Teaching Materials Using Case Studies

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Why This Guide?

Teaching and learning styles are, by their very nature, changing and in recent years there has been a noticeable move from lecture-based activities towards more student-centred activities. Case studies are an increasingly popula form of teaching and have an important role in developing skills and knowledge in students. This guide explores the use of the case-based approach to support engineering education and, more specifically, their role in Materials Science related Higher Education courses. This will include looking at the 'traditional' Materials Science and Engineering courses as well as the more multidisciplinary courses (e.g. Biomedical Materials Science, Sports and Materials Science etc.).

This guide highlights the good practice we have identified, and also discusses our experiences (both good and bad) of the adoption and implementation of this type of learning activity. We hope that by explaining our rationale for the adoption of case studies, and by discussing their development and structure, you will be encouraged to consider your own teaching methods and whether this approach, or aspects of it, is appropriate to you. At the end of the guide are 5 examples of case studies that illustrate some of the different topics discussed below.

Perspective adopted

In this guide, we consider the topic of case studies in its entirety. We begin by outlining our reasons for incorporatin case studies into the teaching syllabus and then look at different aspects of case studies, including subject choice and content development, running and structuring of case studies, and assessment methods. Good practice, and examples of ideas that have been tried and found wanting, are discussed. Gaining feedback on our case studies fron both students and staff has been an important aspect of our research and this is also reviewed.

What Is a Case Study?

It is now documented that students can learn more effectively when actively involved in the learning process (Bonwell and Eison, 1991; Sivan et al, 2001). The case study approach is one way in which such active learning strategies can be implemented in our institutions. There are a number of definitions for the term case study. For example, Fry et al (1999) describe case studies as complex examples which give an insight into the context of a problem as well as illustrating the main point. We define our case studies as student centred activities based on topics that demonstrate theoretical concepts in an applied setting. This definition of a case study covers the variety of different teaching structures we use, ranging from short individual case studies to longer group-based activities. Examples of different styles of case studies are given at the end of this guide.

It is at this point that it is important to make a distinction between this type of learning and problem-based learning The structure and format of our case studies can be likened to project-based learning as described by Savin-Baden (2003). Savin-Baden highlights the differences between problem-based learning and project-based learning and these can be summarised as follows:

Project-based Learning	**Problem-Based Learning**
Predominantly task orientated with activity often set by tutor	Problems usually provided by staff but what and how they learn defined by students

Tutor supervises	Tutor facilitates
Students are required to produce a solution or strategy to solve the problem	Solving the problem may be part of the process but the focus is on problem-management, not on a clear and bounded solution
May include supporting lectures which equip students to undertake activity, otherwise students expected to draw upon knowledge from previous lectures	Lectures not usually used on the basis that students are expected to define the required knowledge needed to solve the problem

Table 1: Differences and similarities between project-based learning (similar in structure to case study learning) and problem based learning.

In practice there is overlap between the two teaching modes and we should not worry too much about clear distinctions. Many of the discussion points in this guide will be relevant to both case studies and problem-based learning topics.

Why Use Case Studies in Teaching?

The discipline of Materials Science and Engineering is ideal for using case study teaching because of the wealth of practical, real life examples that can be used to contextualise the theoretical concepts. Educational research has shown case studies to be useful pedagogical tools. Grant (1997) outlines the benefits of using case studies as an interactive learning strategy, shifting the emphasis from teacher-centred to more student-centred activities. Raju and Sanker (1999) demonstrate the importance of using case studies in engineering education to expose students to real-world issues with which they may be faced. Case studies have also been linked with increased student motivation and interest in a subject (Mustoe and Croft, 1999). In our experience of using case studies, we have found that they can be used to:

- Allow the application of theoretical concepts to be demonstrated, thus bridging the gap between theory and practice.
- Encourage active learning.
- Provide an opportunity for the development of key skills such as communication, group working and problem solving.
- Increase the students' enjoyment of the topic and hence their desire to learn.

Most courses already have some case study teaching in them and we have introduced a greater extent of case-based approach in all of our courses for the above reasons. We have found the use of case studies to be very beneficial, not only to the students but also to our lecturers who have found the learning/teaching experience enjoyable and challenging. Students' comments include:

> *'Well, it's real stuff isn't it? Otherwise you can feel like you're just doing something for the sake of it. When you do a case study you go out and find information that is being used in real life.'*
>
> *'It's something different where you actually apply what you're learning.'*

Did We Find It Hard to Introduce Case Studies Into Our Teaching?

In our experience, an important factor in the introduction of case studies into a course is the style or structure of the course itself. We offer a number of separate courses in our department and have recognised that they fall into two distinct types (defined here as Type I and Type II). Type I courses are the traditional Materials Science and Engineering degrees which are accredited by the Engineering Council and can lead onto Chartered Engineer status. We also offer multidisciplinary courses (Type II courses) such as Bio-Medical Materials and Sports and Materials Science. These courses are not accredited and take students with a wider range of background skills, varied academic qualifications and different career aspirations. Overall, we have found it easier to introduce case studies into our Type II courses and therefore these courses contain a greater proportion of this type of learning. A summary of the differences between these courses is given in Table 2.

Type I courses	**Type II courses**
Content mostly specified by accreditation	Non-accredited courses
Well established courses with existing lecture content	New lecture content often required (for at least part of the course)
Students more likely to have a physical science background (maths, chemistry, physics)	Students likely to have a mixed subject (arts + sciences/ vocational) background
Tends to be more theory-based	Tends to be more application-focussed

Table 2. Differences between traditional, established Materials Science and Engineering degree courses (Type I courses) and the newer (often multidisciplinary) Materials related courses (Type II courses).

Other issues that relate to introducing case studies in our courses (other than due to syllabus/accreditation constraints) are as follows:

- Some lecturers had been teaching their modules for a long time and were reluctant to change the tried and tested formula. Others, however, were keen to experiment with different types of learning as opposed to the traditional 'talk and chalk' method. Those who were open to new types of teaching were generally more involved in the planning and teaching of the newer courses.
- Where case studies have been included in the place of lectures and practicals covering similar topic areas in our traditional courses, we initially did not replace sufficient existing time-tabled teaching to allow for students to carry out background reading and additional research. We have now rectified this.
- We have found it easier to increase the number of cases running in our courses in a gradual manner as we identify the resources, time and support that is needed.

How Do You Develop a Case Study?

There are a number of ways to develop case studies, some more successful than others. The following list covers the main methods and also discusses other options and experiences external to our institution.

- **Developing a case study based on the research interests of staff.** For example, the research area of on of our lecturers is polymeric foams; he is now responsible for a sports and materials science case study analysing running shoe performance including the behaviour of the polymeric foams in the soles. We have found this to be a good method of case study development, as it is easier to locate resources for the case study and the lecturer's in-depth knowledge and interest in the topic add to the case study.

- **Requesting students to develop case studies based on personal interests.**This is a method we have not tried, but is an interesting way to develop case studies and one promoted by Smith (1992). However, problems may arise when trying to involve students. For example, the University of Bath are currently producing a portfolio of case studies to support recruitment and teaching of their undergraduate courses in Materials Science and Engineering and initially approached the students for ideas. They ran a competition where undergraduates and postgraduates were invited to submit proposals and a prize of £250 was offered. Unfortunately, this was not as successful as anticipated and students did not take part in the competition. This may be because the students did not have enough confidence in their abilities to develop a case study or felt they did not have the spare time to work on the topic, particularly as many students take part time jobs to help finance their studies. A more focussed approach of asking postgraduate students, and graduates from the department, to develop case studies based on their experiences/projects is now being pursued.

- **Develop from scratch, maybe following interests/ideas picked up from elsewhere.** This approach ma involve contacting or visiting other institutions to find out what methods and topics they are using.

- **Invite external lecturers, for example from industry, to develop, or contribute to, a case study.** Involving external sources can add new dimensions to the learning activity. One of our case studies looks at materials used in tennis equipment and we invite a tennis coach to brief the students on the topic at the start of the case study. This has been well received by the students who felt it added further insights into the topic. Another approach is to use real-life examples from industry such as described by Raju and Sanker (1999), for example by inviting practising engineers to present examples in the form of a case study. Care is needed if an external lecturer is asked to develop the entire case study to ensure they understand what is being requested of them.

- **Developing a case study to replace more traditional teaching on the same topic.** For example, we nov run a case study on joining processes, which contributes to a third of a module in level 2 (see case study example 5). The topics covered in this case study were previously taught through lectures. We decided to adapt this part of the module to a team case study approach that is continuously assessed with no examination question.

Use of Case Studies to Develop Key Skills

We have found the case-based approach to be a useful method to develop transferable skills. Key skills we have embedded into our case studies include:

- **Group working.** The benefits of group working are well documented, and we have found that a team case study approach can add to the learning experience. In our Sports and Materials Science course group work ha

the added benefit of allowing students to share their personal knowledge and experiences of sport (many students on this course play sport to a high level). Care is needed with group working activities e.g. selecting group membership to ensure smooth group operation/training of students in group working skills. This is particularly important for longer case studies.

- **Individual study skills.** Case studies are a good vehicle for encouraging students to carry out independent research outside of the lecture/tutorial environment.
- **Information gathering and analysis.** Many case studies require resource investigation and encourage students to utilise a number of different sources, i.e. Internet, library, laboratory results and contacting experts in industry.
- **Time management.** Longer case studies require students to really consider how best to carry out the work so that it is completed to the set deadline. Interim meetings with academic staff ensure progress is made during the case study rather than all the work being left to the last week.
- **Presentation skills.** Most of our case studies require students to present their work in a variety of formats, these include oral presentations, articles, posters and reports.
- **Practical skills.** Some of our case studies involve practical work on the components that are being studied. Feedback has shown that many students enjoy the hands-on approach.

Assessment Types for Case Studies

Our case studies encourage learning of both course content and key skills, and careful consideration needs to be made as to how to assess these different aspects. The two main modes of assessment are formative (assessment fo the purpose of improving learning and student performance) and summative (evaluation of student performance against a set of predetermined standards). We use summative assessment to assess the students' understanding of course content, yet realise that a more formative approach is necessary for evaluating key skills development and giving feedback to encourage students to reflect upon their learning experience. Booklet 7 of the LTSN Generic Centre Assessment Booklet Series provides informative and detailed discussions of these modes of assessment.

Group assessment is another area we have had to consider, as many of our case studies are group-based. Learning to collaborate is a useful skill and the ability to produce a group output is an important part of this. In terms of summative assessment, these case studies require students to produce one or more outputs between them (generally a report and/or presentation/poster) and we have used group meetings with supervisors and feedback sessions to provide the formative assessment. In order to produce an individual student mark, we use confidential peer assessment forms and/or an individual executive summary to go with the group output. There is much literature on this subject and our suggestion of some good reads are booklets 9 and 12 of the LTSN Generic Centre Assessment Booklet Series and the SEDA paper 102 'Peer Assessment in Practice'.

Are Case Studies a Good Learning Approach for All Students?

It should be acknowledged that styles and modes of learning vary from student to student. Our case studies are predominantly coursework-based; however, this style of work may not be suited to everyone. Some students may work more efficiently in a formal and time-constrained setting, such as an examination, and although this may not be the better mode of learning, it is one to which they have become thoroughly accustomed to at school. One way in which we have tackled this, in some of our case studies, is to have both coursework and exam assessment on the case study content. Provided that a balance in learning styles is maintained in the overall course then the students are able to develop a range of skills and no student should be unfairly disadvantaged compared to another. Group working may also not be suited to all students. Our feedback on group work has shown that this presented a particular problem for some students. Most students recognise its importance for developing key skills, but many commented on the uneven workload within their groups. Comments included;

> *'It's not fair when other members of the group do not provide any input or aid the group effort yet still get marks...'*
>
> *'I don't like working as part of a team because there are always lazy people who don't do any work and if you don't want that to affect your own mark you end up doing everything. I work well in a team and am quite a good organiser, but tend to do too much of the work.'*

In response to this feedback, we developed a way of tackling the issue of uneven workload. We piloted formal group sessions with the lecturer in one of our case studies (see case study example 3 for details). Student feedback was positive and we feel that this has gone part way to helping the students. Positive comments made included:

'They (the group sessions) enabled the group to set specific targets and identify the roles of each individual'

'A good way of motivating people to actually do some work and not to leave it to the last minute!'

Evaluating Your Teaching

It is all very well to promote case studies as a good form of teaching, but how do you evaluate whether they are meeting the objectives set for them in terms of increasing student enjoyment/motivation, content coverage and depth of learning? Evaluating students' learning can be problematic but essential to ensure good teaching. Some suggestions for evaluation are as follows:

Questionnaire (closed questions): These ask for a specific answer - a circle round an option, items to be ranked etc; there are many standard university versions of this type of questionnaire. This approach can be cost-effective for pro-cessing the data and interpreting the results. However, they limit the responses from the students to predetermined answers.

Questionnaire (open-ended questions): These allow students to fully explain their views and justify their answers. However, it can take time to analyse and interpret the results. We tend to use this approach, particularly with the introduction of new case studies, as we feel the questions evoke more personal and informative answers from students.

Interviews and discussion: Tutorials and staff/student liaison committees offer a good opportunity to discuss the learning experience with students. If assessing a specific case study, it is often better to use a member of staff who is not directly involved in the case study so that students do not worry that negative feedback may affect their assessment.

Independent Evaluator: An extension to the above point is to use an independent assessor who meets with the students. For example, we have a research assistant who is responsible for assessing, developing and evaluating ou case studies. Our assistant has gained feedback using questionnaires and one-to-one and small group interviews. We have found that having an evaluator who is not a lecturer (and not responsible for marking their work) has allowed students to be more direct and honest in their comments on the case studies.

Common Pitfalls

Feedback from both staff and lecturers has highlighted areas for improvement in our case study teaching. Some of these will equally apply to other forms of teaching, for example problem-based learning, small group tutorials, project work etc.

Group working. The subject of group working comes up time and time again in student feedback. We originally provided no formal training for group work and soon recognised that this was an area we needed to address. We have developed a case study for some level1 students that incorporates group training including discussion of group dynamics, group functioning and group meetings. As outlined earlier, we also feel that formal group sessions are helpful for the students, particularly for longer case studies.

Explanation of case study requirements. Feedback has shown that students would like more details on what is expected from them in the case studies e.g. level of independent research and, more specifically, sufficient information on how to write reports, give presentations and design and present posters. This is particularly important at the start of the course as for many students this may be a very different form of learning to what they were used to at school. For example, one student commented after a case study, 'A better brief for the poster would have limited the text content, and a clear aim for what needs to be included would have been helpful'. We have now compiled tips and suggestions for students in these areas, which will form part of our case studies support web-site.

Depth of learning. When examining student use of resources, we found that many of the research-based case studies led students to derive all their information from the Internet. Whilst this is a valuable resource we feel that i can often result in only surface learning. We have found that one way of addressing this is to specify to students tha we are expecting critical analysis in their work. Including a practical component is also a useful way of achieving more in-depth study (see case study example 3). Ensuring that there is progression of learning skills development (e.g. analysis to synthesis etc.) when using a series of case studies is important, rather than repetition of the same skills.

Case study mark allocation. We have had to consider how many credits/marks should be allocated to our case studies. We have found that some students have spent quite a lot of time carrying out independent research yet felt that they have not received enough credit. Greater guidance was required as to how the marks were allocated.

Added workload i.e. not replacing sufficient other teaching. In some cases, where we have replaced existing teaching with case studies we have found that students were actually spending more time working towards the case study than they would have spent in the original mode of learning. Whilst it is encouraging to see such dedication to the topic, we realise that it is important not to overload students with case study work that could compromise being able to complete assignments in parallel modules.

Appendix - Case Study Examples

1 Chocolate - a Materials Approach:

Length:	3 hours (one lab session)
Level:	1st year Materials Science and Engineering Course
Aim:	To demonstrate the relevance of, and application of, scientific theories developed in lectures to a single material. To encourage students to use knowledge from a number of lecture courses in another setting
Key skills:	Group work, presentational skills, time management
Assessment:	Question sheet and group presentation

Students are assigned to groups of 4-6 for the session. Each group is presented with a pack of information about chocolate (raw materials, manufacture, properties, marketing data, heat treatments, compositions, structures etc.) and a set of questions to answer. There is too much information for everyone to read everything, hence the students need to set priorities and allocate tasks to ensure that all the research is completed in time. The groups are also required to give a 5 minutes presentation to the class (they are provided with OHP's and pens) on a given topic, different for each group (e.g. control of taste through composition, structure and processing). The students therefore have to share their findings from the reading and relate the information to their knowledge from other lectures (e.g. what is shell casting, tempering etc.). A final component to the case study is taste testing of a range of different chocolate samples to illustrate the role of composition (sugar, milk, cocoa levels), particle size etc. This element is designed to be both fun and informative, the students particularly like to try the American chocolate, which is almost universally disliked, and determine what the differences are that change the taste compared to the different English chocolate types.

2 Space Shuttle Challenger Disaster

Length:	2 weeks (2 x 2 hour lecture sessions)
Level:	Level 1st year Materials and Engineering course
Aim:	To illustrate the importance of materials science in a real life situation and to encourage students to consider the role of an engineer in the workplace
Key skills:	Individual study, written communication, research skills
Assessment:	Individual report in the style of a popular science magazine article

This case study examines the issues surrounding the space shuttle Challenger disaster and requires students to consider the problem from three main viewpoints: technical, economic/political and social. There are two scheduled sessions, the first is used to outline how and why the disaster occurred. Clips from a NASA video are used to presen technical information on the topic, and video clips of an interview with an engineer involved in the disaster are used to give further insights into the event. Students are encouraged to address issues as they arise and participate in class discussion. At the end of the session the students are told to research independently into the topic to gain a greater understanding of the case study. The following session includes three mini-lectures by technical experts that cover the political history of the program, the impact on society of the teacher in the space program and the technical cause of the disaster (rubber O'ring performance and rocket booster design). These are approximately ten minutes long and after each presentation students are expected to interview the experts to find out further information. Students will have been made aware of this in the previous session so have the opportunity to prepare questions. The session finishes with a role play exercise which requires three volunteer students to act out a telephone conversation that took place between the NASA government and the technical engineers from the company Morton Thiokol.

Students are asked to write an article in the style of a popular science magazine (for example New Scientist/Materials World) considering one aspect of the overall problem. Example articles from Materials World are provided as guidelines for the required technical level and format of the report.

3 Metallic Bicycle Components

Length:	5 weeks (1 introductory lecture, 3 practical sessions, 2 group sessions and a presentation

	session)
Level:	2nd year Sports and Materials Science course
Aim:	To illustrate why given materials are used for a particular application. To give students the opportunity to produce and analyse experimental data in conjunction with carrying out independent research on the topic. To help them to understand and interpret microstructures in relation to material properties.
Key skills:	Group work, presentation skills, time management
Assessment:	Group report and presentation and an individual executive summary

Students are assigned to groups of 5-6 and investigate a number of components: frames, spokes and rims. It begin with an introductory lecture where students are briefed on the topic and the case study objectives are set. The structure of the case study work is also explained to the students in terms of how the practical and group sessions operate. When designing the case study it was clear that it was not practical for all the students to attend all the experimental sessions. To tackle this problem, students are told that each experimental session is limited to two members from each group and different pairs are required for each session. This ensures that all students attend at least one practical session. Each group then has access to a complete set of experimental data, but this depends on good group management and communication. Two formal group sessions are scheduled in the two weeks that follow the practical week. Each group meets with the lecturer and post-graduate assistants for ten minutes to give a five-minute presentation and provide a one-page summary of activity and future plans. If a group member does not attend, they lose marks. The aims of the group sessions are as follows:

- To ensure that progress is being made.
- To enable appointments to be made with the post-graduate students to answer specific technical questions.
- To provide an opportunity for the group to meet and detail activities for the following week.
- To ensure the egalitarian operation of groups.

Students are expected to carry out independent research on the topic to use in conjunction with their experimental data. In the final weeks, students address their case study objectives by handing in their group report and giving a presentation. They also have to submit an individual executive summary, which is used as an individual component to the group work.

4 Windsurfing masts

Length:	3 weeks (Introductory lecture and presentation session)
Level:	2nd year Sports and Materials Science course
Aim:	To demonstrate the application of theo- retical concepts in an item of sporting equipment and to encourage students to carry out independent research and study on the topic
Key skills:	Group work, presentation skills, independent research
Assessment:	Group Report and presentation and peer assessment

This case study requires students to work together in groups of 5-6 to investigate materials selection and construction for windsurfing masts. This is the first case study out of four in which first year students participate. To help the students understand this new type of learning, part of the introductory lecture is used to brief them on wha is expected of them when taking part in case studies. Following this, background information on mast technology provides some details in the areas that students need to consider. Groups then assemble and are given ten minutes to brainstorm what properties the masts may require and suggest suitable materials. Students then discuss and share their ideas. Finally, students are given a basic materials selection chart and are asked to consider materials selection on two variables, density and stiffness. This teaches students how to use these charts and also highlights the type of materials they should be considering.

Windsurfing masts have to fulfil a certain criterion and students are asked to research into the types of material that could be used to meet that criterion. They are also asked to discuss production methods for the mast based on a chosen construction material. This case study asks the students to consider two possible designs and to suggest materials and production processes:

Design 1 (to be considered for a weekend sailor):

- Force 3 wind
- Required modulus - > 10 GPa
- Required strength - > 100MPa

Design 2 (applies to competition masts):

- Force 5 wind and above

- Required modulus - > 100 GPa
- Required strength - > 1GPa

For the rest of the case study students work independently in their groups to research into the topic. They are expected to organise their own work and delegate tasks within the group. In the third week they reassemble to give their presentations, submit their group report and carry peer assessment.

5 Joining Processes

Length:	7 weeks (Introductory lecture, interim presentations, final presentations)
Level:	Year 2 Materials Science and Engineering course
Aim:	To demonstrate to students the application of processes for joining materials which has been covered in year 1 lectures, but also to extend to consider design, defects, production methods etc.
Key skills:	Group work, poster presentation skills, time management
Assessment:	Group Report, poster presentation and peer assessment

Students work together in groups of 6 to specify joining processes for specific components. This activity contributes to a third of a module that was previously taught by lectures. Basic processes for joining are covered in year 1 and this case study extends the analysis to include design, defects and production of joints with reference to specific requirements. The case study involves a number of activities that overlap with the other modules the students are taking, such as Selection and Design, Fatigue and Fracture and Materials Processing. It begins with an introductory lecture in which the lecturer outlines the case study format and gives some background to the topic. Students are then put into their groups and given case study specifications. Each group is assigned a different component for which they have to specify joining processes. These are:

- Pipeline for carrying oil in a coastal environment
- Power station heat exchanger bundles
- Lightweight tube structure (linked at both ends) e.g. for a bicycle frame
- External tram body
- Box girders for bridge section

Students must arrange a meeting with the lecturer after the first week of the case study, after which the groups should contact the lecturer as needed during the rest of the case study. In the fourth week, students are required to give a ten minute interim presentation on their work to date. This provides an opportunity for the lecturer to gauge the groups' progress. The assessment for the activity is made up of three components; a final group report, a poste presentation and the completion of a peer assessment form. In the final week students submit their report and display and answer questions on their posters.

For more information and further examples please visit our web-site at www.cases.bham.ac.uk.

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