P028

Teaching Engineering in a Simulated Industrial Learning Environment: A Case Study in Manufacturing Engineering

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Abstract: *The paper describes a successful attempt to teach the subject area of manufacturing technology more effectively by recognising and addressing the different learning styles of a learner group. A two-fold strategy has been adopted. Firstly, to create a learning environment depicting the 'manufacturing system' being studied by incorporating its key elements, viz. real products and associated tooling parts, together with machinery and the processes involved, vividly communicated through a variety of video clips. Secondly, design and conduct a group activity within the learning environment generating enthusiasm and facilitating active learning with adequate tutor support for learner motivation and sustained attention, with the teaching being enhanced by counterpart PowerPoint slides. The technique builds upon the premise that the students' understanding of engineering concepts is likely to be much better if they can relate them immediately to the context.*

In planning the session, the core principle of constructive alignment has been adhered to, i.e. designing the teaching process to positively engage students in the learning activity with primary focus on achieving the intended learning outcomes. In developing the delivery strategy, we have changed our approach from the previous tutor-centred activity to a more student–based activity, with the tutor adopting mainly a facilitator role in the latter. These are discussed in the paper and the pros and cons of different approaches evaluated. The scope and potential for application of the concept of 'teaching in simulated semi-industrial learning environments' to other engineering subject areas are highlighted through further examples.

Introduction

The authors' view is that engineering students' grasp of the engineering concepts is considerably enhanced if adequate opportunities are provided to interact with industry throughout a programme of study. Engineering courses utilise different strategies to provide interaction with industry, among which work placements play a major role. The work placements provide a valuable opportunity for the student to be exposed to the world of work, which broadens the student's outlook to learning and supports the learning experience. However, considering the diverse range of engineering applications, it is unlikely that the student will have exposure to a wide range of industries through work placements and therefore the opportunity for enhancement of technical knowledge would be minimal. Here, a well planned series of industrial visits could fill the void, but unfortunately it is difficult to find time for this within an already condensed academic schedule. In teaching very practical subjects such as manufacturing technology, such exposure is vital to the learning process and therefore the next best viable option would be to ‘bring industry to the class room’.

The strategy we have adopted is to create a learning environment incorporating, as far as possible, key elements of a particular manufacturing scenario and thereby enriching the student learning experience. In doing so the tutor’s experience and imagination will play a vital part in creating the learning environment appropriate to the subject topic under consideration, using a variety of resources available to him/her, and identifying the teaching strategy to involve active participation of the learners. In our experience, engineering teachers who closely interact with industry have the knowledge and the ability to do this; however, what are often lacking may be the vision and the awareness of the need to adopt a truly professional approach to teaching, a key element of which is the appreciation of how students learn best.

A secondary, yet very important objective was to get the learners thinking about the learning process itself by indirectly guiding them to reflect on their own preferences and approaches, often summed up as ‘preferred learning styles’ (see for example, HEA – Engineering Subject Centre Guide: **Learning Styles**, 2004). This is perhaps one of the most important things that we as teachers could do to support learning.

Context

The learner group of 15 students on the Foundation degree in Materials Engineering programme were at level 5 of studies (equivalent to the second year of an UK Bachelor’s Degree). They were all mature students from different industry sectors studying on a part-time basis. The tutors felt that this was an 'adult' learner group, ready for such an activity.

By the time this learning-teaching innovation session was conducted, the learners were familiar with the tutors' practice-oriented approach to the subject, and were also expected to have reached a stage of maturity in managing their learning. It was thus anticipated that this would enable the group to effectively participate in the session.

Rationale

Student’s understanding of engineering concepts is likely to be much better if they can relate them immediately to the context. There is potential cost of using examples in terms of time not spent covering additional material, but again if the success of a lecture is to be judged in terms of learning outcomes, this may be a cost worth incurring.
(HEA – Engineering Subject Centre Guide: **Guide to Lecturing**, 2005).

Since this is a key subject area of industrial application the tutors had, in previous teaching in this module as well as in the associated laboratory sessions, taken care to communicate meaningfully the industry interface of the manufacturing topics being taught. For example, the teaching session on 'heat treatment practice' was developed using a real crankshaft as the centre-piece of attention and the students guided to think critically about the key learning outcomes through this. Pre-planned questions were posed intermittently and the discussion was partly managed based on the learner response to these. The session was followed by a formative assessment task titled 'product realisation', and this task too was on an exploratory examination of real products. The overall session plan for this session is given in Annex 1 in a concise form.

Although active interaction with the learners was successfully managed during the session, this was still more in the realm of a teacher-centred activity. The experience was thought provoking, and was used as the basis for moving towards a more student-centred activity, with the tutor mainly adopting a facilitator role. Student-centred and tutor-centred approaches both have their own value, and bring variety to the learning process making it interesting to the learners while sustaining the enthusiasm of the teacher.

The session on 'tool steels' which is the focus of this paper, again relates to a highly application-oriented and largely interdisciplinary area of manufacturing engineering. It incorporates a blend of subject knowledge in the areas of mechanical engineering and materials engineering. Fig. 1 shows the interaction between key elements of the system and this has to be effectively communicated to the students for the learning to be meaningful.

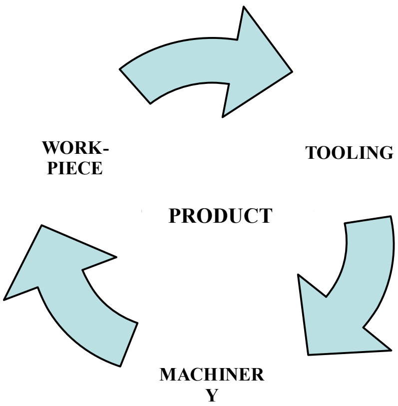

Fig.1 The Manufacturing Cycle

Moving from a tutor-centred (teaching) approach to a learner-centred (self-directed learning) approach is particularly appropriate with student cohorts from industry on Foundation Degree type programmes or with more mature groups of students on regular courses, for example those who have undergone a prolonged period work placement. The transition between the two approaches has to be carefully managed, but a mixed approach is perhaps the best. This will of course depend not only on the experience and maturity of the teacher, but also the teacher's own knowledge and awareness of the professional approach to Learning, Teaching and Assessment (LTA). In preparation for this teaching innovation we found the HEA - Engineering Subject Centre: **Guide to Lecturing** (2005) a very useful resource to catalyse thinking and generate ideas.

The critical question was 'how exactly are we going to organise this?' This meant taking the discussion of tutor preparation and activity away from 'how to organise the subject matter' into 'how to organise the student learning experience'.

Session Planning and Conduct

Throughout the teaching in this module the background thinking was strict adherence to underlying principles of a 'learning outcomes approach to curriculum design', viz. Constructive Alignment (HEA - Guide for Busy Academics: **Using Learning Outcomes to Design a Course and Assess Learning**, 2003).

The main steps in the alignment process are:

1. Defining the intended outcomes (the curriculum objectives)

2. Choosing teaching/learning activities likely to lead to help and encourage students to attain these objectives
3. Engaging students in these learning activities through the teaching process.
4. Assessing students' learning outcomes using methods that enable students to demonstrate the intended learning and evaluating how well they match what was intended
5. Arriving at a final grade, and perhaps in the case of formative assessment, giving feedback to help students improve their learning.

(HEA - Guide for Busy Academics: **Constructive Alignment**, 2002).

Identifying the Strategy

The entire session was built upon a core activity which simulated the 'manufacturing system' depicted in Fig.1. An attractive range of real products together with the associated tooling parts, representative of several key sectors of manufacturing where tool steels are widely used, viz. machining, press work, hot-forging, die casting, injection moulding etc., were identified well in advance and rationally grouped. Creating an enquiring attitude was considered essential for learner motivation and active participation in the session. The learners had been already groomed for the session through a pre-session activity promoted via the Blackboard Virtual Learning Environment (VLE). This took the form of a fact-finding mission involving their own industry sector (Annex 2). To set the stage for the session to be effectively conducted in small groups, the room had to pre-arranged with the items tidily arranged on tables to create the desired impact as the learners walked in for the session.

Managing the Session

The reader is referred to the detailed session plan given in Annex 3.

The session commenced by identifying the key elements of the 'manufacturing system' and their interactions, following which the group task was introduced (Annex 4 – Guidance note to groups). While the learners were actively engaged in the task, the tutor also had a very dynamic role to play as facilitator, encouraging the students and motivating them towards completion of the task, clarifying any doubts and relentlessly eliciting information from the groups, and above all modelling the way that an engineer would approach the task. This was very necessary to keep the momentum of the session going. When the student interest appeared to be at the peak, the Learning Outcomes of the session were introduced. It was considered pertinent to introduce the Learning Outcomes at this stage rather than at the start as the students were now in a better position to comprehend, having gone through the activity. Following this, adequate opportunity was provided to present the group findings and for interaction between groups and interaction with tutor. This is perhaps the most productive phase of the exercise since it enabled effective exchange of ideas and experiences. The session progressed with captivating video clips being shown, representing the critical features of the manufacturing cycle in all the major sectors of manufacturing covered during the group activity, supported by a parallel presentation of PowerPoint slides particularly to demonstrate the nature of tool-work interaction. Following a break, the remaining part of the session was used to drive home the underlying engineering principles and concepts based on the strong foundation laid in the earlier parts of the session.

Preparing students for learning to learn

Previous teaching in the module gave the tutors the opportunity to study the behaviour pattern of the learners, individually and as a group. As the session under discussion was towards the end of the year it was considered pertinent to address some of the broader programme objectives as spelt out in the Programme Aims and Programme Learning Outcomes documents, in particular the issue of 'learning to learn' (please refer to Annex 5). These are often forgotten in teaching at module level, and the students (and staff) need to be reminded of these time and again.

An attempt was made to make learners reflect on ‘how they learn best’ through an assignment (Annex 5) based on a proven self-scoring online tool particularly applied in engineering (Felder and Silverman, 1988*)*, introduced well in advance through the Blackboard site. A parallel objective was for the tutors to obtain a feedback on the preferred individual learning styles of the students in our preparation for the current session.

Reflection

The tutors perceived by the very positive student response to the learning activity that the session was managed efficiently and effectively, and achieved its intended objective.

The key to the success of the session was in the effective realisation, through rigorous planning of the session, of steps 2, 3 and 4 of the alignment process described above. These are: choosing the most appropriate learning activity for the topic; encouraging and engaging students in the learning activity through the teaching process; and, in a formative sense, assessing students’ learning by enabling them to demonstrate their understanding of the concepts through dialogue and discussion. The strategy of introducing Learning Outcomes after the students had engaged in the preliminary phase of the task had the desired impact but, with hindsight, more positive attention could have been drawn to the outcomes intermittently during the session.

The Video clips helped establish forcefully the missing link between the work-piece and the tooling in the manufacturing cycle (Fig.1), viz. machinery, and they seemed to be of appropriate duration and content.
Video clips, if used carefully, can considerably enhance student learning by helping contextualise material through the provision of examples. By providing interest and variety in a lecture, they can increase student motivation and interest”
(HEA - Engineering Subject Centre: **Guide to Lecturing**, 2005)

The Guide states that the two important points to consider in using videos are ‘what length of clip should I use?’ and ‘what are the best sources of video material?’ If the video is being used to illustrate a point, the Guide suggests that is best to keep the clip to no more than 5 minutes.

The educational strategy of 'Teaching Engineering in a Simulated Industrial Learning Environment' serves to address some of the key objectives of the Engineering Council – UK spelt out under ‘Threshold Standards of Competence and Commitment’, for example,

> Engineers must be competent throughout their working life, by virtue of their education, training and experience to: use a combination of general and specialist engineering knowledge and understanding to apply existing and emerging technology”.

(UK Standard for Professional Engineering Competence, 2005)

Extending the Concept

The concept of 'teaching engineering in a simulated industrial learning environment' has considerable scope and potential for teaching not only manufacturing engineering topics, but also most other engineering subject areas where direct practice-oriented module content is found. For example in teaching automotive engineering, many interesting simulated learning environments could be created. Another example is in refrigeration and air-conditioning where direct links with domestic appliances (using split sections and dismantled component parts) would be possible. The range is limitless provided the teacher has sound subject knowledge and sufficient practical exposure. Such techniques and tools are already used by many engineering academics, but if one is fully conscious of their impact on student learning, then effective and focused harnessing of the scattered tools, techniques and resources towards realising the session learning outcomes would be possible. The cumulative influence on realising module objectives and thereby the overall programme objectives would be tremendous.

One way of improving the innovation could be incorporating multiple-choice questions (MCQs). Either as a pre-session activity through the Blackboard Virtual Learning Environment, or perhaps more appropriately at the commencement of the session itself to catalyze the thinking process, a few carefully designed MCQs can be posed to the learners. Finding answers could be a group or individual activity, testing the learners' prior knowledge on the topic and making them self-assess what they know and what they do not know. The session would provide most answers but some gaps can be deliberately left and the learners directed towards finding answers in their revision work. Perhaps the end of module assessment process could be directly linked to these MCQs; for example, when the compulsory first question in an unseen paper consists of a large number of short questions examining the breadth of knowledge acquisition. Strategic improvement of the 'physical learning environment', for example rearrangement of tables and student positioning, display of a few attractive posters depicting industrial processes and applications relevant to the topic, techniques such as a key video already running as students walk in and settle down etc., can all be used to make the session presentation more lively. Above all what is needed is the tutor's enthusiasm and imagination.

Conclusion

It is pertinent to conclude this case study by quoting from Felder and Silverman (1988):

Learning styles of most engineering students and teaching styles of most engineering professors are incompatible in several dimensions. ………..

These mismatches lead to poor student performance, professorial frustration, and a loss to society of many potential excellent engineers. ………….

Although the diverse styles with which students learn are numerous, the inclusion of a relatively small number of techniques in an instructor's repertoire should be sufficient to meet the needs of most or all of the students in any class. ……..

In a nutshell, this is what we set out to achieve in this innovative teaching session.

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ANNEX 1

Session Plan for tutor-centred teaching session - **Heat Treatment Practice**

Plan			
Time	***Learning Activities*** The session is centred on an exciting real engineering product (brought to the session). Students are prompted to think critically about the key Learning Outcomes through this. Questions (pre-planned) are posed intermittently and discussion partly directed by learner response to these. A semi-Industry environment created through a video clip.	***Teaching activities*** The teaching activity primarily based on a well designed PowerPoint presentation. Knowledge enhanced by an accompanying explanatory lecture note (distributed). Use of White board where necessary. A video clip vividly communicating practical aspects.	***Resources*** Forged Steel Crankshaft PowerPoint Presentation Handout (on PP) Lecture note Video clip
10 mins	**Opening/Initial activities:** • Recall learning during the previous session based on the Iron-Carbon Phase Diagram and the microstructure of steels. • Introduce the Learning Outcomes (and some terminology) of the session making reference to the Crankshaft on display. (Property requirements, manufacturing sequence, stress relieving, through hardening and 'size-effect', steel type, surface hardening) Note: Attention particularly focused on the overall module outcomes through this approach)		Crankshaft (on prominent display throughout session) PowerPoint
40 mins	**Development of topic/session:**		Handout on PP Lecture Note

10 mins	**Closing Activities:** Video Clip on industrial practice of Heat Treatment (This is a focused video, presenting the Heat Treatment applications in the same sequence as they were presented during the lecture and consciously planned to serve as an effective lecture summary.) In concluding the session: **Now to the 'Product Realization' formative assignment.**	Video clip

ANNEX 2

Blackboard Announcement

Session on Tool Steels

A metal-working **'system'** consists of three key elements, viz. the **machine**, the **work-piece** and the **tooling**, the interaction of which results in the **product** becoming a reality. So far our primary concern in this module has been the work-piece, specifically its metallurgical constitution and control. This session will examine the role of the tool/die/mould in the manufacturing system and within this context the metallurgy of tool steels.

A group activity is planned to enhance learning as the session covers a very important area. As a pre-session activity, examine to what extent the organization you are working in (not necessarily in your own sphere of activity) uses tool steels (if at all) and in what areas, directly or indirectly. Find out by what 'labels' these steels are identified, either classification codes or commercial names. It is important that you bring this information to the session. A quick meeting with a colleague knowledgeable in this area may help.

ANNEX 3

Session Plan for student-centred learning session - **Tool Steels**

Plan			
Time	*Learning Activities* The session is centred on a topic associated with diverse manufacturing applications. Students are guided towards the key Learning Outcomes through a group learning activity surrounding a variety of real tooling parts/ products (brought to the session). Knowledge acquisition in a semi-Industrial learning environment created through video clips, real parts etc. Increasing the awareness already created among learners on their preferred learning styles through a proven self-scoring on-line tool introduced earlier through the blackboard site.	*Teaching activities* An active teaching style is adopted throughout for learner motivation. The teaching is primarily based on a selection of video clips vividly communicating a variety of manufacturing activities run parallel with counterpart PowerPoint slides. Knowledge enhanced by an accompanying explanatory lecture note (distributed). Pre-planned and spontaneous questions are posed intermittently and discussion partly guided by learner response to these. Use of white board where necessary. Playing an educational video on Learning Styles	*Resources* A selection of manufactured parts/ tooling representative of all sectors. Video clips on selected key manufacturing operations. PowerPoint slides (and handout on ppt). Lecture note. Video: Learning Styles

20 mins (5) (15)	**Opening/Initial activities:** Introduce the **'manufacturing system' concept** and identify the three key elements of the system. Recall previous learning (this has mainly been on the work-piece, now the focus is on tooling) Introduce the **Group Task** and commence group activity (Please refer task brief for details)	A selection of manufactured parts/ tooling Group task brief and data sheet on tool steels

 40 mins (15) (15) (10) **10 mins** **30 mins**	**Development of topic** **<u>Segment 1</u>:** **Learning Outcomes** of the session introduced at this stage. Feed-back sought from individual groups and **guided discussion** based on this. Opportunity for interaction between groups and interaction with tutor. **Video clips** of selected manufacturing processes, specifically showing tool-work interaction. <u>Sequence</u>: Cutting Tools, Press Work, Hot-forging, Die Casting, Injection Moulding (Parallel with the video clips, the relevant PowerPoint slide to be displayed highlighting the tooling features). **Handout on ppt. distributed at this stage.** Classification and designation: **AISI system** **Lecture note distributed at this stage.** **Break** **<u>Segment 2</u>:** Introduce the '**Time-Temperature sequence chart**'. Draw attention to: stress relieving, pre-heating stages, soaking time at hardening temperature, quenching step (including size effect), Time-Temperature-Transformation diagrams for selected AISI grades. M_s and M_f temperatures. **Retained austenite and dimensional instability** **Martempering** Tempering (including **multi-tempering**),secondary hardening and '**red hardness**' Mechanical Property control: Hardness – Toughness balance.	 Handout on PP Video Clips on five key manufacturing processes Lecture Note

15-20 mins	**Closing Activities:** With reference to the **'Identifying your Learning Style' assignment** previously undertaken, attention of learners drawn briefly to learning so far on the module, and in general learning in the overall programme. Finally playing a selected segment of an educational **video on Learning Styles**	Video: "Learning Styles"

ANNEX 4

Group Task Guidance Note

Group Activity

On the table you have parts related to a manufacturing process (or processes). In a small group (2/3) you are expected to closely examine the items and attempt to come out with answers to the following:

You may spend 10-15 minutes on this activity.

1. What is it that you have examined? What is the manufacturing process(es) the items are linked with?

2. If it is a tool, what could be the material? Can you relate it to the list provided? (or is it outside the list).

3. Importantly, what are the main properties/characteristics you expect from the tool/die/mould materials in this process(es) to withstand the demanding conditions it will experience during interaction with the work-piece? List them.

In the next 10-15 minutes, the discussion will be based on your findings.

ANNEX 5

Learning Styles Assignment Brief

Identifying your "Learning Style"

Introduction:

Following successful accreditation of the Foundation degree in Materials Engineering, It is now timely and opportune to plan you career with an informed and intelligent approach.

Are you aware that one of the overall **Programme Aims** are:
"*Provide a positive and enjoyable learning experience which lays the foundations for life long learning".*
Programme Learning Outcome 2.4 a (Key Skills) states:
"Identify personal educational and training needs, plan self-learning and improve personal performance."

This simple formative task is intended to address the above.

Learning Styles

For you, experience gained through life, education and work plays a central role in the process of learning. Learners develop different *learning styles* that emphasize preference for some modes of learning over others. We, who are responsible for organizing learning, need to be able to create opportunities for learning that are sensitive to these different styles of learning.
An awareness of learning styles is important for the teacher planning a course module, as a variety of strategies to promote learning can be considered, whilst for the learner an awareness of his own style is key to lay the foundations of self-directed learning through life.

Approaches to Learning

In a *deep approach* to learning, the student's intention is to understand the subject in a way which is personally meaningful to them and which engages their own experience and previous knowledge, becoming actively interested in the course content. A *surface approach* on the other hand is characterized by the intention to use the information in an instrumental way, i.e. merely to meet the requirements of the situation (course) or in other words simply to pass. There is no sustained personal engagement in learning. The *strategic approach* to learning is sometimes seen as a positive hybrid of deep and surface approaches, the primary objective of the learner being to achieve the highest possible grades. Thus it is mainly assessment driven.

Is this very task a burden to you or something you will enjoy doing?

What you have to do

The *Index of Learning Styles* is an on-line instrument used to assess preferences on four dimensions (active/reflective, sensing/intuitive, visual/verbal, and sequential/global) of a learning style model formulated by Felder and Silverman, **particularly applied in Engineering.**

Simply take the short test, i.e. attempt the “Index of Learning Styles Questionnaire” that can be submitted and automatically scored on the Web. Your score on each of the 4 preferred dimensions of learning will be returned to you as a “Results Sheet” together with a “Description of the Learning Styles and Strategies”.
E-mail the results sheet via Blackboard, read the description and reflect on your own approach to learning on the course so far.

Note: You will learn more about Learning Styles in a future session, so be prepared.