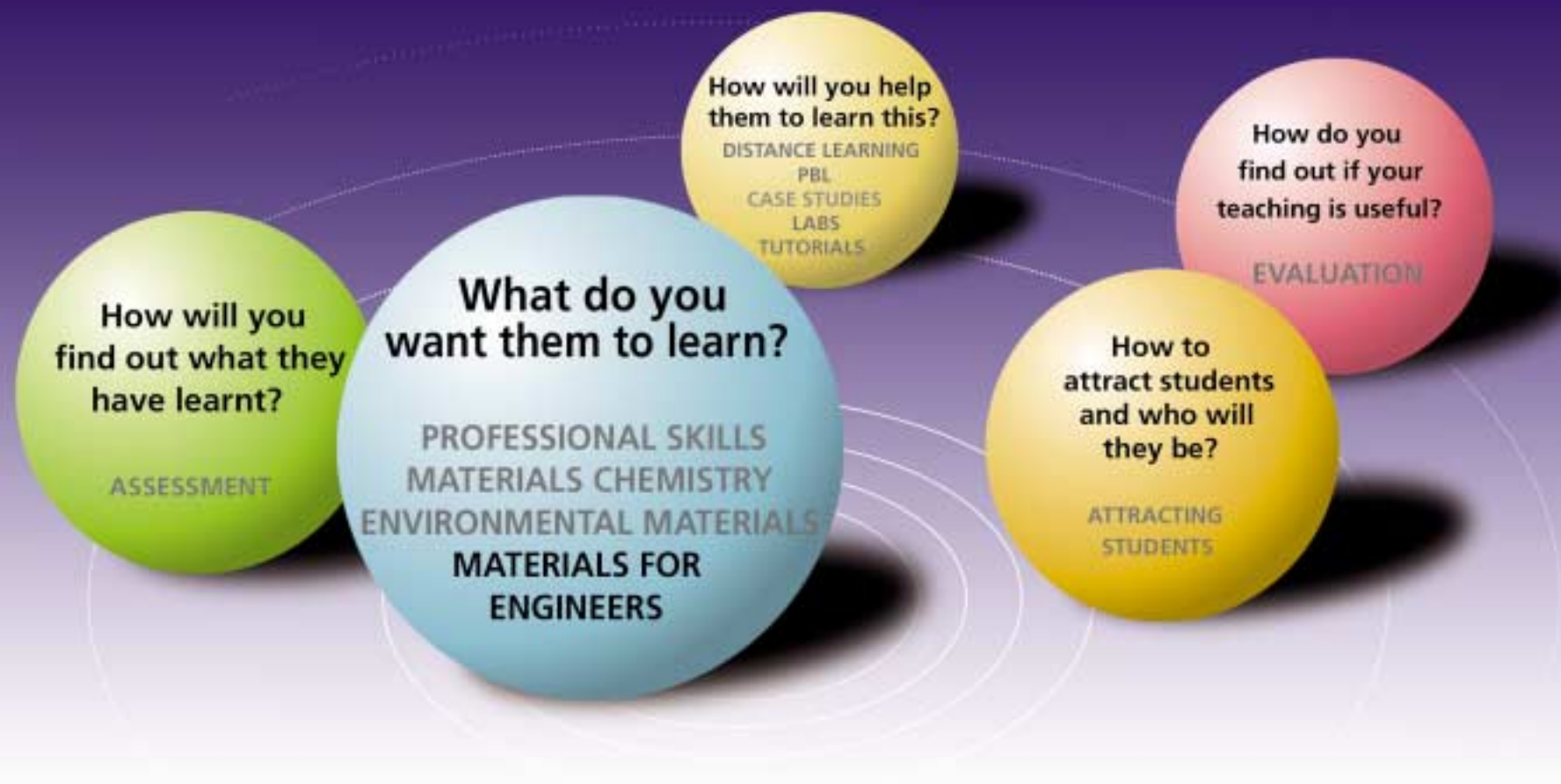
Materials for Engineers

Mike D. Bramhall



UK Centre for Materials Education

Published by: The UK Centre for Materials Education

Series Edited by: Caroline Baillie
and Leone Burton
Illustrations by: Z*qhygoem
Designed by: Unity Communications
Printed by: Ashley Printers

Product development

INTRODUCTION

Many of our community, lecturers in the disciplines of and relating to Materials Science and Engineering, have expressed interest in simple-to-use guides to support the workshops we run on learning and teaching. As part of our 'Thematic Groups' scheme, we have established 12 themes for this special focussed support, each of which is led by a 'Thematic Group Leader'. During the first two years of the scheme, workshops have been held on these themes and this has enabled the leaders to further explore relevant issues with lecturers and feed the results into this series of booklets.

Learning and teaching is a continuous cycle represented in the diagram below:

We can start at any point around the cycle. If we are in the business of teaching it certainly helps if there is someone to teach! Not such a funny joke in the current climate with reducing numbers of students in technical disciplines. Hence one of our main concerns is how can we approach schools and work with school students to attract them into Materials areas. 'Attracting Materials Students' by Cheryl Anderson explores how we can work with schools and the wider community to ensure a diverse and inclusive group of able students on our courses. Once we have a class to teach, what would we like to teach them? The first reaction to such a question is to make a list of topics or knowledge. However, this is only a beginning, and a very limited one. Not only are there many skills and attitudes that we would

like them to develop, but learning is more complex than simply the what. It also involves the how. 'Developing Professional Skills' by John Wilcox explores the approach to empowering students to track their own skills development as they progress. 'Materials for Engineers' by Mike Bramhall, 'Materials Chemistry' by Stephen Skinner and 'Environmental Materials' by Cris Arnold, focus on what we might like to include in a specialised curriculum, for targeted students. The knowledge, skills and attitudes or learning objectives identified for each course must be assessed if we are going to give credit to students for learning what we want them to learn. 'Assessing Materials Students' by Lewis Elton gives support to the development of assessments and assignments that do in fact give marks for those things we want to acknowledge, rather than those aspects that are simply easy to assess!

Believe it or not it is only at this stage that we can really consider how we should teach the students to learn these things. We all know about lectures but will we use in addition or instead: tutorials ('Tutoring Materials' by Adam Mannis and Shanaka Katuwawala), labs ('Teaching Materials Lab Classes' by Caroline Baillie), case studies ('Teaching Materials Using Case Studies' by Claire Davis and Elizabeth Wilcock), problem based learning ('Learning Materials in a Problem Based Course' by James Busfield and Ton Peijs) or even learning at a distance ('Learning Materials at a Distance' by Mark Endean)?

The final stage before we start all over again is to see if we have done what we intended to do. We may have already found out whether, and how effectively, the students learnt what we wanted them to (i.e. if the assessment matched the learning objectives and if our teaching methods suited the students' learning approaches). If this has not proved to be as ideal a scenario as we would have wished we will need further input to analyse what has happened. 'Were the course objectives inappropriate?' 'Am I sure that the assessment did not force my students into taking a surface approach? ' Did the students take on surface approaches to learning because of my teaching?' Ivan Moore's 'Evaluating a Materials Course' will give you the tools of the trade to conduct your own thorough evaluation and enable you to develop an improved course for next year's cohort. Which brings us back to the beginning of the cycle. 'Are we attracting students with appropriate abilities for this course?' And on it goes ….

In writing these booklets, and running the workshops we have had a lot of fun and we hope that you catch the flavour of this in using them. Stay in touch and give us feedback about your ideas in implementing any of the suggestions. As a community we can learn most from each other.

Caroline Baillie and Leone Burton
Editors

Materials for Engineers

Mike D. Bramhall

WHY THIS BOOKLET?

The subject of materials is an important part of the education and training of engineers, and yet it is sometimes undervalued or minimised in the curriculum of engineering undergraduate courses. All products are made from materials and manufacturing industries need to have a thorough understanding of materials and their properties if they are to be successful in a global competitive environment. Ideally a company employs a metallurgist or materials scientist or materials engineer to undertake the important role of materials selection, and all aspects related to design and manufacturing with materials. However, there has been a decline in specialist materials courses in recent years. It is therefore becoming increasingly important to train engineers in the fundamentals of materials engineering, so that they are able to undertake this role if required.

Materials is taught on numerous traditional mechanical/electrical/civil engineering courses. It is also taught on technology courses such as:

- Sports Engineering
- Bio-medical Engineering
- Automotive Technology
- Dental Technology

So materials is an important area of expertise that all engineers and technologists need to have an awareness of.

The scope and range of topics that we could teach is huge, so in teaching engineers we need to decide what the fundamental taught areas need to be. This booklet aims to indicate some of the subject areas within materials that might be covered on an engineering or technology course. Ideas are discussed on how to improve the teaching of materials to engineers and how to motivate the student through effective use of resources and case studies.

WHAT IS THE STATUS OF MATERIALS WITHIN ENGINEERING DISCIPLINES?

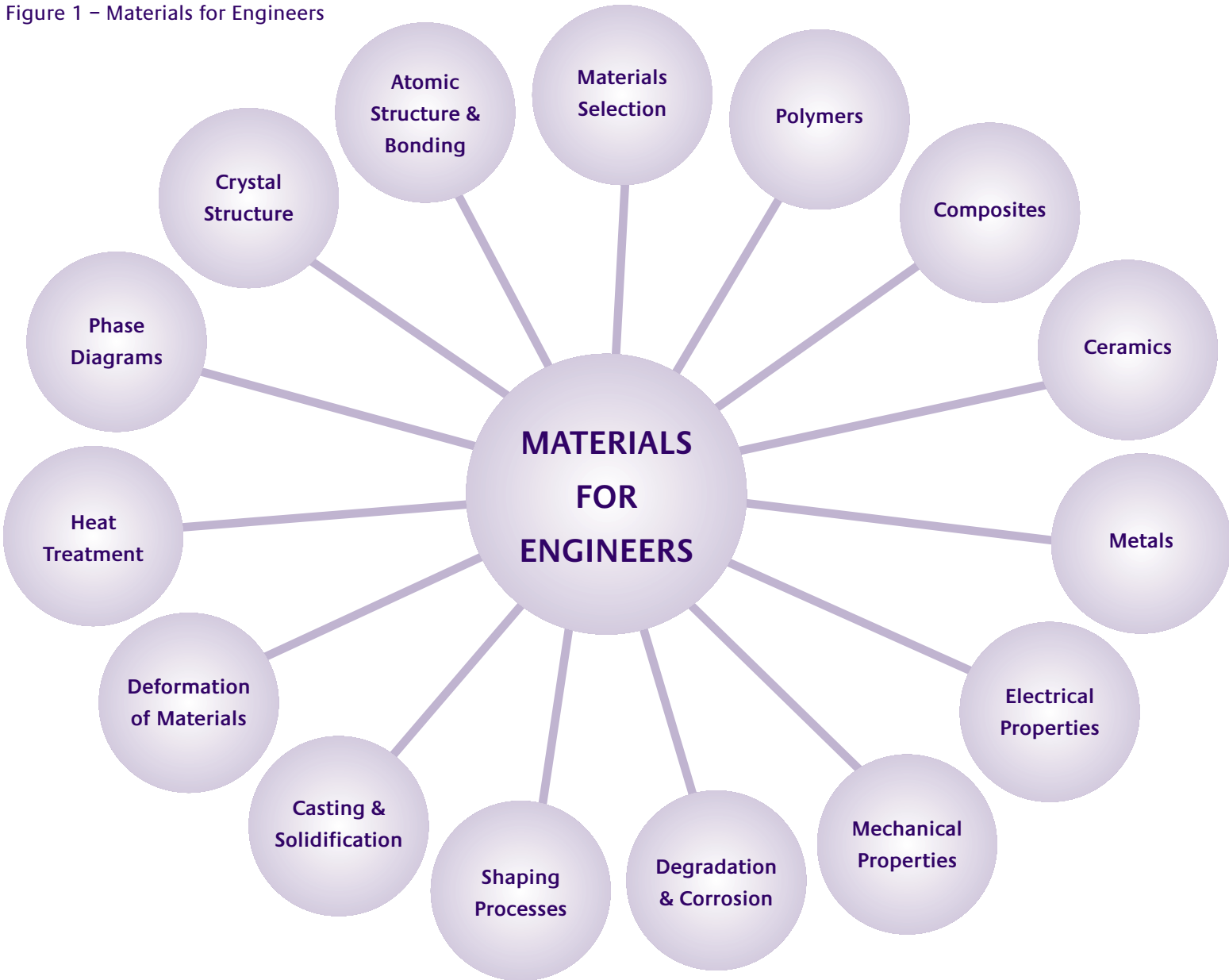
Materials is often seen as a subsidiary subject by engineers. Only when materials failure occurs does the importance of materials selection become apparent. It is therefore important when teaching engineering students that they accept the value of the materials science element of the course. Materials has its foundations in physics and chemistry and is regarded by many materials academics as a science and tends to be taught with an emphasis on 'why?' rather than 'how?' Engineers may regard the subject in a more practical sense and may wish to know what engineering properties materials have, rather than the science that explains why materials behave as they do. The engineer's focus on applications places value on materials selection over materials science theory. Selection by software programs

limits the engineer's feel for the material (e.g. for aesthetic purposes) and this may constrain innovation. It is therefore important when teaching engineering students that they are taught the underpinning science, whilst also being given the opportunity to gain a feel for materials through practical sessions, perhaps by mechanically testing materials to determine properties.

WHAT KEY ASPECTS SHOULD BE COVERED IN A FIRST YEAR MODULE IN MATERIALS?

What does the mechanical or design engineer or technologist need to actually know about materials? The following diagram gives a possible overview of what could be included in a first year curriculum:

Figure 1 – Materials for Engineers



In the first year the engineering student needs to be taught the underlying fundamental principles of materials. They also need to find out about all the different types of materials available, with some idea of how to select them for certain applications. This means quite a full syllabus if it is to be done correctly. However, some academics are under pressure to reduce teaching hours and hence have reduced contact time with students. In some cases the amount of taught material has to therefore be reduced. If this is the case we need to consider what the minimum requirements are in terms of topics to be taught. So what topics do we really need to have in the curriculum? Do we need for example all of the following?

- Periodic Table
- Electronic structure of materials
- Crystal structure
- Dislocation theory
- Diffusion theory
- Phase diagrams
- Microstructure

Is it really necessary for the Periodic Table to be dealt with in detail, or would an overview suffice? Some think that topics such as atomic bonding and diffusion within crystals should not be taught to an engineer, as they don't need to know this to select a material for an application. However, it could be argued that an understanding of these topics is fundamental to understanding 'why' we choose a certain material or 'why' we choose a certain process to treat or fabricate a material. A knowledge of structure and bonding also leads to a better understanding of the properties of materials and how and why they can be changed by processing. Let us look at one approach to topics taught in a first year class for engineers over one semester:

Week	Lecture (1 hour)
1	Materials Classification/Periodic Table/Bonding
2	Crystal Structure of Metals – FCC/BCC/CPH
3	Solidification/Grain Structure and Defects
4	Principles of Alloying
5	Stress-strain/tensile testing/hardness tests
6	Steel and its heat treatment
7	Copper alloys, microstructure and properties
8	Polymers, classification, structure & properties
9	Composites, types and properties
10	Ceramics, classification, structure & properties
11	Toughness and Fracture
12	Creep & Fatigue

This lecture programme would also be supported by appropriate laboratories and tutorials. Other topics that are in the first year curriculum diagram, Figure 1, could replace some of the above topics, or could be taught through student case studies and assignments associated with the module. Later three examples of case studies are given that could be utilised. For some topics you may decide to put them into a second year or final year module.

IMPROVING THE TEACHING OF MATERIALS TO ENGINEERING STUDENTS

Students need to have the fundamentals of materials in place very early on. Having decided on the main topics that you wish to cover, one potential problem is that the students aren't really interested in materials as it is not a core topic for their award. So, how do we ensure that our engineering students generate an intrinsic interest and

motivation in studying materials? There are several points that we need to consider to address this. We need to:

- Review the materials content of the course
- Appreciate where the first year student is 'at'
- Adjust to their diverse intellectual levels
- Think about the relevance of the taught materials
- Think about how we can generate interest and motivation within the student

The Review Case Study Assignment requires students to gather technical information with regard to materials for a specific product and gain in-depth knowledge about a particular set of materials or products, going much further than could be accomplished in a classroom situation.

Learning Outcomes:

At the end of the assignment the students will:

- have gained in-depth knowledge of specific materials
- be able to recognise the basic principles of selecting materials for a particular application
- be able to explain materials characteristics and properties, and relate them to performance, manufacturing process, and/or the environment
- have developed team working skills, information gathering and communication skills

Assignment Brief

This assignment combines both individual and group work. Students arrange themselves into small groups. The first task is to select a project from the list. Students must then allocate individual and group tasks for information gathering within the group. Students may submit individual reports and the group could do a presentation that integrates the individual's contributions.

Suggested Project titles:

'Dental materials'

'The role of materials in the automotive industry'

'Materials for bicycle frames'

'Materials used in the aerospace industry'

'Body armour materials'

'Materials in the electronics industries'

'Materials in information technology'

'Designing with composites'

'Materials used in sports'

In addition, learning may be supported by the use of available software such as *'MATTER'*[1] and 'Cambridge Engineering Selector'[2].

Overview of 'MATTER' Award winning software for teachers and students of materials science, engineering and related subjects.

The challenging concepts of this subject area, which can be

difficult to grasp, are made easier to understand with this collection of completely interactive learning modules, which have been designed to make use of those functions best performed by computer.

Designed to complement traditional teaching and learning methods, it also serves as a stimulating resource for teachers explaining new concepts. Students learn new aspects of materials science whilst testing their knowledge by answering the questions which appear within each module on the CD-ROM.

Key benefits for the user:

- fully interactive – the first CD-ROM of its kind for materials science
- versatile format – Windows™ and Macintosh™ versions on the same CD-ROM
- comprehensive solutions manual from publisher also available
- can be used as a supplement to any materials science textbook[3, 4]
- superb study aid – the CD-ROM provides many opportunities for self-assessment

'MATTER' is very useful in teaching numerous materials modules, such as for example to aid the teaching of 'crystal structure' to first years, 'phase diagrams' to second years and 'composite mechanics' to final year engineers. Cambridge Engineering Selector is an excellent tool for materials selection and can be used at all levels.

Learning Outcomes:

At the end of the assignment the students will:

- be able to recognise the basic properties of materials for a particular component and reasons for selection of that material
- be able to recognise the basic principles of selecting manufacturing processes for a particular component
- be able to explain materials characteristics and properties, and relate them to performance, manufacturing process, and the environment
- have developed information gathering skills
- have improved their written communication skills

The Reverse Engineering Case Study **involves students taking apart a familiar product and determining the materials used for each separate component.** An example could be a Belt Electric Sander. Students can undertake various tests to determine the materials that it is made from. In their reports the students can critically appraise the choice of materials selected and suggest alternatives. The students could analyse the design and possible methods of manufacture of each component. This activity illustrates to the student the integrative role that materials plays in engineering design and manufacture.

Product development

Assignment Brief

The 'belt sander' consists of a number of materials and components produced by a range of manufacturing processes.

Investigate and identify the materials used in the belt sander. Explain how you determined what (you think) the materials are.

- Why have these particular materials been chosen? Discuss what alternatives could be employed – why? What properties do they possess/need?
- How have the component parts been manufactured? Why has that process been used? What alternative processes could be used?
- What are the effects of the *process* used and the *materials* on the environment? Is the product recyclable?

Some other ideas on how to engage engineering students are listed below:

- Use web based material that is easily accessible by the student
- Try visual animations to help explain the processes/theories involved
- Present content material in an interactive format
- Problem Based Learning makes theoretical aspects more pragmatic for students
- Use of anecdotes and stories
- Industrial visits, work placements and visits from industrial experts
- Exploring everyday uses of materials
- Utilising memorable models
- Use 'Snappy Technology' – 'nano' technology and 'smart' materials
- Links to research topics in the department
- Use interesting artefacts
- Industrial component failure is a way of linking relevance of materials to engineering and can help in stimulating student motivation

Another Case Study exercise, Product Development, could be used with final year and Masters engineering students:

The Product Development Case Study **requires students to be involved with an innovative design that gives them the opportunity to apply their materials expertise in the concept design of a new or improved product.** Working in multi-disciplinary teams means that an engineer will learn about materials by acting as a materials engineer, or by working with a materials student and learning from them during the process.

The Assignment

The students produce a feasibility study for a new product. This feasibility study should comprise a specification for the product and a commercial justification for its further development. It is the student's choice to decide whether they are presenting the case to a Board of Directors whom they wish to persuade to take the product as part of their portfolio or whether they are asking for capital to exploit the product themselves. The choice of product is their own. The product must use existing technology or an obvious extension of it. The students must demonstrate their claim that the product has value and marketability. The team should be a multi-disciplinary team of engineers working together.

At the end of the assignment the students will:

- Recognise the requirements of materials selection in concept designs
- Be able to produce a product design specification
- Recognise the basic principles of selecting manufacturing processes for a particular product
- Have developed information gathering, communication, business and research skills

What about assessment?

You may wish to consult the thematic booklet *Assessing Materials Students*[5] in the first instance. There is general agreement that engineers should not only be tested by 'memory' exam questions. In the study of materials it is possible to use concept-based questions, with some numerical elements, the part liked by numerate engineers! Think about using coursework assessments that are integrative in nature, such as the 'Reverse Engineering' or the 'Product Development' case study.

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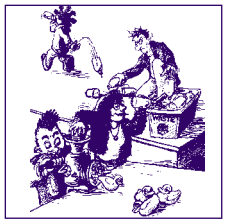
NOTES

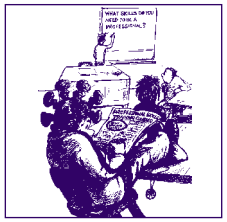
Other Booklets in the Series:

Attracting Materials Students – Cheryl Anderson

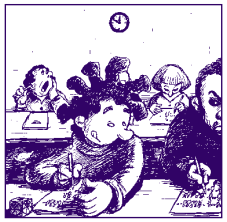


Environmental Materials – Cris Arnold

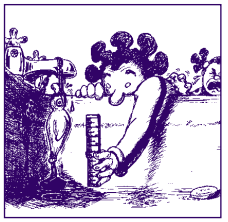
Teaching Materials Using Case Studies – Claire Davis and Elizabeth Wilcock



Developing Professional Skills – John Wilcox

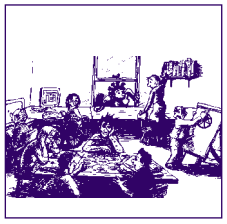


Assessing Materials Students – Lewis Elton

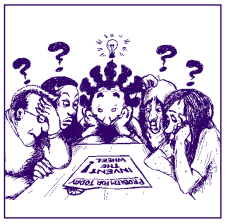


Learning Materials at a Distance – Mark Endean

Materials for Engineers – Mike Bramhall



Tutoring Materials – Adam Mannis and Shanaka Katuwawala



Learning Materials in a Problem Based Course – James Busfield and Ton Peijs

Materials Chemistry – Stephen Skinner

Teaching Materials Lab Classes – Caroline Baillie

Evaluating a Materials Course – Ivan Moore

Materials for Engineers

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