PROBLEM BASED LEARNING AND ITS USE ON THE AUTOMOTIVE ENGINEERING DESIGN COURSE AT COVENTRY UNIVERSITY

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SYNOPSIS

The Automotive Engineering Design course at Coventry University has been in operation since October 1989 and has earned a reputation for creating able engineers well prepared for industry.

When originally conceived, a problem led approach to learning was adopted across the course. This approach best enables the course objectives to be satisfied. However, there is nothing new about problem-based learning for engineering design educators but for our engineering science colleagues a degree of novelty has been encountered by this approach. But is the success of the course purely down to this teaching and learning approach?

This paper will discuss the opportunities, benefits and limitations of the problem-led approach being extended across a whole course. The paper also will address how the use of industrially defined problems in engineering design projects has been critical to the development of the course. The paper will then attempt to identify the key factors that lie behind the success of the Automotive Engineering Design course.

Finally, a set of best practice guidelines for engineering design education will be presented based upon my experiences as the Course Tutor and a teacher of engineering design on this course.

INTRODUCTION

The teaching of engineering design is core to all BEng and MEng courses in engineering. Design by its very nature is an integrating activity and is usually taught at its highest level through project work. This singular form of problem based learning is chosen to help students acquire the skills and competency in design expected of a professional engineer. Therefore, teachers of engineering design are already familiar with problem based learning at degree level and particularly with the concept of engaging students with real engineering problems to solve.

However, what if problem based learning is extended across a whole course and used for teaching engineering science too?

Well, at Coventry University, we have such a course - BEng Automotive Engineering Design. As Course Tutor for five years and core member of the engineering design teaching team, I believe I am well positioned to comment upon the opportunities, benefits and limitations of extending the problem-led approach across a whole course.

The BEng in Automotive Engineering Design

The BEng with Honours degree in Automotive Engineering Design aims to produce professionally qualified engineering designers who, with appropriate industrial experience, are able to achieve Chartered Engineer status. The course started operating in October 1989 and since then over 220 students have been given University awards. Full-time and sandwich study routes are offered, but it is the sandwich route with a minimum 36 week industrial training placement prior to Final Year that is preferred. There is no part-time study route available for this course. The course is accredited by the Institution of Mechanical Engineers and, in anticipation of SARTOR 97, the entry requirements for new students is 18 points or more at A-level or its equivalent.

Part 1 of the course is common with other BEng courses, sharing core modules in solid mechanics, thermofluid mechanics, materials and manufacturing technology, engineering design, mathematics, computing, electrical technology and experimental methods.

From Part 2 onwards, the organisation, structure and assessment methods adopted for the course support a teaching approach that is problem-based. The philosophy behind using this learning approach is that engineering science is fully integrated with design and used in the process of synthesis as well as analysis. Science is not introduced until the need for it is presented through the problem. The problems are taken from the automotive industry and are supported by real data and hardware. Formal end of year examinations are not used because it is considered that this form of assessment does not match achievement of the course objectives. Importantly, assessment takes place on a continuous basis throughout the academic year. The course defines, through detailed objectives, the quality of performance expected from the students. The objectives range from attitudes and values, through personal and mental skills, to specific skills with the process of synthesis and with the application of a core knowledge syllabus. The taxonomy of objectives is based upon Carter [1]. All assignments and projects have clearly defined aims and objectives that guide the student's learning. A studio-based work environment provides the student with the amenities to support the problem-based learning approach.

The links with industry are strong. For example, students from this course have been employed by many of the vehicle manufacturing companies in the UK, e.g. Rolls-Royce Motor Cars, Daewoo Motor Company, Jaguar Cars, Rover Group, Ford Motor Company, Aston Martin Cars, both as graduates and for industrial training placements. Similar links are evident with supply chain companies and design engineering companies, e.g. Lotus Engineering, GKN Technology, MIRA, Ricardo Group, British Steel, and commercial vehicle manufacturers, e.g. Massey Ferguson, Dennis Specialist Vehicles.

Project work is linked with industry and this provides students with the opportunity to familiarise themselves with the demands of the commercial sector. Each student is required to carry out an individual engineering design project in the Final Year. These projects are linked to industry and the activity spread over the academic year, with the Summer Term wholly devoted to the project and culminating in an end-of-year degree show. The most notable project has been with Thrust SCC, Richard Noble’s world land speed record car, when students from Part 2 of the course assisted the Chief Mechanical Designer of Thrust SSC with the detailing of suspension and steering parts.

Thus, graduates will enter industry as engineering designers with the ability to undertake design projects. They will be able to identify the steps required to complete the projects and to carry out the necessary work to bring them to a successful conclusion, with an appropriate level of supervision. Graduates will not have, necessarily, all the skills and knowledge required for all projects. However, they will be able to identify any deficiencies and be capable of acquiring the knowledge or skills themselves, or of calling in specialist support.

Critical Appraisal

The original design of the course, for which the SEED curriculum for design [2] provided a clear structure, was first described in some detail by Griffiths [3,4,5]. Since then, the course has earned a reputation for creating able engineers who are well prepared for industry. The most recent comments of the External Examiners to the course best reflect the current status of the course and demonstrate that the course is satisfying its overall aim to create professionally qualified engineering designers.

Dr Gordon Bacon [6]:

- *“...projects were demanding, relevant and could generate a variety of approaches leading to different solutions.”*

- *“The risk with such a range of projects was that there would not be equal possibilities for good project activity.”*

- *“The changes which are made each year indicate the level of commitment by the staff to develop the course while maintaining a high standard.”*

Prof. Mogens Myrup Andreasen [7]:

- *“I recognise the standard of achievements and performance as very high.”*
- *“In general the reports show very competent craftmanship of design.”*
- *“It is surprising to find how important the students period in industry is for his personal development.”*
- *“.. the course’s excellent results is not only created by good concept and precise administration, but also by charismatic tutors. The school should carefully keep these tutors in responsibility, not to hazard the course.”*

Robert Deboo-Jones [8]:

- *“The concept of the course is the jewel in the crown. Its unique nature is creating the right product for its chosen market objectives and producing young engineers well equipped for a career in industry.”*
- *“... students do appear to have developed a level of practical application which is admirable.”*

In my own Course Tutor’s Report for the 1996/97 academic year I commented as follows:

- *“During the last five years the course has established its true identity and now provides an educational experience that is unique to Coventry University. Each year has seen incremental improvement to a course that was established with a strong concept and well defined educational goals. The enthusiasm of staff and students alike reflects the unique opportunity that the course provides for both to explore the bounds of engineering design activity. The continued theme of project work linked with the automotive industry has enabled the course team to provide exciting and realistic learning experiences for the students. The strength of the industrial training programme reflects a genuine belief in the benefits that each student gains from the year out and the opportunity it provides to launch a worthwhile career in the automotive industry.*

In 1998 the course was subjected to a periodic review within the University. Whilst the course has been modified in the detail of its organisation and structure, it should be noted that the learning objectives, philosophy, teaching methods and assessment approach of the original course have been preserved. The continued use of these core components of the original course design reflects the confidence we have at Coventry University that the overall aim of the course is being satisfactorily achieved by the use of this teaching and learning approach.

But is it the use problem based learning alone that has contributed to the success of the course?

PROBLEM BASED LEARNING

In all aspects of modern engineering courses, student learning is supported by **problem solving** tasks. Coursework assignments, laboratory work, examinations and project work usually require students to utilise existing knowledge and skills to solve problems. These problems are devised or selected to assess a student’s mastery of their knowledge and skill base.

In contrast, **problem based** learning is an approach that stimulates student learning through tackling problems that require students to identify the knowledge and skills necessary to solve the problems. In this learning approach, problems should ensure that students build upon their existing capabilities by demanding that new knowledge and skills are acquired. In this way, learning can be developed in either breadth, depth or both (Figure 1).

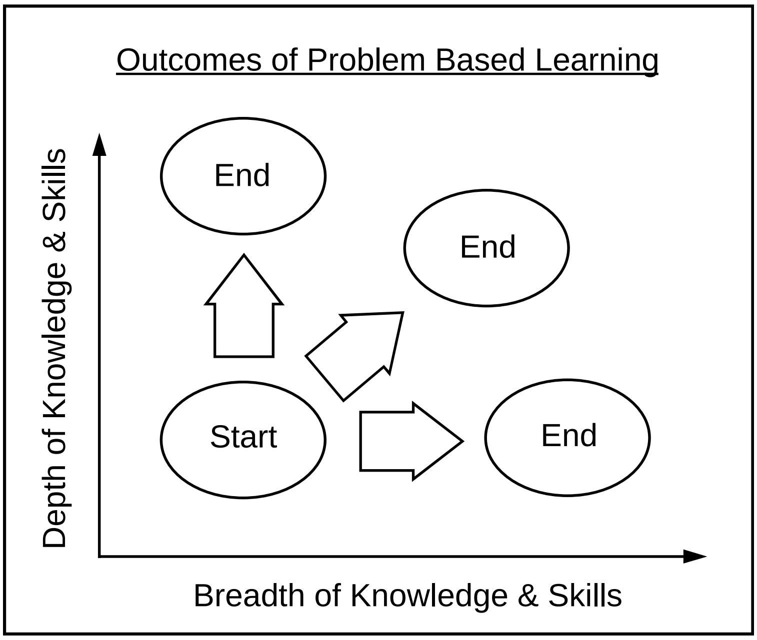

Figure 1: Outcomes of Problem Based Learning

Across any engineering course, we can identify a mixture of both problem solving and problem based learning techniques. Problem solving techniques are favoured in engineering science subjects where learning and assessment are focused within the domain of each subject. Whereas, problem based learning is more common in engineering design and project work where solutions to practical engineering problems are required. In particular, new knowledge and skills will be acquired if the problems are current and require novel solutions.

Course Wide Problem Based Learning

The BEng in Automotive Engineering Design uses a problem based learning approach across the course. This means that engineering science subjects and engineering design utilise a common learning approach. The course wide adoption of problem based learning means that students are tasked with coursework assignments throughout the academic year in all subject areas. The assignments also have a design emphasis with product design solutions required as a deliverable. The type of assignments include:

- Open ended design projects: These projects will be structured by the students themselves and will cover the complete design process and have no unique solution.

- Structured design projects: These projects will be structured by the tutors to achieve a specific learning aim which could be concerned, for example, with the analytical skills required in applying engineering science to prove design proposals. The case study may be used in this context.

In Part 2 of the course, structured design projects are favoured as a means of ensuring that the breadth of the engineering curriculum is covered. However, as students acquire more knowledge and master the skills of design, the emphasis of assignment work changes to open ended design projects. The final year individual engineering design project is open ended and students are expected to demonstrate their capabilities in all phases of the design process.

Course wide problem based learning has meant that my colleagues who teach engineering science subjects, generally, have had to make significant changes to the style of their teaching to suit this approach. To help them with this adaptation, a programme of staff development activities was devised for the course team. The outcome is that solid mechanics, thermofluid mechanics, materials and manufacturing subjects are taught with a emphasis on design projects. Consequently, students have plenty of opportunity to develop good design skills and form good working habits which they can apply in all their assignment work. The design practices and skills acquired in one subject domain they transfer to other domains.

However, to ensure that the use of problem based learning does not become limited within the domain of each subject, some assignments are introduced and supervised by two or more subject tutors. In this way, for example, solid mechanics and engineering design can be fully integrated with appropriate tutor support in each subject. This is wholly appropriate for a design course that aims to produce graduates capable of dealing with the integrative nature of engineering design problems. Furthermore, integrative assignments provide assessment opportunities in more than one domain of the curriculum.

For the students, course wide problem based learning has meant adapting to a student-centred approach to learning that requires them to have a greater ownership of their learning development. This is not a trivial expectation of using this approach, and experience shows that students do not readily adapt to this style of teaching. The approach does not allow a student merely to attend lectures, take notes and cram for end of year examinations; it requires participation, commitment, discipline and action *throughout* the academic year.

Reflection

To enable students to adapt to the problem based learning, reflection is used to evaluate the effectiveness of their learning, comprehend the reasons for difficulties encountered and plan corrective actions where appropriate. Reflecting on what one has done in a concrete experience is believed to be very important in self-development and is one of the elements in experiential learning which leads to deep understanding (Figure 2). This can be carried out in plenary sessions where it is tutor led and is usually focused upon progress in assignments or through the media of a Reflective Journal.

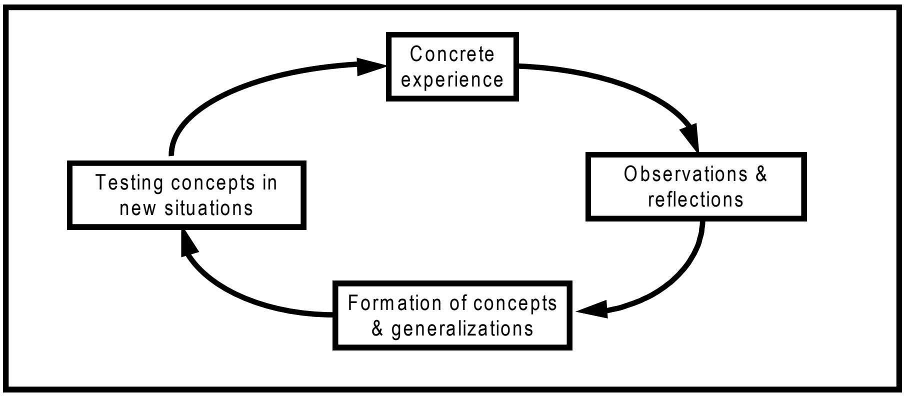

Figure 2: The Kolb Experiential Learning Cycle

The reflective journal is a confidential document prepared regularly by the student and passed to the tutor for comment and advice. In the journal, students record data on their personal performance resulting directly from some activity or assignment, and from a reflection on that activity and other similar situations where the same skills were required. In addition, they identify strategies for improving their performance when use of the same skill is required again. In assessing the journal, the tutor will look for development of the student's learning ability.

My own experiences and observations of course wide problem based learning shows that the approach is particularly successful where it is associated with reflection. Tutors who engage students in reflection, particularly in their own subject domain, are able to give students the confidence to find appropriate solution strategies to the problems they have been set. Time must be set aside for reflection - students should not be left in a continuous cycle of concrete experiences. In cases where staff set open ended design projects reflection must occur at an early stage of the project. If this does not happen, students can flounder around in their search for the appropriate knowledge, skill or strategies needed to solve the problem, and the tutor relies upon the student having existing problem solving skills which have been developed elsewhere in the course. Whilst this is acceptable towards the end of the course, it is inappropriate at earlier stages where the core knowledge and skills are still being developed.

Industrial Projects

The use of industrially defined projects is a great strength of the course. From Part 2 onwards, students are required to tackle real problems with current commercial objectives to satisfy. These projects can be presented either as structured assignments or as open ended design tasks. An advantage of the problem based learning approach is that problems can be easily changed each year whilst still satisfying the learning objectives of the course. It is a credit to the course team that they are willing to use real problems in a teaching environment and provide learning experiences that concern modern automotive products. Also it is possible to introduce new industrial projects at short notice and provide a quick response to a company's needs. For example, a request to review the design of a product made in April will become the Summer Term design assignment for Part 2 students.

The use of industrial projects for final year individual work is an established principle of the course. The emphasis is put on students to obtain suitable projects from industry for themselves. In this way, students can pursue a design problem that is of particular interest to them and link it with a company whom they see as a potential employer. In this way, the student has to behave in a professional manner and act as a design consultant; ownership of the task is placed firmly with the student. This approach has led to a large variety of projects being undertaken over the last few years with a range of different companies and products, with few project repeated between years. These projects provide access to modern artefacts, engineering data, manufacturing technology, commercial issues, practising engineers and opportunities for continued co-operation between organisations. Undertaking industrial projects provides a highly stimulating and informative environment that enables students and staff alike to maintain a knowledge of current practices in industry. Staff enjoy the flexibility the course allows for industrial project work and, consequently, have become loyal supporters of the course.

I believe the use of industrial projects has been a key element in the successful implementation of course wide problem based learning. The novelty of tackling current industrial problems has meant that staff cannot rely upon well practised design assignments that have been repeatedly presented on previous occasions. The new tasks demand that staff help students explore new skills, knowledge and techniques and be prepared to work *alongside* students in the process. When the same design problem is repeated each year, the assignment tends to become highly structured and can lead to it becoming a problem solving task with all the necessary knowledge and skills identified by the tutor and presented formally to the students in anticipation of the task. Industrial projects taken from the automotive industry have enabled the course to develop from a general mechanical engineering design base into a truly sector focused course. This is appropriate for a problem based learning course where the extent of the curriculum covered depends upon the demands of the problems tackled. By using problems from the automotive sector, students on this course acquire the knowledge and skills immediately demanded by the industry.

SUMMARY

The following bullet points summarise my observations of course wide problem based learning. Not all of the points have been discussed above but they can be inferred from the statements made.

Opportunities of Course Wide Problem Based Learning

- Ideally suited to design courses.
- Flexibility of programme content.
- Develop design process skills in all subjects areas.
- Integration of subjects through integrative projects.
- Present real engineering problems.
- Ensure teaching curriculum constantly updated.
- Provide team working opportunities.

Benefits of Course Wide Problem Based Learning

- Creates ownership of learning by students.
- Students continually practise their design skills.
- Students acquire deep learning of fundamental principles.
- Provides students with the confidence to tackle new problems.
- Students recognise the need to continually acquire new knowledge and skills.
- Students acquire team working skills and are well prepared for industry.
- Real problems provide access to modern technology and involvement with industrialists.
- Students work alongside staff.
- Creates loyalty amongst the teaching team.

Limitations of Course Wide Problem Based Learning

- Knowledge and skills base limited to the range of problems tackled.
- Longer time required to present knowledge base.
- Staff need to be prepared for all problems.
- New staff are often unfamiliar with approach and are intimidated by its novelty.
- Reflection is key to successful implementation.
- Engineering design specialists necessary to ensure holistic solutions are generated.

CONCLUSIONS

The adoption of a course wide problem based learning approach is highly appropriate to a course that aims to produce engineering designers. However, its use will not guarantee the success of a course. If this approach is to be used, it needs to be implemented by staff in all subject domains, involve reflection as an integral part of learning development, utilise demanding and exciting projects which are carefully chosen to enable the learning objectives to be fulfilled, and be supported by students committed to student centred learning activities.

Students who participate in this learning approach become highly motivated and capable engineering designers who have little difficulty entering the engineering industry. Staff who participate in this learning approach have the opportunity to engage students in interesting and highly relevant design problems.

Good Practices in Problem Based Learning

The following I consider to be essential elements for successful implementation of course wide problem based learning:

- Train staff to familiarise them with the teaching approach and to give them the confidence to adapt.

- Staff need to be prepared with a broad range of knowledge and skills and be prepared to present them in an ill-defined sequence in any programme of activity.
- Assignments need to reflect a balance between structured and open ended design projects, with the latter favoured towards the end of the course.
- Staff led and personal reflection is an essential aspect of the student's learning development and time needs to be set aside for this critical activity.
- Real engineering design tasks, preferably with industrial involvement, ensure that assignment work is current and in keeping with the problem based learning philosophy.
- Encourage industrial training placements to enable students to further develop their knowledge and skills prior to the final year of their course.
- Encourage students to find their own individual final year projects to enable them to pursue their own interests and demonstrate their skills to a potential employer.
- Do not become overly concerned with the need to cover a broad spectrum of knowledge and skills; concentrate on developing deep learning of fundamental engineering principles and design processes.

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DISCLAIMER

The opinions expressed in this paper are personal only and not necessarily those of Coventry University. Whilst I have tried to ensure that the information given is factually accurate neither I nor the University can be held responsible for any error.

REFERENCES

1. CARTER, R.: *A Taxonomy of Objectives for Professional Education.* Studies in Higher Education, Vol. 10, No. 2, pp 135 - 150, 1985.
2. *Curriculum for Design - Engineering Undergraduate Courses*, SEED 1985.
3. GRIFFITHS, P.J.: *BEng in Automotive Engineering Design (A New Course*). SEED 90. Proc. of 12th Annual Design Seminar, pp 1-8. Hatfield Polytechnic, June 1990.
4. GRIFFITHS, P.J.: *Engineering Designers for the Automotive Industry - A New Approach to Academic Formation.* Proc. Education in the 1990's for the Automotive Industry - Is there an agreed diet? IMechE C427/29, Autotech 1991.
5. GRIFFITHS, P.J.: *Total Course Design - for a BEng Automotive Engineering Design.* Report of the joint IMechE/Entra Conference 'Towards Quality Learning', Robinson College, Cambridge, April 1992.
6. BACON, G: *External Examiners Report - BEng Automotive Engineering Design: 1996/97 Session.* Internal Document, Coventry University, 1997.
7. ANDREASEN, M.M.: *External Examiners Report - BEng Automotive Engineering Design: 1996/97 Session.* Internal Document, Coventry University, 1997.
8. DEBOO-JONES, R.: *External Examiners Report - BEng Automotive Engineering Design: 1995/96 Session.* Internal Document, Coventry University, 1996.
9. ROBOTHAM, A.J.: *Annual Course Monitoring Report - BEng Automotive Engineering Design: 1996/97 Session.* Internal Document, Coventry University, 1997.