CES EduPack Teaching Resource

SAMPLE MICRO-PROJECTS

Materials Science & Engineering and Eco & Sustainability

Mike Ashby, January 2019

Which ceramic thinks it's a metal?

Four Sample Micro-Projects

Materials Science & Engineering

1. Are Additive Manufactured materials any good? (Metals)
2. Zirconia, a ceramic that thinks it's a metal

Eco & Sustainability

1. Does polyethylene have a bad carbon footprint?
2. Coping with critical materials

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These micro-projects are part of a set based on Mike Ashby's work to help introduce students to materials, processes and rational selection.
The Teaching Resources website aims to support teaching of materials-related courses in Design, Engineering and Science.
Resources come in various formats and are aimed primarily at undergraduate education.

www.grantadesign.com/education/teaching-resources

Micro-projects.

These ***Micro-projects*** are short investigations of Materials aspects of Environment and Sustainability that can be completed in less than an hour. Each poses a set of questions that can be answered using the Materials Science & Engineering database or the Sustainability database, in CES EduPack. All micro-projects start at a level that is readily accessible, using the SEARCH function to find records, creating charts using the CHART/SELECT function, and extracting relevant data from a Record and its linked SCIENCE NOTES. Guidance notes in blue give guidance.

Each Micro-project has an attached ***Discussion Point*** – a challenge to go further – highlighted in red and separated from the Micro-project by this separator:

The Discussion Point poses a question linked to or arising from the micro-project. Responding to the Discussion point requires independent thought and research, takes longer, but is rewarding if followed. It is an add-on for more advanced study.

Each Micro-project, and its Discussion point, has a fully worked **Answer** or ***Sample Response***, available to instructors who have a CES EduPack license. Charts shown in the responses are reproduced exactly as produced by the CES Software. Project files that re-create these charts are also provided for license holders.

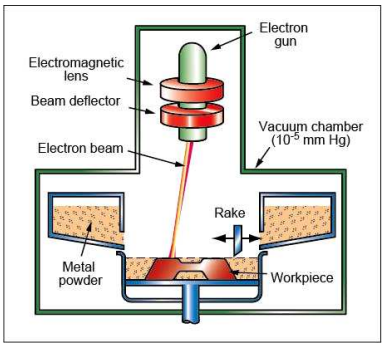
The learning outcomes are

- Ability to use the CES EduPack at an introductory level
- Expanded understanding of issues relating to Eco-design and Sustainable Development
- Ability to tackle open-ended, potentially complex, problems in a limited time-frame
- Skills in rapid-search techniques
- Ability to summarize and present information clearly and concisely
- Team work and communication skills.

MS&E Micro-project 1

Are materials made by additive manufacture any good? (metals)

- ***Additive Manufacture (AM)*** technologies use computer-controlled deposition to build shapes layer-by-layer. All can create shapes of great complexity without the need for dies or molds. The precision and surface roughness, at present, are limited to ±0.1mm at best and the process is slow (typically 1 to 20 hours per part) but the freedom of choice of shape is enormous. What about the properties of metals shaped in this way: are they as good as those of materials made by conventional methods such as casting or forging?



Electron beam melting (metals)

- Which metals can be shaped by AM? (Open the record for the process shown in the figure and copy the materials to which it is linked from the tab at the bottom of the record.)

- Explore the properties of conventional Titanium alloys, for which there is a record in the MS&E DB, by making a chart with Tensile Strength (MPa) on the y-axis and Elongation (%) on the x-axis. (Use the "Define your own subset" option or use a Tree stage to isolate Titanium alloys. Just one big bubble appears on the chart.)

- AM methods are new – there are not yet many measurements of the properties of AM materials. The alloy Ti-6Al-4V is one of the most studied. The table lists data from five independent tests.

AM method	Tensile strength (MPa)	Elongation (%)
Renishaw Ti-6-4 (annealed 750 C)	1120 - 1150	6 – 8.5
Renishaw Ti-6-4 (annealed 850 C)	1030 - 1070	6.5 - 10
SLM Solutions Ti-6-4 (annealed)	965 - 985	9 – 10.5
Optomec Ti-6-4 (no post processing)	1060 - 1080	10 - 12
ARCAM Ti-6-4 (hot-isostatic pressed)	960 - 985	13.5 - 16

Add these materials to the MS&E database. (Adding a new record: Right-click on a chart. Select "Add record". Enter a name: Renishaw Ti-6-4. Enter the data. Return to the chart – Renishaw Ti-6-4 now appears on it).

- Add a title to the chart, reset both axes from log to linear to give a fair comparison and adjust the range of both to give a well-proportioned chart. How do the properties of Ti-6Al-4V made by AM compare to those of conventionally cast Ti-6-4? (To adjust an axis, double click on the axis name, then make the changes in the Axis settings box.)

- ***Discussion point: Material that can be shaped by Additive Manufacture.*** AM is seen as a component of the evolving "4th Industrial Revolution" (following the revolutions of steam, electricity and information technology). The spectrum of materials that can be shaped successfully by additive manufacture is increasing rapidly. Carry out a survey of reports on materials for additive manufacture, linking them to the industrial sector to which they contribute.

MS&E Micro-project 2

Zirconia, a ceramic that thinks it's a metal

- What is Zirconia? (Use the Search facility to find the record. To copy and reuse text and images from a record: right click on the opened record, select Copy, then open WORD and Paste. The entire record is pasted into WORD. You can then copy and re-paste the bits you want for a report.)
- What makes it special among ceramics? (Explore the record to find out.)
- What is the value of its Fracture toughness?
- How does this compare with the Fracture toughness of other ceramics? Make a bar-chart of Fracture toughness for Technical ceramics to find out. (When you open the "Materials" data-table of the MS&E DB, a set of panels, each labelled with a sub-set of materials, appears on the right. One panel says "Technical Ceramics". Clicking on that limits the selection and charts to technical ceramics.)
- Reset the scale from log to linear and adjust its range to run from 0 to 10. (To make the changes, double click on the axis name to re-open the Axis Settings box, select "Linear" and adjust the range.)
- What does "Fracture toughness" measure? (Try the information ("*i*") link next to the property name on any materials record to access Science notes.)

Discussion point: What gives Zirconia its unusual Fracture toughness?

http://www.ceramcoceramics.com/materials/zirconia/zirconia.php

Eco & Sustainability Micro-project 1

Does polyethylene have a bad carbon footprint (CO_{2e})?

Open the CES EduPack Level 2 Sustainability database.

- What is meant by the "carbon footprint" of a material? (Records for materials in the CES EduPack Sustainability database include the *CO2 footprint, primary production*. Try the ⓘ link next to the property name on any material record to access a Science note that explains what it is.)

- What are its units? What does the "e" in CO_2e mean? (Try the ⓘ link again.)

- What is the carbon footprint for production of polyethylene? (The carbon footprint appears in every materials record as "CO2 footprint, primary production".)

- What is "bad"? Make a bar-chart plotting the carbon footprint of the materials. If "bad" means big carbon footprint, which material is least bad? Which material in this database is the least good? How bad is polyethylene? (Click on "Chart/Select", select All materials > Chart, then choose "CO2 footprint, primary production" for the y-axis. To separate the material classes on the chart, click on x-axis > Advanced > Trees and select Metals, Polymers, Ceramics and Hybrids. Divide the chart by eye into 5 roughly equal sections and label these Very low, Low, Medium, High and Very high.)

- ***Discussion point (requiring wider investigation or thought).***
  About 4% of global carbon emissions per year arise from making cement. There's no carbon in cement, so why does it have a carbon footprint?

Eco & Sustainability Micro-project 2

Coping with critical materials

Open the CES EduPack Level 2 Sustainability database and select the Elements data-table.

- What is a "Critical" material? (Records for the Elements contain a block of data headed "Critical materials information". Try the ⓘ link next to the property name to access Science notes explaining what the property is.)

- What criteria are used to assess criticality? (The Critical materials information and its ⓘ links can help here.)

- Which elements are ranked as critical in the USA?

- Why is Yttrium on this list? Consider
  (a) the main mining areas and
  (b) the Principal use and Substitutes in reaching a conclusion.
  (The Elements record for Yttrium gives Main mining areas and Principal uses and Substitutes.)

- ***Discussion point (requiring wider investigation or thought)***
  What steps can nations take to allay concern about critical materials?

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Open Educational Resources include:

- Interactive Case Studies
- Getting Started Guides
- Materials Property Charts
- Engineering Data Booklets

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Other Resources Available:

- 25 PowerPoint lecture units
- Exercises with worked solutions
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- White Papers
- Solution Manuals

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The Teaching Resources website also contains other resources donated by faculty at the ~1000 universities and colleges worldwide using Granta's CES EduPack and includes both resources that require the use of CES EduPack and those that don't.