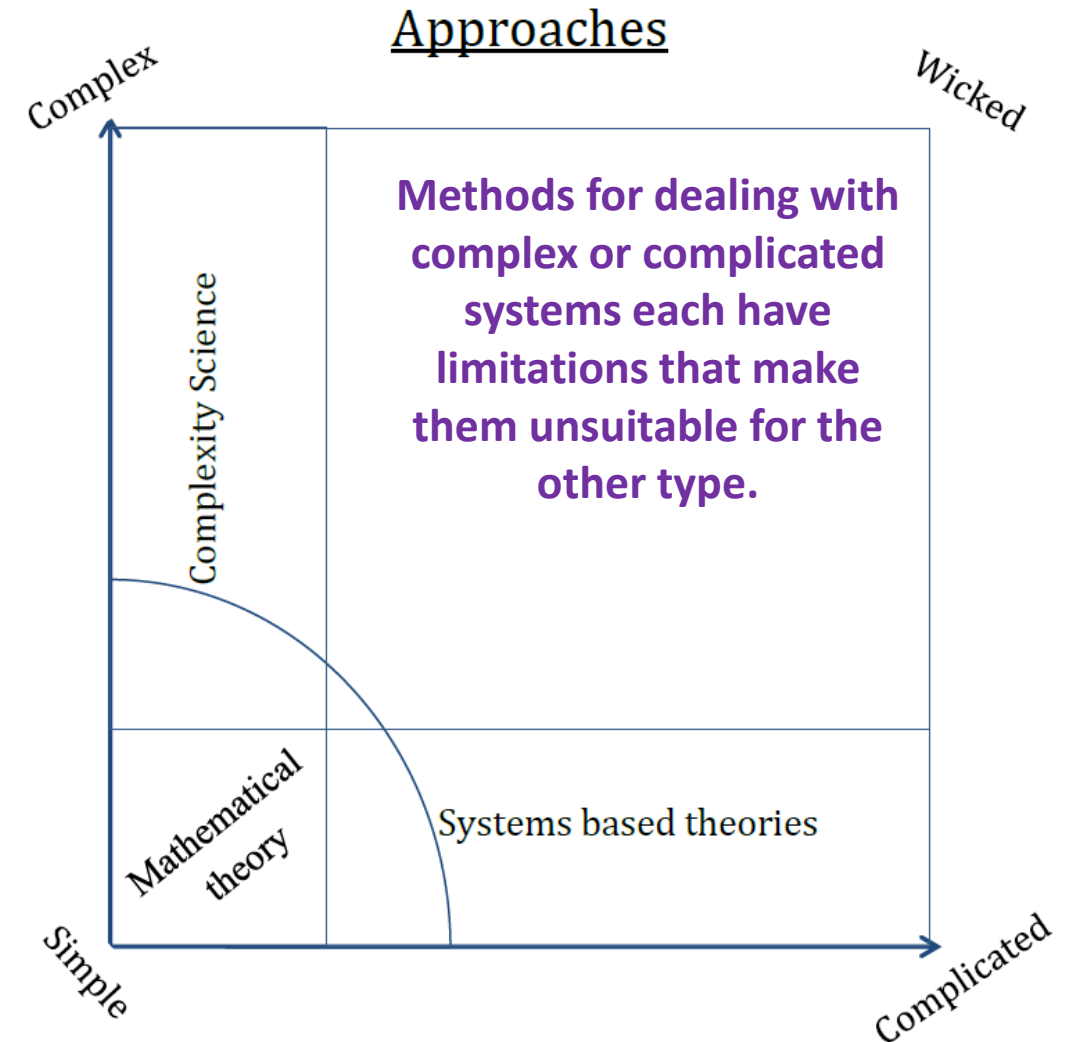
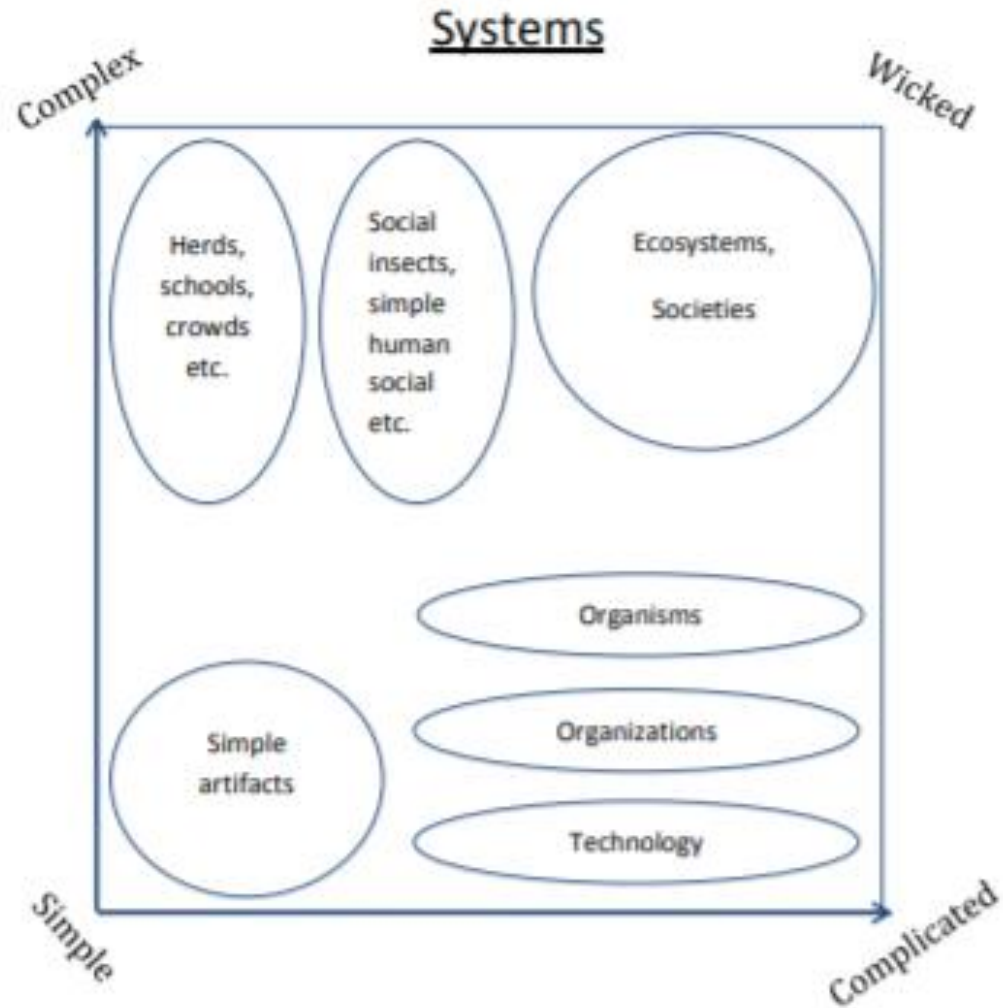
SOCIAL MEDIA

POPULISM

'ALTERNATIVE FACTS'



Complicated AND complex makes 'wicked'...



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!!!

28. Owl counted the days it rained in November and found that $\frac{4}{6}$ of the days were rainy. How many days were NOT rainy?

Forest Fox says $\frac{2}{6}$ of 30 is 20. so 20 day were not rainy.

Flora Fox says $\frac{2}{6}$ of 30 is 10. so 10 days were not rainy.

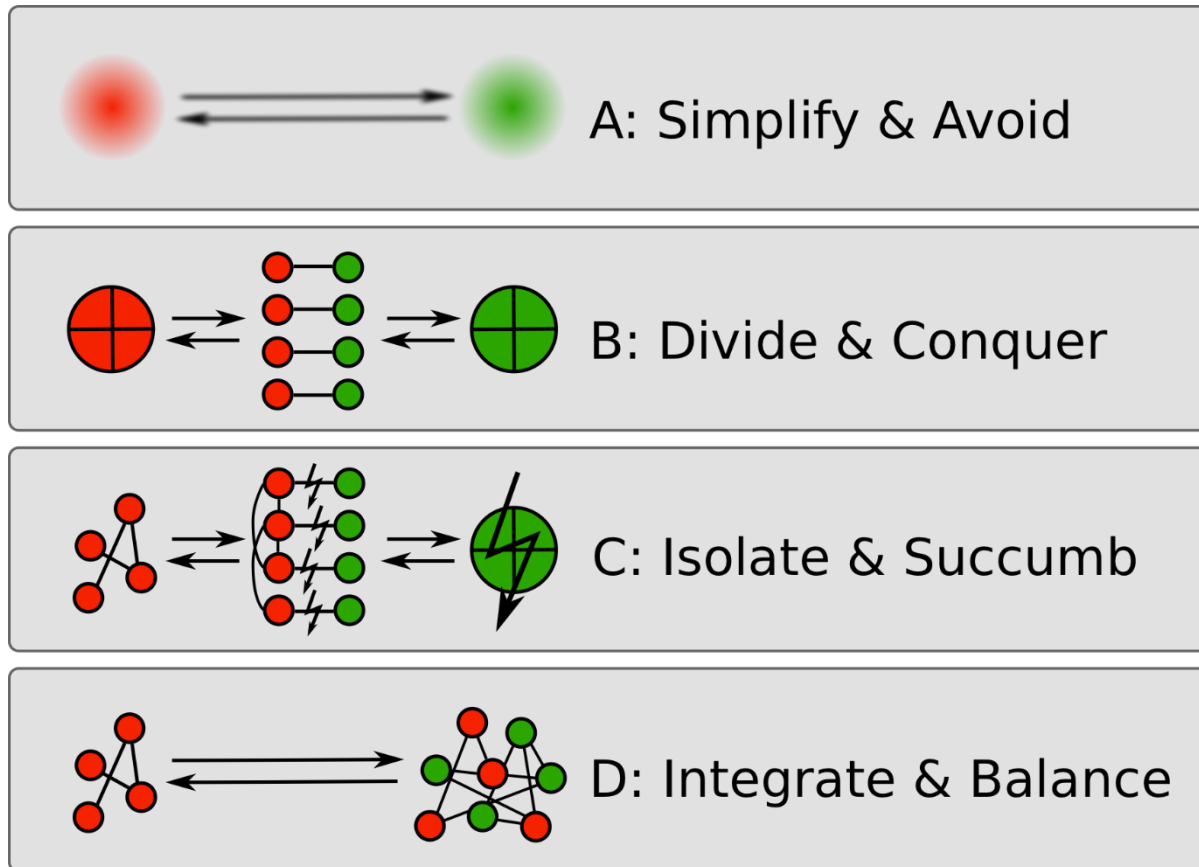
Who is right?

Who made a mistake?



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:



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**.

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

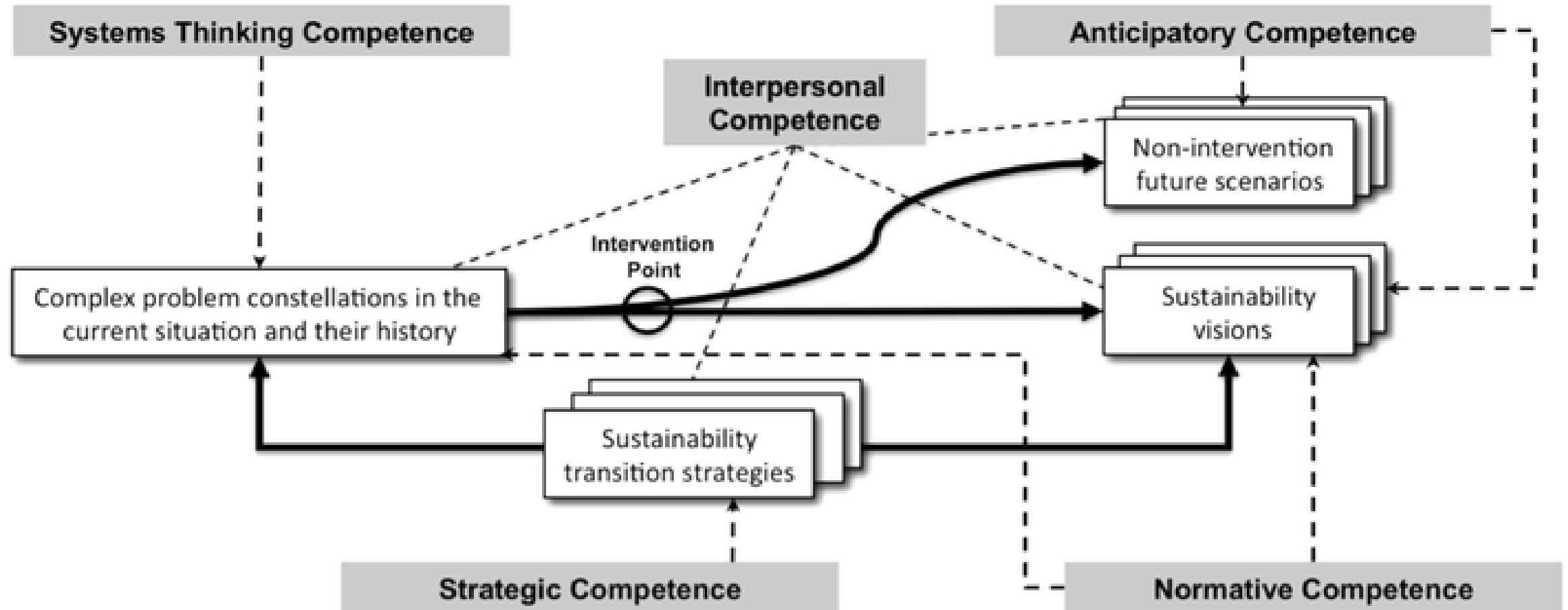


Shuri, Princess of Wakanda, master inventor and engineer



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

- | | |
|-------------|---|
| STRUCTURAL | <ul style="list-style-type: none">• different <u>problem parts</u> that together make up the overall problem;• different <u>improvement measures</u> 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 (<u>problem part interaction</u>);• 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 (<u>improvement measure interaction</u>);• unintended, <u>secondary problems</u> that could be caused by improvement measures; |
| REFERENTIAL | <ul style="list-style-type: none">• <u>stakeholders</u> and their interests in relation to the overall problem, individual problem parts, and/or improvement measures;• <u>spheres of influence</u> 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 (<u>lack of information</u>);• the importance of incomplete control and predictability for the outcome of improvement measures (<u>uncertainty</u>);• the importance and influence of the local problem context for the outcome of different improvement measures (<u>local context</u>). |

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!



Conference

Eleventh International Conference on Engineering Education for Sustainable Development

🕒 18 - 21 Jun 2023 [Add To Calendar](#)

📍 Colorado State University, Fort Collins, USA [Get Directions](#)