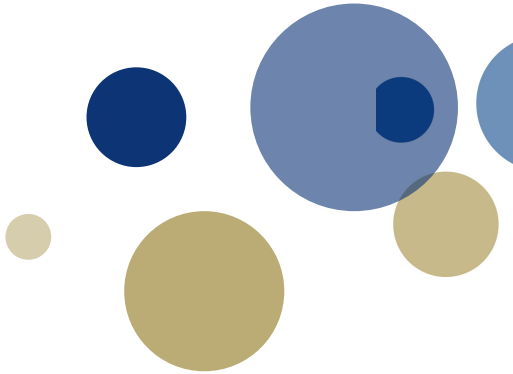
NTNU

Kunnskap for en bedre verden



A Programme Driven Approach to Mathematics in Engineering Education

Frode Rønning
Department of Mathematical Sciences
Norwegian University of Science and Technology
Trondheim

Engineering education at NTNU

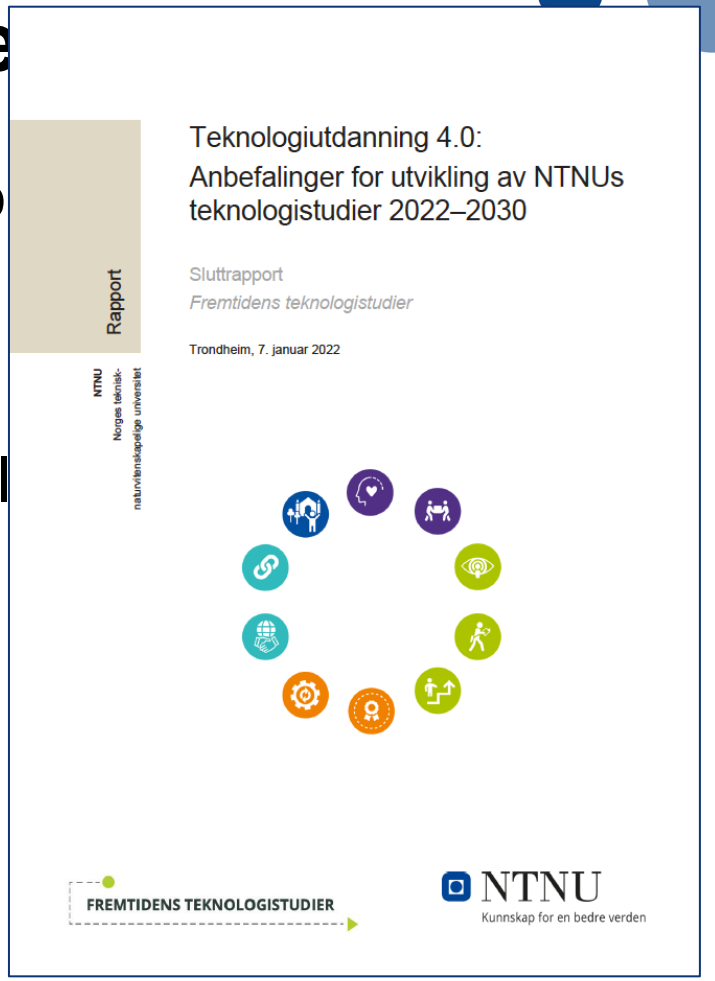
- 12 three-year BA-programmes (>1000 new students each year)
- 17 five-year MA-programmes (≈1700 new students each year)

The five-year MA-programmes (sivilingeniørprogrammene)

- 17 different study programmes – from 20 to > 200 students in each programme
- 5 courses (7.5 ECTS) mathematics and statistics
- With small variations, identical for all programmes, up to now …
- Technology Studies for the Future
- Important principles
  - A programme driven approach
  - Contextual learning
- Inspired by the CDIO principles (Crawley et al., 2014)

The five-year MA-programmes (sivilingeniørprogrammene

- 17 different study programmes – fro
  students in each programme
- 5 courses (7.5 ECTS) mathematics
- With small variations, identical for al
  now …
- Technology Studies for the Future
- Important principles
  - A programme driven approach
  - Contextual learning
- Inspired by the CDIO principles
  (Crawley et al., 2014)



cdio
CONCEIVE DESIGN IMPLEMENT OPERATE™

Mathematics as a Thinking Tool

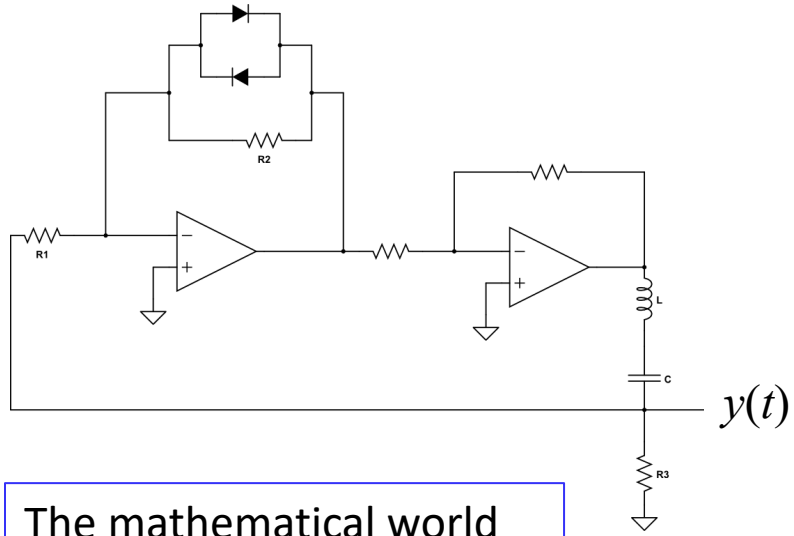
- Goals of the project
  - Use mathematics in realistic engineering situations
  - Enhance computational aspects of mathematics
  - Strengthen students' experiences of the relevance of mathematics
- The project includes these programmes:
  - Electronics Systems Design and Innovation (from 2020)
  - Chemical Engineering and Biotechnology (from 2022)
  - Cybernetics and Robotics (from 2022)
- The project is based on
  - Mathematics taught by mathematicians, engineering taught by engineers
  - Shared responsibility:
    - mathematicians responsible for providing mathematics relevant for engineering.
    - engineers responsible for showing the students how mathematics can be actively applied in their engineering field.

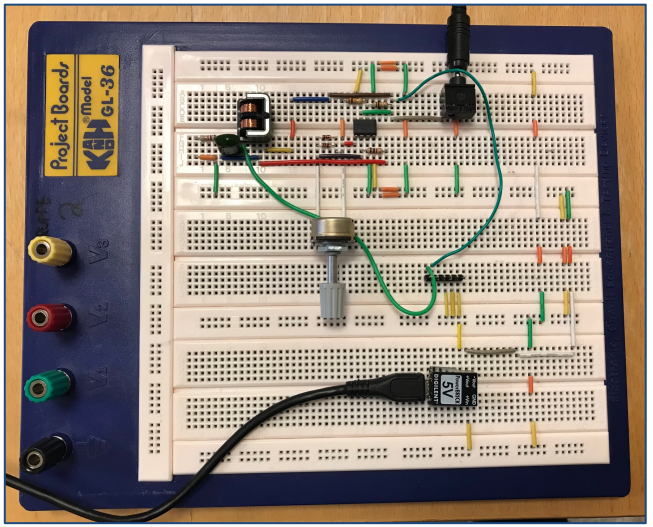
Thematically Integrated Motivational Example (TIME)

- A TIME is a case selected from an engineering context bringing together several topics and illustrating in a motivating way how the chosen topics work together to bring about a phenomenon or effectuate a purpose.
- The case should be chosen in such a way that essential mathematical concepts are necessary for its explanation, analysis and/or design.
- The TIME should be dealt with in both a mathematics course and in one or more engineering courses.
- Example: A non-linear oscillator

A non-linear oscillator

The engineering world





The mathematical world

$$\frac{d^2y}{dt^2} + \frac{R_3}{L} f(y) \frac{dy}{dt} + \frac{1}{LC} y = 0$$

where $f(y) = 1 - \frac{dg(y)}{dy}$, and

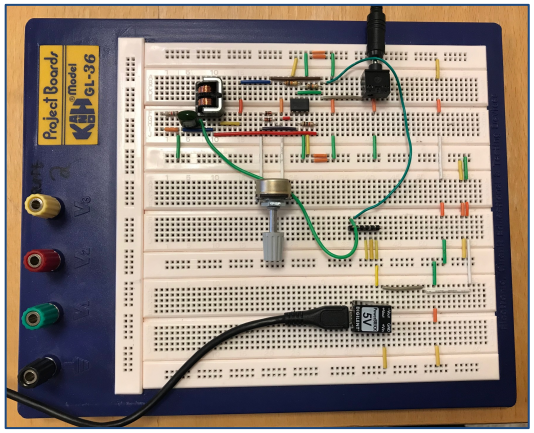
$$g^{-1}(y) = 2R_1 I_0 \sinh\left(\frac{y}{V_0}\right) + \frac{1}{R_2} y$$

An auto-oscillating system

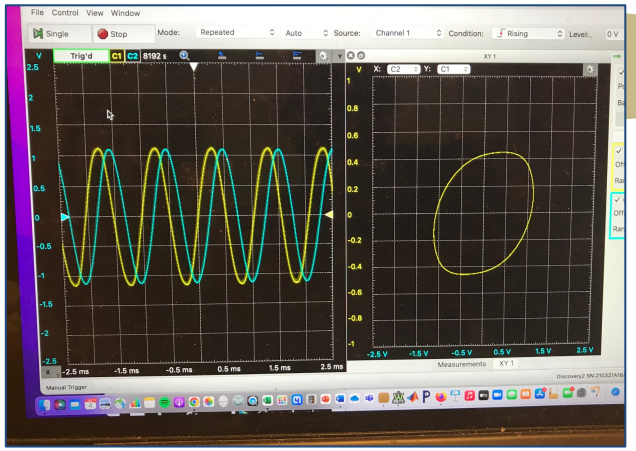
A non-linear differential equation

A non-linear oscillator

The engineering world



Measuring



Comparing

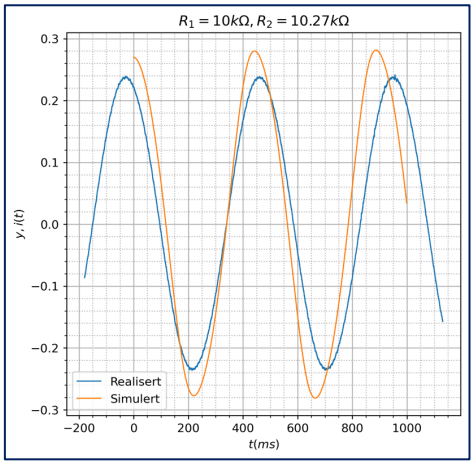
The mathematical world

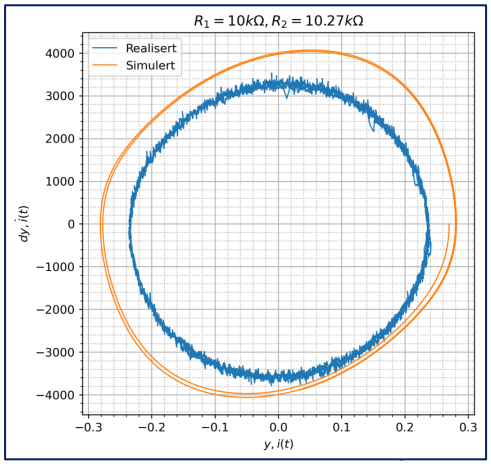
$$\frac{d^2y}{dt^2} + \frac{R_3}{L} f(y) \frac{dy}{dt} + \frac{1}{LC} y = 0$$

where $f(y) = 1 - \frac{dg(y)}{dy}$, and

$$g^{-1}(y) = 2R_1 I_0 \sinh\left(\frac{y}{V_0}\right) + \frac{1}{R_2} y$$

Computing





Survey results – 1st year students

Experienced relevance of mathematics	Completely agree	Partly agree	Partly disagree	Completely disagree
I have seen why mathematics will be important for me later in my studies.	34/**82**	38/**18**	21/**0**	7/**0**
In my work with other courses (i.e., not mathematics courses) I have seen the importance of learning mathematics.	37/**85**	44/**13**	14/**0**	5/**0**
I don't think the mathematics I have learned is very relevant for my study programme.	5/**2**	25/**2**	44/**18**	26/**78**
So far, in my work with other courses (i.e., not mathematics courses), I have managed with the mathematics I learned at school.	28/**7**	32/**11**	24/**49**	16/**33**

Results from survey including the Electronics Systems programme (boldface), $n = 45$, and "the rest", $n = 494$.

New survey will give possibilities to compare Chemistry and Cybernetics before and after entering the project.

Some challenges

- We are now in the third year with mathematics for *Electronics Systems Design* and in the first year with *Chemical Engineering and Biotechnology* and *Cybernetics and Robotics*
- How to scale up to include the 14 other Master of Technology programmes at NTNU?
- Possible model: Create clusters of programmes getting the same mathematics courses
  - How many clusters?
  - How to compose the clusters?
- We are currently running a survey among the MT programmes to map out the needs for mathematics

Trends from this survey

- We see varying degree of engagement
  - Some programmes have clear opinions on what they need, and when they need it
- Linear algebra is needed early (1st semester)
- Computational (numerical) methods should be more strongly emphasised
- Multivariate calculus and vector calculus could be postponed (2nd year) for some programmes

Necessary conditions for contextual learning to succeed

- Mathematicians need to engage with engineering problems
- Engineering teachers need to engage with mathematics
- Teachers from both fields need to talk together
- Cannot be too dependent on a few enthusiasts