Teaching Materials To Engineering Students: National Support For Materials Faculty

Adam Mannis and Caroline Baillie

Imperial College, London
and
UK Centre for Materials Education

INTRODUCTION

In the UK, government higher education funding councils have since 1999 placed a high priority on developing schemes to foster and support education developments embedded within disciplines. Part of the rationale for this is an acknowledgement that academics best appreciate, assimilate and implement a pedagogic approach when it is presented to them within their own discipline. In addition, it is felt that many university centrally based educational centres have not been as effective as predicted. This may in part be due to their generic nature and their inability to enter into subject level discussions with academics.

In 2000, the higher education funding councils established the Learning and Teaching Support Network (LTSN), a new national initiative for the implementation of 24 Subject Centres, with the aim of stimulating the sharing and dissemination of good practice and innovation in learning and teaching through the provision of subject based support. A Centre was funded for the materials community, entitled the UK Centre for Materials Education, in order to support the unique needs of programmes specialising in the broad discipline of Materials Science & Engineering. The Centre aims to support departments in their delivery of teaching and learning in materials education, rather than prescribe what those approaches should be. It provides both a proactive and a responsive service to the needs of the UK materials community, assisting practitioners to:

- adopt good and innovative practice in learning and teaching, informed by research
- participate in, and benefit from, appropriate staff development
- offer a rounded and stretching educational experience to its diverse student body, so as to attract students of the highest quality
- deliver learning and teaching efficiently and effectively
- have enhanced awareness of the needs of students and the conditions in which they are most likely to learn successfully
- respond to national initiatives and expectations in education and learning.
MATERIALS CONTEXT

Materials Science & Engineering is an unusual discipline, in that it is itself quite multidisciplinary. It has elements within it of all the basic sciences: chemistry, physics, maths, sometimes biology; and it can be applied to any engineering field: mechanical, chemical, civil, electrical, etc. As such, in some institutions it is not possible to take a degree course in materials, but only as a specialisation of engineering. However, it is a unique field of study with an increasing wealth of techniques and knowledge leading to an understanding of the structure/property relationships of materials and their use in different applications. Because of its special nature, Materials Science/Technology/Engineering (as it is all three) has one major advantage and one major disadvantage.

The first is that the ways of thinking that students are introduced to is generally wider than an average science or engineering degree, precisely because it does draw on thinking and lecturers from many different backgrounds. This brings about the possibilities of deep approaches to learning, as it has been shown that being subjected to many ways of thinking helps students to be more creative and to think on higher levels. This is of course very challenging at the same time, which brings us to the disadvantage which materials suffers. As it is a discipline which emerged from metallurgy in the 1960s, it is still not a well understood subject by many schools careers offices, and less so by parents. Students will be introduced to engineering and science, and it is not uncommon for students to take materials after they have been rejected from other, better known and more competitive disciplines. This therefore does not mean that it is any easier for the weaker students. Hence, the teaching must take account of a range of abilities, whilst dealing with the greater range of thinking that the subject requires.

Similar to developments in the US, a growing number of Materials faculty in the UK are in broader engineering departments, due to recent changes in which many dedicated Materials departments have been integrated within Engineering/Technology schools. The current situation is as follows:

- materials programmes are taught in a small number of dedicated Materials departments
- large numbers of Materials degrees are taught in Engineering schools
- many Materials modules are taught as part of common 1st years in Engineering programmes
- certain new Materials degrees are now emerging, combined with Chemistry, Sports Science, and Medicine.

As such, there are a new range of issues relating to the teaching of materials within a broad engineering context which Materials faculty must now deal with. Also, what works in some contexts and is considered best practice will not work in others, and as such the materials community need to develop and share their experiences.
TEACHING MATERIALS TO ENGINEERING STUDENTS

With the above materials context in mind, the UK Centre for Materials Education recently organised a one-day national “Materials for Engineers” Workshop, in response to requests from the community. The aim of the Workshop was to bring together Materials faculty from across the UK, to identify areas where the UK Centre for Materials Education could provide national support, and to identify and discuss key issues relating to the teaching of materials within a broad engineering context. These key issues were examined in the light of recent educational developments and educational research. Discussions at the Workshop were based around the following three main themes:

- Designing a common 1st year course of materials for engineering students
- Motivating students of mixed abilities and backgrounds
- Implementing teaching and learning innovations for better student understanding.

Designing a common 1st year course of materials for engineering students

*Key Issues:*

What are the key concepts needed in a first year course of materials for engineering students? What do they need in their future? Is the core course in first year for engineering students the same as for first year materials students?

- How do faculty present the core material without it becoming meaningless?
- Should faculty teach ‘dislocation theory’ for example, or would the concept of ‘strengthening’ be better if faculty had less time and students did not need to know all details?
- If students are to understand materials and how to select and use them, knowing when to ask for more detailed advice, then what is the minimum they should learn?
- Faculty need to reconsider the reduction that goes on in engineering departments, so that they do not reduce materials to blanket areas and try to ‘cover’ for example, polymers, in two hours, etc; but try to locate the most important concepts and spend two hours helping students to understand and use these.

How to establish the common 1st year course:

1) Establish a course team, involving materials and engineering faculty:
   - Important to establish shared responsibility from all involved.

2) First develop a common philosophy for the course (e.g. structure/properties), before focusing on course content:
   - Important to maintain the same common philosophy of teaching materials in subsequent years of the degree programme.

3) Compromises are needed from the course team in establishing key material concepts for separate engineering disciplines involved in the common 1st year:
   - Important that compromises are agreed amongst the course team.
4) Review the success of the common course at the end of each year, using student feedback and an analysis of course results:
   - Important to be flexible to changes based on a review of the course.

5) Since a common 1st year course involves teaching large classes in lectures, the course must be supplemented by tutorial and/or laboratory classes of smaller student numbers, in order to verify lecture content and to establish a relevance of the key material concepts for the separate engineering strands involved in the common 1st year:
   - Important to provide adequate resources for such supplementary tutorials and/or laboratory classes.

**Motivating students of mixed abilities and backgrounds**

**Key Issues:**

“Materials for Engineers” classes often consist of students of mixed abilities and backgrounds, with and without chemistry or maths. The class may even be from different disciplines or branches of engineering. Therefore, faculty have to teach students the same core materials course: how can they deal with this, and motivate the students?

- What can faculty learn from motivation literature about what to do with students in large lectures, to help them realise that materials is not just something to be swallowed whole and regurgitated in an exam? i.e. how can faculty help develop a deep approach in students?
- Can faculty teach general principles in lectures and apply these to different contexts (e.g. different problems for different branches of engineering) in associated tutorials?
- How do faculty go about teaching to different backgrounds, so as not to lose the well prepared students through boredom and the less experienced ones by moving too fast?
- When teaching in a generic context, how can faculty help to make materials appreciated as a subject in its own right and not the poor relation, or seen as something else like chemistry?

**Increasing student motivation for studying materials:**

Materials is often seen as a subsidiary subject by engineers. Only when materials failure occurs does the importance of material selection become apparent. What can faculty do to encourage motivation for studying materials?

1) Faculty need to appreciate where the first year student is 'at':
   - They need to adjust to the diverse intellectual levels and styles of learning of their students
   - Often, they are not thinking of what the student is receiving.

2) Students need to have the fundamentals of materials in place very early on, and the cross disciplinary aspects of materials need emphasizing:
   - Stress the importance of concepts rather than details
• Encourage linking of concepts across modules, so curriculum design is extremely important.

3) Faculty must continually emphasize the relevance of studying materials to students:
   ▪ Justify the importance of materials to society
   ▪ Continually impress on students, what is the point of doing this?
   ▪ Materials selection, manufacture and design challenge is intrinsically rewarding
   ▪ Stress the wide range of career opportunities that the study of materials affords
   ▪ Use graduate profiles to remind students that the course is worthwhile.

4) Giving realistic feedback to students is crucial to motivating students:
   ▪ A good personal tutor system can make a significant contribution here
   ▪ Use assessment to check for understanding not rote learning.

5) Interactive teaching helps increase motivation:
   ▪ Introduce fun things to do and real examples of materials to students
   ▪ Group work can help motivate students.

**Implementing teaching & learning innovations for better student understanding**

**Key Issues:**
How do faculty stimulate students to develop a 'feel' for a material and a mental picture of how a material behaves? What teaching and learning innovations help address the changing skills base of engineering students?

- How can faculty help students gain an appreciation of materials when they don’t get to *feel* the materials?
- What can faculty do to ensure that there is an adequate balance of theory and practice, and that students see subject relevance?
- Faculty need to carefully consider assessment to make sure that materials is not assessed by memory-only exam-style questions, which can be the case for relatively less mathematical subjects. Even in the first year concept-based questions are necessary.

**Implementing an innovation --- the case for PBL (Problem Based Learning):**

1) PBL involves students working in teams on case studies in which realistic industrial problems are solved, the aim being:
   - to integrate knowledge and skills (multidisciplinary)
   - to acquire knowledge through self-study (learning to learn)
   - to teach students to work in groups
   - to improve communication skills
   - to improve problem solving ability.

2) Every student is part of a small team (of approx six), supervised by a tutor.
   - Important that the tutor does not impose their own knowledge and standards on the students, but instead helps them to find their own way in solving the case study.
3) Since students work in small teams and only individually cover one aspect of the problem, faculty need to ensure individual students learn all topics in the case study. This can be achieved by:
   - Having a case study mark (individual and group), but also have an exam that covers all case studies.
   - Students submitting an individual report on part of the problem, but the group combining reports and each student having to write an abstract, introduction and conclusions.

4) Important for faculty to ensure that all students contribute and learn all skills.
   - Rotate the chair and minute-taker roles that students adopt in weekly team meetings.
   - Ensure a balance of students in each team; i.e. natural leaders, team workers, etc.

NATIONAL SUPPORT FOR MATERIALS FACULTY

Support for teaching and learning among Materials faculty in the UK is been provided through the following ongoing activities of the UK Centre for Materials Education:
   - Materials Education Network: a forum for materials faculty to discuss relevant issues in teaching and learning and to exchange experience
   - departmental support visits
   - workshop programme: both national and departmental events
   - Teaching Development Grant (TDG) programme
   - Fund for the Development of Teaching and Learning (FDTL) projects.

Materials Education Network
A network and community of interested Materials faculty from across the UK has been created. This has been achieved by creating a national focus for academics through providing a physical location for the UK Centre for Materials Education, a library of teaching resources, web-site, publications, workshops, visits, discussion lists and individual support.

This national disciplinary network provides a dynamic area for Materials faculty to discuss issues concerning student learning, on a national level. Faculty, who usually only meet to discuss research, are finding new reasons to talk to each other. They are inspired by the very diversity of institutions that are involved.

Departmental support visits
The UK Centre for Materials Education has conducted an extensive programme of visiting Materials faculty in university departments across the UK. These departments have been selected because they fulfil one of the following criteria:
   - a department offering one or more programmes in materials
   - an engineering department with a strong engineering materials bias.
Each visit was undertaken with the Head of Department and other academics interested in teaching and learning issues, and served the following functions:

- established personal contact, providing an outline of philosophy and aims of the Centre, and established a methodology for further work
- emphasised collaboration rather than prescription, and stressed the importance of promoting community, rather than individual development
- enabled institutions to engage in dialogue, to explore issues more fully and to raise their own concerns/needs
- established ‘communality’ in terms of problems/issues faced by Materials faculty and identified possible strategies to meet these
- enabled each institution to identify, and hence make more public, development initiatives they had undertaken in their own context, thus providing potential resources for the wider community.

These visits also form the basis of gathering information for both a needs analysis survey, and a baseline survey of teaching and learning innovations/practices.

**Workshop programme**

A national series of workshops is regularly organised on relevant topics by the UK Centre for Materials Education. These are offered to the materials and engineering community on topics identified either by the Centre or in response to requests from the community; e.g. lecturing techniques & styles, small & large group teaching, problem based learning, objectives of laboratory work, etc., as well as C&IT aspects.

In addition, a comprehensive programme of staff development workshops are facilitated by the Centre, to provide opportunities for professional development in teaching and learning. These normally take place on site within departments, on topics requested by them, and which can be tailored specifically to meet their needs.

**Teaching Development Grant (TDG) programme**

One of the strategies of the Centre has been to provide small seed-corn funding to colleagues in a number of institutions to undertake small-scale year-long development projects, with expert guidance and support provided by Centre staff. This scheme has generated much interest in UK Materials faculty. It presents an extremely effective way of working developmentally with the materials community, and outputs from the funded projects are made available to the whole community via a final workshop, Centre web-site and final reports.

**Fund for the Development of Teaching & Learning (FDTL) projects**

The UK government higher education funding councils in 2000 provided funding for the establishment of the following three projects aimed at encouraging innovation and stimulating developments in teaching and learning within the area of materials technology:

- The Keynote Project (focusing on key skills in the curriculum)
- DOITPOMS (enhancing student learning through the use of C&IT)
- Tutoring Materials (identifying good practice in Materials tutoring).
These projects are built around consortia of UK universities, so that there is an immediate sharing of good practice. The role of the UK Centre for Materials Education is primarily in disseminating FDTL outcomes, as well as facilitating communication and networking between the projects and other interested parties.

In ‘Tutoring Materials’ for example, relevant teaching and learning issues that the FDTL project is addressing were first identified from national Quality Assessment Audits of the subject, and a consortium of ten diverse institutions was then established to identify best practice of optimal tutoring conditions in Materials across the country. These institutions are now pioneering a range of tutoring methods, such as problem based learning, video-conferencing, peer tutoring, on-line learning, group work with peer assessment, and personal skill development classes, among many others.

The project is exploring the use of tutorials in relation to issues, such as, student support and student progression, curriculum design, teaching approaches and staff development, the development of employment skills and the encouragement of deep approaches to learning among students, as well as addressing diversity in the student population in terms of cultural background, gender and abilities.

SUMMARY

The role of disseminating information on effective and innovative teaching, learning and assessment practices within the materials higher education community is central to the activities of the UK Centre for Materials Education. The Centre distinguishes between two levels of dissemination. Firstly, active engagement with the community through Teaching Development Grants, staff development opportunities, and FDTL projects, with the output of supporting change in practice in learning and teaching. Secondly, knowledge brokerage within the community, whereby academics have access to ideas for innovative and good teaching and learning practices, to provide a starting point for them to go on to develop their own teaching practice.

A key component of the Centre is the development of a clear and considered strategy for dissemination and transfer to institutions, so that all Materials faculty nationally are able to identify appropriate practice for themselves and improve their practice. The UK Centre for Materials Education therefore aims for national solutions focused on collaboration and community, rather than competition and fragmentation.

REFERENCES

AUTHORS

ADAM MANNIS is a researcher at Imperial College, with experience in the areas of engineering applications and education innovations. He is currently Project Manager of the ten-partner consortium FDTL project ‘Tutoring Materials’, hosted by the UK Centre for Materials Education.

DR. CAROLINE BAILLIE is a lecturer in materials science and engineering, as well as educational development. She is currently on secondment from Imperial College, Department of Materials, to act as Deputy Director of the UK Centre for Materials Education. She is also Director of the FDTL ‘Tutoring Materials’ project. She researches aspects of materials science, as well as student learning issues in science and engineering areas.