

### 3. DESIGNING PROJECTS FOR LEARNING

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#### INTRODUCTION

This chapter aims to provide an introduction to the essential characteristics of designing projects for learning. The approach I adopted in engineering education has been used and refined over a period of sixteen years and has proved popular with the vast majority of students over that period.

The chapter opens with a comparison of project-based learning with traditional teaching methodologies. This is followed by a discussion of learning outcomes and assessment, and a short section on project supervision. The chapter ends with an overview of teaching and assessment methods in project-based learning that I have developed, as an integral part of a four-year undergraduate engineering degree programme at NUI Galway.

Over the past number of years, there has been an increasing emphasis on design activities within engineering education, an emphasis that reflects a paradigm shift away from traditional teaching-based courses, towards a more constructivist view of learning and assessment (Gibson, 2000). This shift has involved a greater use of projects in the learning and assessment process. Some authors have attempted to coin new terms to cover these activities: Project Oriented Learning, Project Organised Learning, or POL for short (Rompelman, 2000). The context for project-based learning is defined and limited by the educational philosophy of each teaching establishment, the available manpower and physical resources, the structure and content of the particular degree programme and, last but not least, the experience and preferences of individual teaching staff.

In an engineering and science context, projects have traditionally been based on methods of solution (and solutions) known to the course tutor. However, even in this context, more advanced learning may demand a development of the solution methodology by the student and may have no known solution at the start of the activity. One such learning activity is engineering design.

Before looking at a specific example of project-based learning at NUI Galway, it is fruitful to examine those general elements that characterise project-based learning, and are essential in encouraging students to learn.

On a practical level, the most difficult and perhaps the most significant aspects for teachers, in the change from a traditional to a project-based learning pedagogy are:

- The emphasis on syllabus is replaced by the establishment of learning outcomes
- Meetings, seminars, presentations, etc. replace the emphasis on formal lectures
- Assessment (of learning outcomes) is normally undertaken through a variety of complementary methods

It is a peculiar fact that students still tend to be assessed by traditional means, i.e. written examinations, despite the fact that many teachers are moving away from traditional teaching

methods. In this respect, it is important to note that each teaching method, and corresponding learning outcomes, demands specific forms of assessment (Gibson, 2002).

**PBL AND TRADITIONAL PEDAGOGIES**

The following table summarises the main characteristics of PBL and traditional pedagogies (Gibson, 2000).

**Table 1: Characteristics of traditional and project-based approaches in education**

Course feature	Traditional	Project Based Learning
<b>Course &amp; curriculum Organisation</b>	Theory followed by applications	Integrated theory & applications Theory introduced in context of real engineering problems
<b>Course structure</b>	Subjects compartmentalised  Students separated by discipline and chronology  Subjects taught by single lecturers	Some subjects integrated across disciplines and chronology Flexible  Subjects taught by teams of lecturers in support of project-based learning
<b>Course emphasis</b>	Presentation of content	Presentation of content and solution of problems Development of skills
<b>Course content</b>	The syllabus	Learning outcomes
<b>Course assessment</b>	Terminal examinations	Presentations, meetings, reports, etc.
<b>Teaching Style</b>	Instructional approach: lecturing  Single learning style: intuitive, verbal, deductive, reflective, sequential	Instructional approach: lecturing, group exercises, multimedia, interactive tutorials, laboratory and project work  Full spectrum of learning styles: sensing & intuitive, visual & verbal, inductive & deductive, active & reflective  Active learning (discussion, explaining, solving problems, brainstorming, trouble-shooting, generating questions)
<b>Student role</b>	Passive observations	Sequential and global
<b>Student tasks</b>	Closed-ended problems  Individual student	Closed and open-ended problems  Individual and cooperative
<b>Course grading</b>	Norm referenced	Criterion referenced
<b>Assessment &amp; evaluation of course &amp; lecturers</b>	Outcome assessment: post-course student evaluations	Evaluate course: examining student products. Extent of learning outcomes assessment.  Outcome assessment: post-course student evaluations  Examination of representative student products

Back in 1989 and, indeed earlier, I perceived the activity of engineering design as a means of introducing students to activities of **doing** as well as of **thinking** in a potentially creative environment as part of their overall learning activities. This was seen as an introduction to how engineers actually work in their chosen profession. Project-based learning was introduced without much analysis of what exactly its components were. At that time, I had a good deal of professional engineering and lecturing experience but no knowledge of teaching pedagogy.

## LEARNING OUTCOMES

As noted above, the switch to learning outcomes can create real difficulties for those teachers (and students) established in traditional teaching and learning methodologies. For this reason, it is valuable to look at the “standard” references in this area.

In regard to overall learning outcomes, the typology of Romiszowski (1981) divides these into four broad areas:

- *Cognitive skills*: knowledge and information
- *Psychomotor skills*: physical and motor actions
- *Reactive skills*: effective responses to individuals, events, and situations
- *Interactive skills*: social and communication effectiveness

The well-known taxonomy of Bloom (1965) provides a more detailed and hierarchical structure in the cognitive domain:

**Table 1: Hierarchy of the cognitive domain (Bloom, 1965)**

6	Evaluation	Ability to make a judgement of the worth of something
5	Synthesis	Ability to combine separate elements into a whole
4	Analysis	Ability to break a problem into its constituent parts and establish a relationship between each one
3	Application	Ability to apply rephrased knowledge to novel situations
2	Manipulation	Ability to rephrase knowledge
1	Knowledge	That which can be recalled

Simply stated, the course or programme designer needs to consider the various learning outcomes and select those most appropriate, in the **context for learning**. The context for learning is defined by the level of knowledge, the range of prior experiences, manpower and physical resources, structure and content of the degree programme and, last but not least, the experiences and preferences of individual teaching staff. In brief, the course designer needs to consider just what can be achieved in the real world, not what might be done in a preferred ideal one. Quite frequently, this search for objectively defined learning outcomes leads to an identification of pedagogical obstacles that were not previously recognised. These discoveries often lead to improvements (and/or changes) in the overall structure of the degree programme and in manpower and physical resources. An obvious example of a change in physical resources is the division of a large lecture hall into smaller seminar rooms.

Before proceeding to the details of defining learning outcomes, it is important that an effective **learning model** be adopted (Savoie, 1994). In regard to project-based learning, an effective learning model should contain the following elements:

- 1) Identify a suitable project
- 2) Describe the project in the context of the students’ world
- 3) Organise course content and facilities around the project
- 4) Encourage students to take responsibility for defining their learning experience and planning project activities
- 5) Encourage collaboration via learning teams
- 6) Demand all students demonstrate the results of their learning through a product and/or performance

## Defining Learning Outcomes

Having gained a general understanding of learning outcomes, it becomes necessary to give some thought to defining them and assessing them. From my experience these two areas are dealt with simultaneously, but for the sake of clarity in this chapter, I will deal with each aspect sequentially. It must be stressed that it is important to get these two areas as accurate and comprehensive as possible, since the prepared paperwork and assessment schemes will likely be scrutinised by academic staff, external examiners, accreditation agencies and not forgetting, by students themselves. This information will also, generally, appear in official publications and on the website.

Learning outcomes, as noted above, are normally identified under several headings. The exact number and type of headings depends to a large extent on the context for learning and, in consequence, varies from degree programme to degree programme, from teaching institution to teaching institution, and from country to country. Generally, learning outcomes are defined under numerous skills and/or attributes. Candy (1994) highlights five of these, namely:

- Knowledge skills
- Thinking skills
- Personal skills
- Personal attributes
- Practical skills

On a practical level, there is little point in defining learning outcomes if they are not going to be assessed in an effective manner and the strict confinements of language do not enhance the teaching and assessment process in any way.

There is no ambiguity in the learning outcomes listed below, which I developed for a new undergraduate programme in Engineering Design. At the end of the programme, the students will be able to:

- Have a sound base in the fundamentals of engineering science and mathematics
- Have a good understanding of, and familiarity with, modern Information and Communication Technologies (ICT)
- Have an understanding of the importance of human and environmental factors in design
- Be aware of the professional, business and legal responsibilities of design engineers
- Have a solid grounding in transferable skills such as oral and visual skills, team-working, the ability to “learn how to learn”, and the ability to synthesise and apply acquired knowledge to the solution of problems
- Have the ability to define problems and develop design specifications
- Have the ability to generate and develop alternative solutions to design problems and then make informed and/or optimal choices as to the preferred solution
- Have an understanding of the role of specialist design engineers in the different branches of engineering

In order for these learning outcomes to be assessed, it is abundantly clear that students will be required to demonstrate competency in these areas.

In some respects, the establishment of learning outcomes is the easy part of setting up a project-based learning programme or course. The crucial area of assessment may demonstrate that at least one of the learning outcomes cannot be assessed effectively as part of a given course and needs to be dealt with separately or as part of another course. It must be recognised that

learning outcomes and their assessment are not carved in stone and can, indeed should, be reviewed periodically to determine their effectiveness and accuracy.

### ASSESSING STUDENT LEARNING

It is always useful when setting out on a new journey to have a helpful guide for reference. In regard to the topic of assessment, Brown, Bull and Pendlebury (1997) provide useful guidance.

Oral presentations are a common feature of project-based learning courses. It is perhaps informative to present an example of one such scheme developed by the author in conjunction with a colleague for use as part of an undergraduate course in geology.

**Table 2: Example of an oral presentation assessment scheme**

	<b>Abysmal</b>	<b>Poor</b>	<b>Fair</b>	<b>Good</b>	<b>V. Good</b>	<b>Excellent</b>
<b>Presentation skills</b>						
Introduction	0	2	4	6	8	10
Structure	0	2	4	6	8	10
<b>Content</b>						
Relevance of material	0	4	8	12	16	20
Depth of research	0	Binary	Binary	Binary	Binary	10
<b>Comprehension</b>						
Grasp of content	0	6	12	18	24	30
Response to questions	0	4	8	12	16	20

The main characteristics of this scheme are easily identified: weighting given for different aspects of the presentation, a simple sliding scale of marks from zero, in this case, to the maximum. The final element is a binary scale, which asks the question: “has the student read the text(s) or not?” In the above example, it is clear that the main emphasis is on comprehension of the researched material. Presentation skills, receive only a few of the total marks available. It is important to realise such schemes need to assess the prime learning outcome(s), and the scheme should be discussed with students so they know what is expected of them and can prepare accordingly.

Project reports are also widely used as part of project-based learning. One such marking scheme developed for the assessment of project reports in engineering design has been discussed at length in an earlier publication (Gibson, 2001). A slightly simplified version is presented below:

**Table 3: Example of an assessment scheme for a project report**

	<b>Poor</b>	<b>Fair</b>	<b>Good</b>	<b>V. Good</b>	<b>Excellent</b>
<b>Presentation skills</b>					
Layout, references, language, etc.	2	4	6	8	10
<b>Methodology and understanding</b>					
Comprehension, analysis	4	8	12	16	20
Synthesis, organisation of ideas	4	8	12	16	20
Evaluation, objectivity	4	8	12	16	20
<b>Content</b>					
Information evaluation, fieldwork	2	4	6	8	10
Laboratory work, modelling, creativity	2	4	6	8	10
Software design, mathematical skills	2	4	6	8	10

In this marking scheme, the main emphasis is on methodology, understanding and, in the last section, on the “content” or “difficulty” of the project. It is my view that engineering students should be rewarded for taking on and completing technically difficult projects. Assessment schemes must not be seen as fixed entities and their effectiveness should be evaluated periodically and improved upon or replaced.

## PROJECT SUPERVISION

Effective project supervision depends on three elements:

- Course content
- Learning outcomes
- Class size

Course content is outside the scope of this chapter, and learning outcomes have been dealt with above.

In regard to class size, I have been lucky enough to deal with relatively small class sizes of up to 45 students. That being stated, project-based learning is not effective with large groups. The first priority is to break a large class into manageable units (or learning teams) of no more than 6-8 students. If this requires taking on extra staff, recruiting graduate assistants, calling on external organisations, or other creative support mechanisms, then so be it. Project-based learning will not be effective in a large class environment and will inevitably create additional administrative problems for teaching staff. It must be decided at this stage if teamwork is a required learning outcome and, if so, how it will be assessed. In any case, how will it be encouraged? Of assistance in this regard are Belbin ([www.belbin.co.uk](http://www.belbin.co.uk)) and Myers-Briggs [www.knowyourtype.com](http://www.knowyourtype.com)

It is important to organise regular meetings with each student group. The format and content of such meetings must be decided at the outset. It must be clear whether the meetings will form part of the assessment process and if so how. Will outside expertise be used in these meetings? A method I have used successfully for many years is to allocate a period each week when a group of engineering designers can make an appointment for a meeting with their design “client.” In this way, students have the opportunity to take ownership of their design project and their individual contribution to the project objectives can be realistically assessed.

The above topics cover but a small selection of project-based learning characteristics that need evaluation. It may seem daunting until a start is made and experience acquired. In the wide armoury of tools and backup available, many institutions have established, or are developing, Centres for Learning and Teaching to advise and assist teachers to improve and develop their teaching. It is important to remember the contributions of ICT:

- For delivery of content – via the web, CD-ROM, etc.
- For assessment of individual course elements
- For provision of a Virtual Learning Environment (VLE) – *Blackboard, WebCT, Claroline, etc.*
- For expert feedback and mentoring
- For delivery of shared programme elements

For a further discussion on using technology to support project-based learning see chapter 17 of this handbook. Finally, it may be helpful to provide an overview of the teaching and assessment methods that I have developed as an integral part of a four-year undergraduate engineering degree programme at NUI Galway.

## **A PROJECT-BASED LEARNING COURSE IN ENGINEERING DESIGN**

All undergraduate engineering programmes offered at NUI Galway span four years, the first two being largely common between the various disciplines. These concentrate on basic engineering science, mathematics, information technology, etc. It is the syllabus in the third and final year that gives each degree programme its individual identity and flavour. The Bachelor of Engineering (BE) programme in Industrial Engineering and Information Systems (IEIS) contains several elements not commonly found in more traditional branches of engineering: Industrial management, organisational development, managerial economics, ergonomics, human biology, operations research, reliability, safety, and quality. There are also a number of optional subjects in final year. The degree programme includes an industrial placement period of five months at the end of third year and an industry-based project in final year.

The course in engineering design I teach in the third year of the undergraduate programme. It is currently valued at 20% of the overall assessment in that year. Numerous improvements have been made to the course since its introduction in 1989. The underlying emphasis on project-based learning has, however, remained unchanged. A major revision in format and content was introduced in 1996 and a full description of those changes has already been published (Keane and Gibson, 1997). The course currently consists of three complimentary project-based learning elements:

- Oral and Written Communications, which involve short individual assignments and group environmental projects - 3 European Credit Transfer System (ECTS) credits
- Engineering Graphical Communications, which involve individual assignments and instruction in computer-based solid modelling using Autodesk Inventor (3 ECTS credits)
- Engineering design projects, which involve student groups in product, process and systems design activities (6 ECTS credits)

Some details of the scope and content of these design projects have been published and there is a strong emphasis in many of the projects on a continuous development of student competencies in ICT. Comprehensive assessment criteria have been developed over the years and are presented to students in the early part of the teaching semester. Assessment is largely by means of oral presentations and written reports but also includes an evaluation of individual student contributions to design seminars and client meetings as noted above. Details of the assessment methods and learning goals fall broadly in line with current best practice in Europe (Gibson, 2001). Generally, the marking schemes are readily accepted by students and are particularly well received by external examiners and quality review panels. The assessment schemes have been found satisfactory across a wide variety of project content and fairly consistent and repeatable across a number of examiners from different backgrounds.

This third year introduction to a broad range of engineering design activities can be continued by students in their final year of study through an optional course in engineering design. Additional courses are also available at graduate level. All courses I teach at NUI Galway utilise project-based learning extensively.

## **CONCLUDING REMARKS**

Project-based learning has been a recognised aspect of engineering education for forty years or more, yet there are many higher educational establishments, and many academics, that still remain sceptical of its value. Internationally, some institutions and individuals have embraced

project-based learning willingly, others more reluctantly, others under government edict and/or through accreditation requirements.

The basic building blocks of project-based learning have been presented above. It must, however, be remembered that the primary beneficiaries of the change from traditional teaching methodologies to project-based learning should be the students and, in this respect, it is absolutely essential to provide them with attainable goals, an assessment scheme, timely feedback (both positive and developmental) and an appropriate learning structure. And, as an aid to improving the adopted project-based learning pedagogy, it is helpful to obtain feedback through the use of teaching evaluation forms. Finally, it needs restating that the change to project-based learning requires a sound pedagogy (Bagley and Hunter, 1992):

- Inform students through coaching and/or facilitation
- Motivate all students through interesting and demanding projects
- Activate all students using appropriate teaching structures
- Interact with students to encourage team building
- Produce a tangible output from each project and from each student

The switch to project-based learning can be a challenging, enjoyable and rewarding experience for both teacher and learner.

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