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An Introductory Teaching Resource for Materials Science and Engineering

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Abstract

The academic areas of Materials Science and Materials Engineering have different emphasis at different Universities. Some would argue that the former is more focused on understanding materials (why) while the latter is more focused on making use of them (how). Another way of looking at these areas is that they emphasize the microscopic (or even nanoscopic) aspects of materials or the macroscopic aspects, respectively. Together, they constitute an important part of many engineering programs and may therefore be treated jointly as Materials Science and Engineering. In this paper, we have investigated a number of curricula and syllabi to identify a list of topics/concepts that appear central to the learning objectives of Materials Science and Engineering. Among the top candidates were: *characteristic material properties of the main material groups*, *modification of microstructure by various (thermal/mechanical) processes*, *binary phase diagrams*, *micrographs* and *materials characterization and testing*.

Working in a project involving students of engineering and Materials Science, databases were designed containing facts and visual information for the purpose of introductory materials teaching. A non-exhaustive review of existing teaching resources for these areas reveal that many are highly specialized on one topic (e.g., crystallography) or one group of materials (e.g., metals). We are therefore exploring the ways to integrate several of the core themes mentioned in the list above, to facilitate assignments, projects or self-directed studies in Materials Science and Engineering. A standard materials selection software package was used as a starting point, since it offered comprehensive material property databases and the possibility to add tailor-made data records and entire data tables. Furthermore, links between, e.g., heat treatments, phase diagrams and micrographs can be set up.

In this paper, we report on an initial review of data compilations and tools, the results of a survey and focus groups responding to an explorative version of a database. We aim to share our findings over the materials community hoping to get feed-back and inspire educational ideas.

1. Introduction and Background

Although hugely successful in terms of research (novel materials, research funding, Nobel prizes *etc.*), Materials Science and Engineering is relatively small in undergraduate education compared to, say, Mechanical Engineering. The subject is, however, fundamentally important to Mechanical Engineering and relevant courses are therefore incorporated into many such educational programs. Departments, courses, and educators within these disciplines are entangled in each other (see Figure 1). Research associated with Mechanical Engineering is often connected to Materials Science or Materials Engineering, at least methodologically.

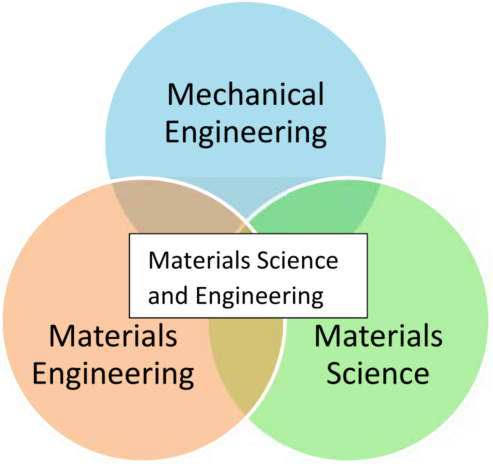


Figure 1. Venn-diagram of Educational disciplines.

This paper considers the further development of a widely available and established software teaching resource, CES EduPack[1], which supports teaching of Materials in engineering, science and design. CES EduPack (referred to as *the software)* is specifically developed for education and at the same time forms part of a family of tools used for materials-related applications in industry and research (CES Selector and Granta MI)[1]. This software was originally intended for a *Design-driven* approach to Materials teaching (see Figure 2) and is well known for materials and process selection within technical design[2]. However, it also provides an introduction to the underlying science, for example, through the built-in interactive *Science Notes*, facilitating a more flexible *on-demand* approach to learning. Visualization tools also promote the understanding of the science behind material properties. Traditional Materials Science courses are normally *Science-driven* (see Figure 2), whereas Materials Engineering teaching might be a mix between Design-driven and Science-driven, usually strongly connected to applications. The question that we wish to explore is: could CES EduPack be developed to better support both or a combination of these approaches?

Based on the results of an informed curriculum/syllabus selection, focus groups and an initial survey, we have identified areas where additional data and new linked datasets (called *data tables*) might support educators in Materials Science and Engineering. Here, we outline a structure for a new database and suggest potential new data tables for it. We wish to gather opinion as to their utility and the priority that the Materials education community attaches to them.

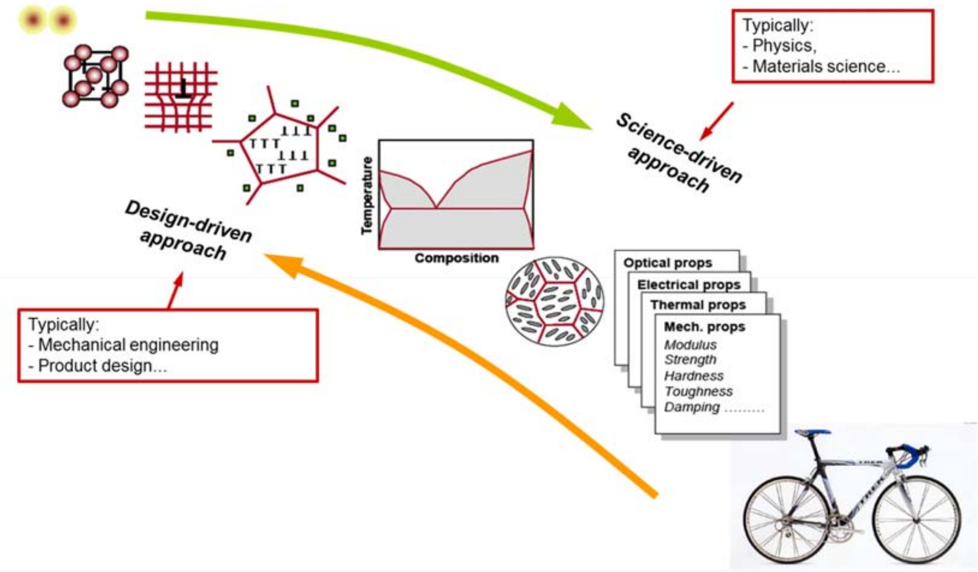


Figure 2. The difference between a Design-driven and a Science-driven teaching approach[2]

2 Methodology

Syllabus Comparison

Globally, University curricula of Materials Science and Engineering vary considerably. Study programmes range from pure Materials Science, deeply focused on the microstructural understanding of properties, to industrial applications with only the basics. Furthermore, many Universities have Materials Science courses closely related to Engineering. Five relevant syllabi (see Table 1) were studied to identify target areas and learning outcomes.

Table 1. Description of the courses selected to represent relevant syllabi

#	University	Degree	Course Syllabus
1	Tampere University of Technology (Finland)	MSci	Materials Engineering
2	Cambridge University (UK), Material Science Dep.	MSci	Materials Science
3	University West (Sweden)	BEng	Materials Science and Engineering
4	University of Illinois (US)	BSc	Materials Science and Engineering
5	McMaster University (Canada)	BSc	Materials Engineering

This set of courses was selected in order to reflect the different needs in North America, continental Europe, and the UK. Figure 3 indicates how they compare to each other.

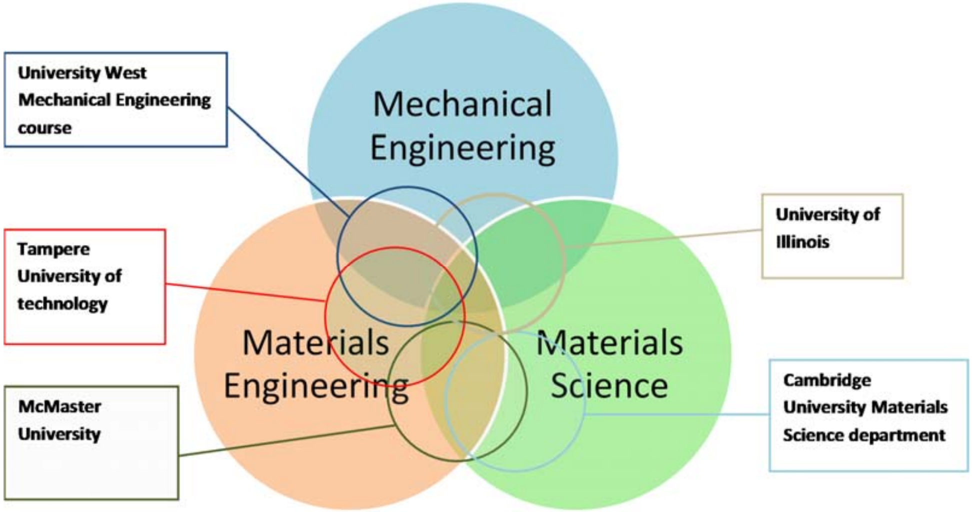


Figure 3. Curricula/syllabus assignment to the scope of Materials Science and Engineering

Focus Groups

Two focus groups were formed, one consisting of 5 students of Materials Science at Cambridge University (UK), second-third year of study (2 male, 3 female) and one group consisting of professionals with materials-related jobs, age 24-45 (2 male, 3 female, all with relevant degrees in Physics, Mechanical Engineering or Materials Science). Both groups met twice independently, once to brainstorm and generate ideas for a Materials Science and Engineering related resource and once, several weeks later, to evaluate a more developed concept. The results from these groups together with interviews with experienced Professors in the field, fed in to the concept proposed and the initial prototype.

Survey

After the production of a tentative database structure for the Materials Science and Engineering database (see section 5), initial feed-back was collected from an international group of educators (Canada, US, Sweden, Belgium, UK) of materials-related courses, all experienced users of the software system in relevant courses.

3 Outcome of Curriculum/Syllabus Analysis, Focus Groups and Survey

The Learning outcomes, or in some cases the corresponding content of the syllabus, were compared and analysed for the five courses mentioned above. These are summarized in Table 2.

Table 2. Learning outcomes from selected syllabi (from web) projected onto discipline: 1 Tampere University of Technology (Finland), 2 Cambridge University (UK), Materials Science Dep, 3 University West (Sweden), 4 University of Illinois (US), 5 McMaster University (Canada)

#	*Learning outcomes/content relating to Materials Engineering*	*…relating to Materials Science*	*…relating to Mechanical Engineering*
1	*• Broad knowledge of the material properties, their utilization, and development of these properties to meet the requirements set by different applications.* *• Broad knowledge on the development, properties and behaviour of metallic and ceramic materials under various conditions and in different applications.* *• Understanding of manufacturing technologies and how they are used to affect properties and structure*	*• Understand basic structure-property relationships.* *• Understand research techniques and methods.* *• Knowledge with emphasis on structure/properties of polymers and biomaterials*	*• Understanding how to utilize properties in practice, apply knowledge in materials selection*
2	*• Some attention to processing and what are the results of that. Often analysed through microstructural behaviour as well*	*• Property relations to microstructure, material analysis methods, microstructure processing.* *• Understanding the cause of the properties/results.* *• Investigating material behaviour*	*• Very brief introduction to material selection and merit indices*
3	*• Modification of properties via processing.* *• Influence of temperature and environment to the properties*	*• Describe different materials at the structural level.* *• Explain mechanical and thermal properties of materials based on the inner structure.*	*• Interpreting material properties to use them in design applications.* *• Estimate life cycle and select materials for mechanical/product design.*
4	*• Materials Synthesis and processing cover the methods to alter the microstructure*	*• Understanding of materials via microstructure, predicting properties and looking at their causes.* *• Techniques of microstructural analysis* *• Atomic bonds*	*• Many courses eventually lead to the application of material properties in design.* *• Courses on pure mechanics*
5	*• Minerals and materials preparation, extraction, manufacturing, processing.* *• Polymer synthesis, metallurgy.* *• Selection of processes for industrial applications (with much attention to Iron and Steel making processes and their selection).* *• Application of materials in electronics and fabrication techniques for electronics.* *• Corrosion protection.*	*• Nature of defects in microstructure, functional properties, crystal structure, bonding.* *• Thermodynamics in materials, Phase diagrams* *• Crystal structure properties and analysis.* *• Being able to mathematically model diffusion processes, creep, corrosion (separate course on corrosion and sustainability).* *• Microstructure and mechanical property relations (especially for failure)*	*• Materials selection based on materials properties.* *• Laws of thermodynamics*

From the syllabi summarized in Table 2, we extracted concepts that appear important to the desired Learning outcomes. They become candidates for the Materials Science and Engineering database:

- Microstructure Processing (heat treatments *etc*.)
- Materials Characterization and Testing (microscopy, tensile testing, *etc*.)
- Micrograph images of microstructures (optical/SEM *etc*.)
- Phase Diagrams (binary)
- Crystal Structures (images *etc*.)
- Material Failure (case studies *etc*.)

In addition to these areas, interviews and other feed-back have suggested extending the Level 2 data table of the MaterialUniverse in CES EduPack to include:

- Functional materials (piezoelectric *etc*.)
- Nanomaterials (1D, 2D, 3D)
- Generic, folder-level records for the material families and *Science Notes* describing how properties differ depending on material class.

The results from both focus groups, the professionals and the students, indicate that a *Microstructure Processing* data table (heat treatments *etc*.) is the most favoured suggestion. The second choice among the professionals were *Materials Characterization and Testing*) whereas in the student focus group, *Binary Phase Diagrams* came second. A *Crystal Structure* data table was the least popular among both groups.

In the survey (see Table 3) sent out to 10 educators with experience of teaching materials using CES EduPack, we can confirm that there is no clear cut disciplinary background among the educators. Most of them specify several areas (Mechanical Engineering, Materials Engineering and Materials Science) with no strict correlation with the area in which they currently teach. Furthermore, our suggested data tables all received support from the educators, indicating that they indeed reflect typical course content.

Table 3. Outcome of survey concerning educator background and teaching (n=10)

1. How would you classify your background (multiple options ok)?
[9] Materials Science
[5] Materials Engineering
[3] Mechanical Engineering
[3] Other: ***applied physics, physics, device physics***...

2. How would you classify your current teaching (multiple options ok)?
[6] Materials Science
[8] Materials Engineering
[2] Mechanical Engineering
[2] Other: ***design/environment/sustainability*, *sustainability***...

Table 4. Outcome of survey concerning critical preferences of data tables in EduPack (n=10)

3. Considering your needs and competition with alternative tools on the market (critically), would data tables on the following properties be valuable to you?

Alternatives explained:
Yes=Valuable, or **No**=Not valuable enough (no need/added value)
Then try to rank the proposed Data Tables from 1=top, etc.

	[*frequency*]		
Suggested Data Tables for a Level 2 Database	***Yes***	***No***	***Rank***
1 Microstructure Processing Data Table (heat treatments etc.)	[10]	[ ]	…….
2 Materials Characterization and Testing (SEM, Tensile testing, etc.)	[6]	[2]	…….
3 Micrograph Images Data Table (Optical/SEM etc.)	[10]	[ ]	…….
4 Phase Diagram Data Table (Binary alloys)	[7]	[2]	…….
5 Crystal Structure Data Table (Images etc.)	[6]	[3]	…….
6 Functional materials in the MaterialUniverse (piezoelectric etc.)	[7]	[3]	…….
7 Nanomaterials Data Table (1D, 2D, 3D etc.)	[5]	[3]	…….
8 Material Failure Data Table (Case Studies etc.)	[7]	[1]	…….
9 Your own suggestion: *Thermodynamic Data, Case studies on manufacturing progress ratio*			…….

4 Survey of Current Resources Available

A new resource adds most value where educators are currently lacking suitable options. They need to be not only scientifically sound, but easy to use, consistent, and engaging. Furthermore, it must supported in such a way that an educator can be sure that they will be available for the foreseeable future. We have reviewed the content of some comprehensive online resources in this area in order to find the space where a new resource can be of use. The resources reviewed invlude:

DoITPoMS, a freely available teaching resource created by the Materials Science Department of Cambridge University[3]. It offers teaching and learning packages, lecture demonstrations, a library of micrographs and short videos.

ASM International offers an extensive library of Micrographs, Phase diagrams, Crystallographic structures and Failure Case Studies[4].

F*A*C*T, the Facility for the Analysis of Chemical Thermodynamics, created by Ecole Polytechnique and McGill University in Montreal[5], provides thermodynamic data for compounds, engineering alloys.

MATTER is a resource for Materials Science created by the University of Liverpool[6].

We conclude that although large databases of phase diagrams and micrographs are available, these are focused on research and are likely to be overwhelming to students rather than engaging. A resource that connects the two together and provided a sensible journey/narrative through the material by way of microstructure processing, such as heat treatments, is still needed.

There are also many good teaching resources on specific alloy systems or materials analysis techniques, but these are sometimes provided by publicly funded organizations. Open source educational resources relying on public funding may not be sustainable in operation. Granta Design has 20 years of track record to demonstrate endurance. The company has a team to update CES EduPack each year and has the financial infrastructure for software sustainability. However, we cannot be sustainable in an educational sense without a constructive dialogue with the Materials education community.

5. New Materials Science and Engineering Database Development for CES EduPack

The methodology for (linked) materials and process selection was originally developed to support the basic steps in the technical design process. It is implemented in the selection tool of CES EduPack and it is described extensively elsewhere[2]. The tools available, to store, find, display, compare, link and use materials data work equally well with other types of data; indeed, they have been used to create databases as widely diverse as French wines, Sustainable Development and Garden plants.

We have used a related software tool, CES Constructor[1], to create the prototype structure for the database described here. In a structural hierarchy of the software, schematically depicted in Figure 4, it can be seen that we regard the *Data* and the *data tables* as the basis of the software in development. The second tier, *Visualization* (the ability to make property *Charts*) is already part of the software framework and provides opportunities for better understanding of data. New advanced software *Tools* using the proposed data tables are key to successful new applications.

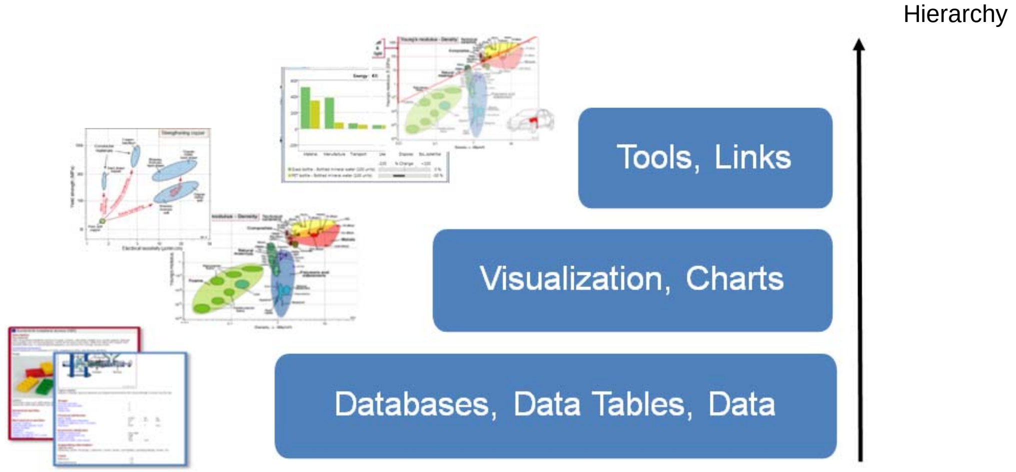


Figure 4. Structural hierarchy of the software: Data as the basis, Visualization as a means to enhance understanding and Tools or Links to perform selection in creative tasks, such as design

The structural hierarchy above is inspired by the modified Bloom's Taxonomy[7] and the *Skills*, *Knowledge* and *Attitude* categories of Learning Objectives/Outcomes commonly used in outcome-based educational systems[8], see Figure 5. In Bloom's taxonomy *knowledge* can be associated with the data-level of the software and both *understanding* and *analysis* are facilitated by visualization of this data. Finally, tools, such as the selection tools are useful in creative applications at the top of the taxonomy. Combined with a suitable assessment, using the software should be helpful in the context of accreditations, such as ABET, or to enable the CDIO Syllabus.

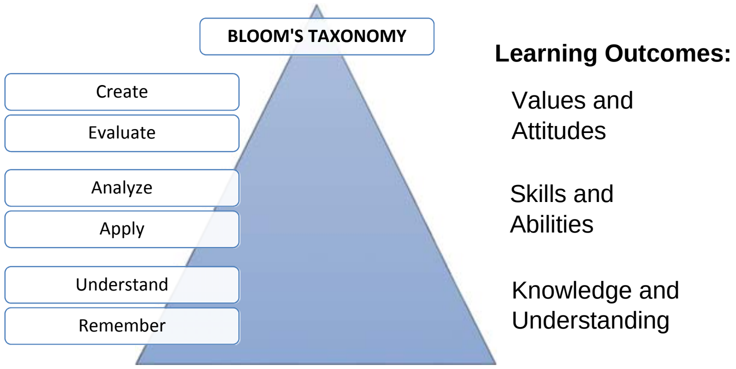


Figure 5. Bloom's modified Taxonomy and one possible conceptual link to Learning outcomes

Based on the information we gathered on tools and curricula, we developed an initial prototype with the following tentative structure where the MaterialUniverse (without Crystal Structures) and ProcessUniverse (without Microstructure Processing) already exist. It is shown in Figure 6. Some important binary phase diagrams are already included in data records for metal alloys but could be transferred to a separate data table. A brief description of each is given, below.

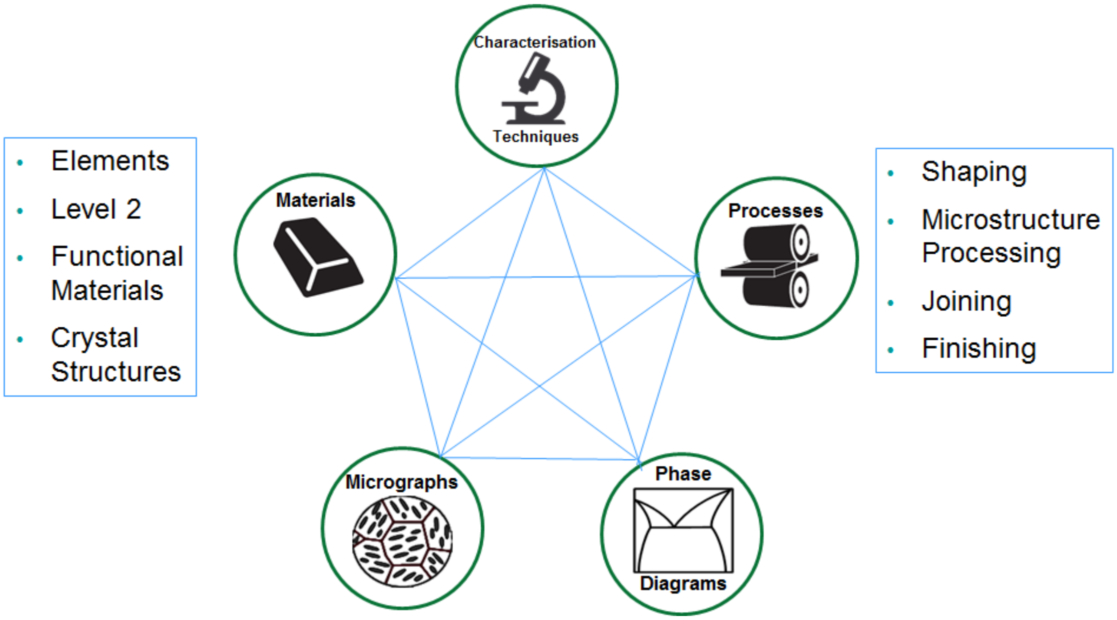


Figure 6. Data tables suggested for the Materials Science and Engineering database

The blue lines in the diagram above represent links between the data tables, such that a Micrograph's record could be linked to the phase diagram where that combination of phases occurs and also to the characterization technique that was used to make the image and of course the material shown and the processes that were applied before the image was taken. Students could therefore explore the story of a material using these links, encouraging self-guided inquiry.

5.1 Extended Element Properties and Functional Materials

The Elements database has already been extended to include crystal structure images for metallic elements, criticality information and Eco properties in the Sustainable Development Edition of the software. There is also ongoing work on Functional materials that would fit into an enhanced data table with material properties.

5.2 Microstructure Processing

This was the top ranked data table by both focus groups and by the survey of educators. As well as the existing manufacturing processes to change the shape of a material, change its surface or join it, there are also processes to change the properties of materials that are not yet available in CES EduPack. This data table requires an extensive Tree structure, see Figure 7. For examples of Data Records, see Figure 8.

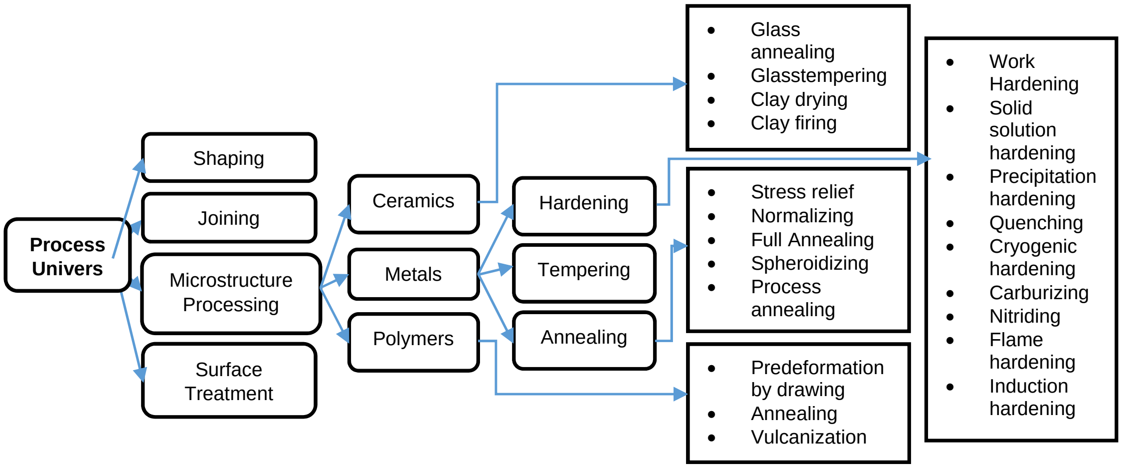
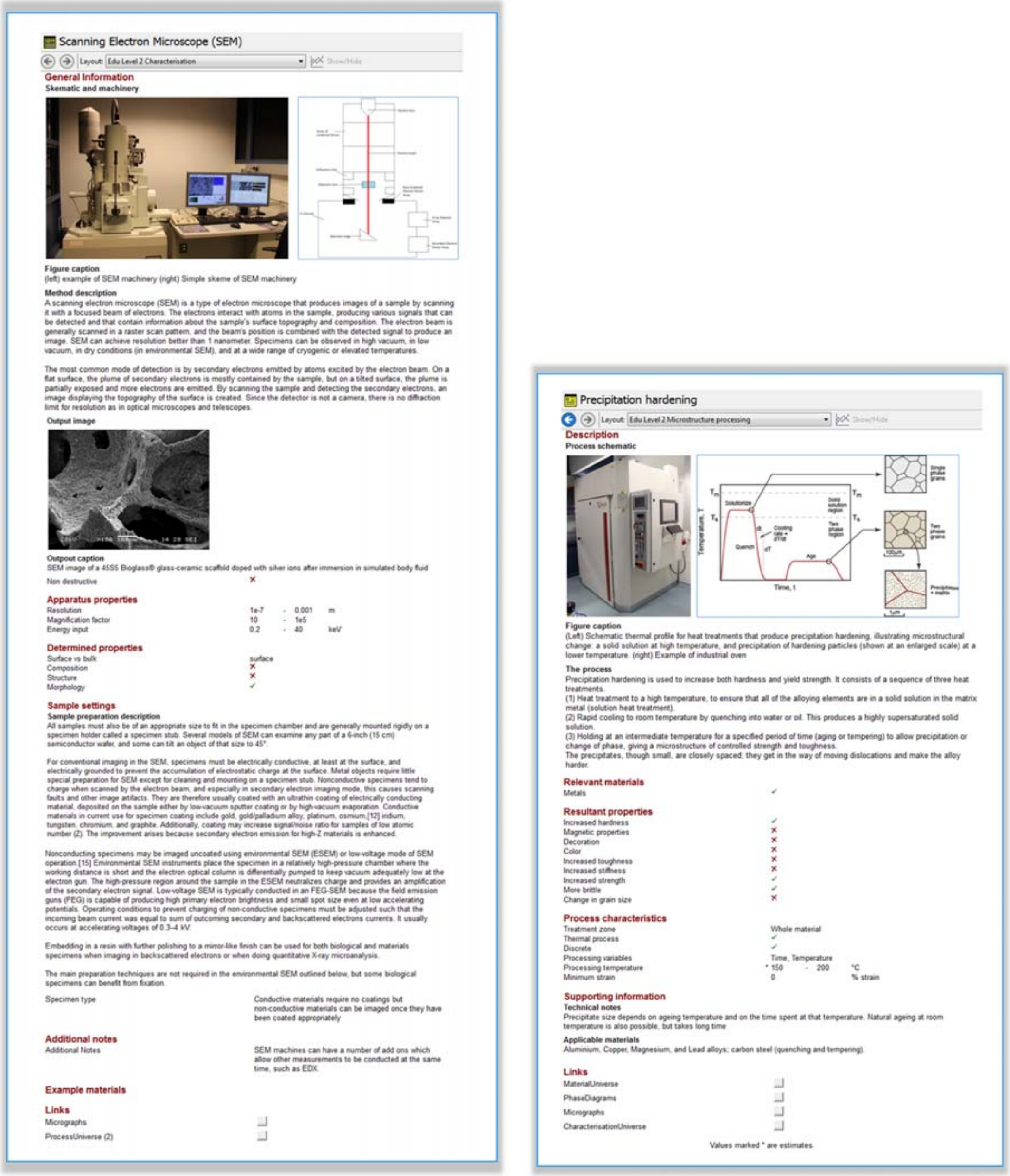


Figure 7. Outline of the contents of the Microstructure Processing data table.

Metals: This would be the basis of microstructure processing. Bulk material strengthening methods (work hardening, solid solution hardening, precipitation hardening), and case hardening can be included. Material softening treatments, such as annealing and tempering would be a complementary set of processing. Inside the records, we propose to have clear descriptions of processes, all properties (increased strength, hardness, toughness *etc.*) that are obtained with the particular treatment, and related alloy groups.

Ceramics and polymers: Generally, the microstructure and properties of ceramics and polymers are governed by methods of shaping. Therefore, very few processes can be added here. For ceramics, we propose to add clay drying and firing, glass annealing and tempering. For polymers, pre-deformation by drawing, annealing, and vulcanisation could be included.



Scanning Electron Microscope (SEM)

General Information

Skematic and machinery

Figure caption

(left) example of SEM machinery (right) Simple skeme of SEM machinery

Method description

A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, in dry conditions (in environmental SEM), and at a wide range of cryogenic or elevated temperatures.

The most common mode of detection is by secondary electrons emitted by atoms excited by the electron beam. On a flat surface, the plume of secondary electrons is mostly contained by the sample, but on a tilted surface, the plume is partially exposed and more electrons are emitted. By scanning the sample and detecting the secondary electrons, an image displaying the topography of the surface is created. Since the detector is not a camera, there is no diffraction limit for resolution as in optical microscopes and telescopes.

Output image

Outpout caption

SEM image of a 45S5 Bioglass® glass-ceramic scaffold doped with silver ions after immersion in simulated body fluid

Non destructive	✗			
Apparatus properties				
Resolution	1e-7	-	0.001	m
Magnification factor	10	-	1e5	
Energy input	0.2	-	40	keV
Determined properties				
Surface vs bulk	surface			
Composition	✗			
Structure	✗			
Morphology	✓			

Sample settings

Sample preparation description

All samples must also be of an appropriate size to fit in the specimen chamber and are generally mounted rigidly on a specimen holder called a specimen stub. Several models of SEM can examine any part of a 6-inch (15 cm) semiconductor wafer, and some can tilt an object of that size to 45°.

For conventional imaging in the SEM, specimens must be electrically conductive, at least at the surface, and electrically grounded to prevent the accumulation of electrostatic charge at the surface. Metal objects require little special preparation for SEM except for cleaning and mounting on a specimen stub. Nonconductive specimens tend to charge when scanned by the electron beam, and especially in secondary electron imaging mode, this causes scanning faults and other image artifacts. They are therefore usually coated with an ultrathin coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. Conductive materials in current use for specimen coating include gold, gold/palladium alloy, platinum, osmium,[12] iridium, tungsten, chromium, and graphite. Additionally, coating may increase signal/noise ratio for samples of low atomic number (Z). The improvement arises because secondary electron emission for high-Z materials is enhanced.

Nonconducting specimens may be imaged uncoated using environmental SEM (ESEM) or low-voltage mode of SEM operation.[15] Environmental SEM instruments place the specimen in a relatively high-pressure chamber where the working distance is short and the electron optical column is differentially pumped to keep vacuum adequately low at the electron gun. The high-pressure region around the sample in the ESEM neutralizes charge and provides an amplification of the secondary electron signal. Low-voltage SEM is typically conducted in an FEG-SEM because the field emission guns (FEG) is capable of producing high primary electron brightness and small spot size even at low accelerating potentials. Operating conditions to prevent charging of non-conductive specimens must be adjusted such that the incoming beam current was equal to sum of outcoming secondary and backscattered electrons currents. It usually occurs at accelerating voltages of 0.3–4 kV.

Embedding in a resin with further polishing to a mirror-like finish can be used for both biological and materials specimens when imaging in backscattered electrons or when doing quantitative X-ray microanalysis.

The main preparation techniques are not required in the environmental SEM outlined below, but some biological specimens can benefit from fixation.

Specimen type	Conductive materials require no coatings but non-conductive materials can be imaged once they have been coated appropriately
Additional notes	
Additional Notes	SEM machines can have a number of add ons which allow other measurements to be conducted at the same time, such as EDX.
Example materials	
Links	
Micrographs	☐
ProcessUniverse (2)	☐

Precipitation hardening

Description

Process schematic

Figure caption

(Left) Schematic thermal profile for heat treatments that produce precipitation hardening, illustrating microstructural change: a solid solution at high temperature, and precipitation of hardening particles (shown at an enlarged scale) at a lower temperature. (right) Example of industrial oven

The process

Precipitation hardening is used to increase both hardness and yield strength. It consists of a sequence of three heat treatments.

(1) Heat treatment to a high temperature, to ensure that all of the alloying elements are in a solid solution in the matrix metal (solution heat treatment).

(2) Rapid cooling to room temperature by quenching into water or oil. This produces a highly supersaturated solid solution.

(3) Holding at an intermediate temperature for a specified period of time (aging or tempering) to allow precipitation or change of phase, giving a microstructure of controlled strength and toughness.

The precipitates, though small, are closely spaced; they get in the way of moving dislocations and make the alloy harder.

Relevant materials				
Metals	✓			
Resultant properties				
Increased hardness	✓			
Magnetic properties	✗			
Decoration	✗			
Color	✗			
Increased toughness	✗			
Increased stiffness	✗			
Increased strength	✓			
More brittle	✓			
Change in grain size	✗			
Process characteristics				
Treatment zone	Whole material			
Thermal process	✓			
Discrete	✓			
Processing variables	Time, Temperature			
Processing temperature	* 150	-	200	°C
Minimum strain	0			% strain

Supporting information

Technical notes

Precipitate size depends on ageing temperature and on the time spent at that temperature. Natural ageing at room temperature is also possible, but takes long time

Applicable materials

Aluminium, Copper, Magnesium, and Lead alloys; carbon steel (quenching and tempering).

Links	
MaterialUniverse	☐
PhaseDiagrams	☐
Micrographs	☐
CharacterisationUniverse	☐

Values marked * are estimates.

Figure 8. Characterization Techniques (left) and Microstructure Processing (right) records

5.3 Materials Characterization and Testing

The second most popular concept in the educator survey was techniques for materials characterization and testing, as determining properties of unknown or newly developed materials is essential to Materials Science. A data table on Materials Characterization and Testing methods needs a complex tree structure that could contain the following, see Figure 9. A Data Record is suggested in Figure 8.

Microscopy-related analysis methods is a given in the analysis techniques' tree. This would include *scanning* and *transmission* techniques, as well as *Scanning Probe Microscopy* and *ultrasonic* microscope (ultrasound), and would describe their limitations and benefits.

Spectroscopy is another important set of techniques. Data inside the records could be something similar to diffraction records. Diffraction Spectroscopy is key in determining the crystal structure of the material. Illustrated information, similar to that of surface processing, could be included as data records.

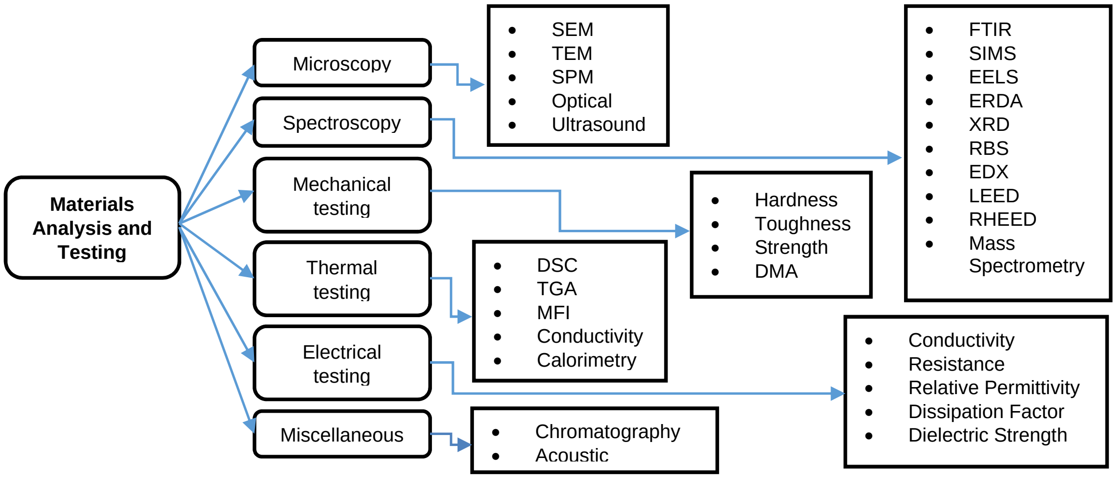


Figure 9. Outline of the contents of the Characterization Techniques data table

Mechanical testing: Data records could be included of methods for determining properties such as shear and tensile strength, stiffness, hardness, *etc*. It could also include more sophisticated test machines such as a *Dynamic Mechanical Analyser* (*DMA)*. Data records would include test method descriptions as well as attributes, describing the function and limitations of the method. Current science notes on mechanical properties could be a good base of information for these records.

Thermal analysis and **Electrical testing** could also be added among analysis methods as well as Chromatography, which can be put in a miscellaneous data folder.

5.4 Phase Diagrams

Phase Diagrams (and phase transitions) are one of the fundamental aspects of Materials Science and Engineering. They are essential to the understanding of many heat treatments, play a major role in welding processes and is important to understand cases of failure. No complex tree structure is needed, since it is binary.

5.5 Micrograph Images

Since microstructures play such an important role in materials analysis, a library of microstructures is suggested. SEM or Optical microstructures. Useful also to future links to failure cases, for example.

6. Summary and Conclusions

As shown above, we have used initial research and feedback to create a prototype structure of a potential Material Science and Engineering teaching resource based on CES EduPack. This structure combines information on microstructure processing, micrographs, binary phase diagrams, characterization techniques and Functional- and Nanomaterials added to the usual data on engineering structural materials and processes in CES EduPack. It takes advantage of the clear navigation of information, and the linking of data tables, already available in the software to, we hope, present the student with pathways through the new topics. What remains to do is to populate all the records with relevant and accurate data.

A Materials Science and Engineering database could be the basis for many interesting tools, such as a Process Trajectory Plotter, Interactive Phase Diagram Visualizer, Microstructure Process Sequence Visualizer to name a few possibilities, with details still to be determined from user feed-back.

In conclusion, this is not the conclusion. This is the start of a project. The reason we have written this paper is because we want to understand what is needed. The authors are hoping that this paper, and subsequent interaction, will give us the opportunity to better understand Materials Science and Engineering teaching in Universities, what resources are already available and what resources would be most valued. Our next step is to encourage people to give feedback and comments on the proposed structure, outlined above. This can be contributed at: http://teachingresources.grantadesign.com/databases-development.

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