MATERIALS EDUCATION
Adapting to the needs of the 21st century
Overview

- Introduction
- History and the present context of Education
- Breadth and Depth
- Materials Systems and Design
- An implementation
- Conclusions
Introduction

- Transmission of **materials** knowledge
  - In ways that recognise its broader context
  - Appreciating its temporal importance and evolution

- Appreciation of balance between breadth and depth
  - Highly complex problems facing Mankind
  - ...of an inherently interdisciplinary nature
History and the present context of Education

Tradition

- Alchemy
- Empiricism

Era of “try it and see” to Era of predictive modelling

Pure sciences
- Physics and Solid-state physics
- Crystallography
- Mineralogy
- Bio- and Environmental sciences

A bridging science
- Chemistry and Bio-chemistry

Applied sciences
- Engineering design
- Architecture, Product design
- Mechanical, Electrical, Civil Engineering
- Chemical engineering and processing
Engaging interest: evolution of materials in products (1)

<table>
<thead>
<tr>
<th>Circa 1900</th>
<th>1940</th>
<th>2012</th>
<th>2050??</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kettles</td>
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<td>[Image of kettle]</td>
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<td>Cameras</td>
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<td>Vacuum cleaners</td>
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Evolution of materials in products (3)

**Trains**
- Circa 1900: Early steam locomotive
- 1940: Modern steam locomotive
- 2012: Bullet train
- 2050??: Hypothetical futuristic design

**Planes**
- Circa 1900: Wright brothers' airplane
- 1940: Classic propeller plane
- 2012: Modern jet plane
- 2050??: Hypothetical futuristic aircraft

**Phones**
- Circa 1900: Early telephone
- 1940: Rotary dial phone
- 2012: Smart phone
- 2050??: Hypothetical futuristic device
The evolution of structural materials

Strength - Density

Early history 3000 BC

The first king: Menes
The evolution of structural materials

Strength - Density

50 BC

Strength, $\sigma$ (MPa)

Density, $\rho$ (Mg/m$^3$)

Ceramics and glasses

Metals

Natural materials

Woods, // to grain

Fir

Pine

Ash

Oak

Wrought iron

Bronze

Silver

Gold

Copper

Lead

Brick

Concrete

Glass

Stone

Shell

Pottery

Tin

Cork

Balsa

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The evolution of structural materials

![Diagram of Strength - Density relationship for various materials including Ceramics and glasses, Metals, and Natural materials.](image)

Henry VIII
The evolution of structural materials

Queen Victoria 1837 - 1901
The evolution of structural materials

Franklin Roosevelt 1933 - 1945
<table>
<thead>
<tr>
<th>Information</th>
<th>Knowledge</th>
<th>Understanding</th>
<th>Synthesis and innovation</th>
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<tbody>
<tr>
<td><strong>Facts, data, methods</strong></td>
<td><strong>How to use information</strong> <em>(shallow comprehension)</em></td>
<td><strong>Origins, context, relationships</strong> <em>(deep comprehension)</em></td>
<td><strong>Extension, innovation, creation</strong></td>
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<tr>
<td></td>
<td><strong>Specialised novice</strong></td>
<td></td>
<td><strong>Specialised expert</strong></td>
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### Breadth and Depth (2)

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#### Information
*Facts, data, methods*

- **Novice specialist**

#### Knowledge
*How to use information (shallow comprehension)*

#### Understanding
*Origins, context, relationships (deep comprehension)*

#### Synthesis
*Extension, innovation, creation*

- **Novice generalist**

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## Breadth and Depth (3)

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Increasing breadth

Increasing depth

Creative generalist

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Some creative generalists...
# Breadth and Depth (4)

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Increasing breadth

Increasing depth

Achievable balance

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Some things don’t change

- Principles of mathematics,
- Laws of physics, chemistry, biology
- The scientific method
Project-based learning, using some of these examples:

- Wind turbines as a contribution to future power provision
- Electric cars as a contribution for future mobility

... but spending equal time on:

- Materials
- Design
- Regulatory restrictions/incentives
- Interests / arguments / influence / welfare of the stakeholders

Grand Challenges for the 21st Century

- Shelter (built environment)
- Energy
- Mobility (transportation)
- Water
- Environment
- Sustainability

(stakeholders can be either government, the supply chain, manufacturers, consumers, unions, the public at large,...)
An implementation (1)

- What is being done currently at TULisbon in a course on Engineering Materials
  - The context
  - The situation until 2009
  - The changes made to the curriculum in 2009
  - Further changes in 2010
  - The outcomes
An implementation (2)

- The context
  - A course on Engineering Materials at the 4th semester of a 10 semester integrated MSc program on Mechanical Engineering
  - A cohort of around 250 students
  - A 14 weeks semester
  - 3 hours of theory + 1 hour problems + 1 hour laboratory per week

- The situation until 2009
  - Course topics centred on:
    - mechanical testing
    - thermal and mechanical treatments of metals
    - long and exhaustive descriptions of each material family
  - Boring classes, not very motivating
  - Students gradually stopped coming to class
  - Fail rate of about 30%
The changes made to the curriculum in 2009

- Design-led approach – starting at the product level and ending at the atom level
- Fundamentals of materials science uncovered where appropriate
- Focus on materials selection instead of materials description
  - Analysing a particular product and setting the design requirements (function, objectives and constraints) to then select the appropriate materials to do the job

Further changes in 2010

- Introduction of concepts of sustainability in the last 2 weeks of the semester (6 hours of lectures)
- Historic perspectives, evolution of the use of materials, look ahead
- World population growth, (perceived) materials scarcity
- Life cycle of products
The outcomes from a student perspective:
- Fail rate dropped from 30 to 12%
- Number of students actively attending increased drastically
- Students feel motivated

The outcomes from the faculty team perspective:
- The team is motivated and willing to explore new developments
- Getting encouraging feedback from colleagues
- Some of the feedback is negative...
Conclusions

- 1st half of 21st century saw a shift of ceramics, polymers and metallurgy from arts to sciences
- 2nd half saw the integration of those into single programs on Materials Science and Engineering
  - These sit as an interdisciplinary subject, linking engineering, science and design
- We now seem to be moving towards programs on Materials Systems and Design
  - Materials courses taught to non-Materials programs will take a broader perspective of materials
  - Grand Challenges may provide motivating themes
MATERIALS EDUCATION:
Adapting to the needs of the 21st century

Thank you

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