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# A CASE STUDY ON ENGINEERING FACULTY DESIGN PROJECTS

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## **ABSTRACT (250 WORDS MAX)**

There is an established trend in engineering education to incorporate a design component for preparing students for real life practice. A recent report entitled *Educating Engineers for the 21<sup>st</sup> Century*[9] stresses that engineering courses need to adapt to the changing needs of businesses and to place a greater emphasis on real-life problems by working in collaboration with industrial partners.

An initial investigation of design projects across four engineering disciplines was carried out to understand the breadth and depth of design projects. This included identifying key characteristics of the design projects, analysis of learning and teaching activities with respect to constructive alignment and investigation of assessment practices in these design projects. This research also examines the type of students' experiences. This paper ends with a discussion on the implications of these findings for design projects.

*Keywords: design project, project based learning, problem-based learning, engineering design*

## 1 INTRODUCTION

Design projects have now become an integral part of the engineering curriculum as a result of pressure from industry, from engineering professional bodies and from academics who want to deliver a high quality educational experience [4]. Given that design is a central activity for engineers, it is not sufficient to have a good knowledge of engineering theory but it is also important to be able design a product that solves an open-ended problem, ideally in a multi-disciplinary team environment.

A major problem within traditional didactic teaching is that it is difficult to enable students to work in teams and students find it difficult to connect the different fragments of knowledge and develop employability skills. In the last two decades however there has been a shift to design education from traditional (instructional) teaching to more student centred with design problems as the driving force. The role of teacher changes from transmission oriented to interaction oriented facilitators of learning. The goal is to move students away from dependency on the teacher to using the teacher's expertise as a consultant.

This new shift gives students more experiential and situated learning opportunities where students are actively experience undertaking the tasks in a real context (often with industrial live projects). Students are able to integrate their conceptual knowledge and factual knowledge resulting in deeper understanding of the engineering discipline.

### **1.1 Research objective and questions**

The specific questions that will be explored in this research are :

- To what extent are problems open-ended?
- What are the limitations of design projects ?
- What are the benefits and limitations of involving industrial partners in design projects?
- What are the roles of industry in the assessment/evaluation of students' work?

- How are the modules structured to support independent learning individually or as a team?
- How is individual contribution measured in team projects (e.g peer review)?
- How are transferable skills assessed in design project?
- How are both the design process and design product being assessed and what is the balance?

The methodology that is employed is a case study research. This approach is used because it provides an opportunity to investigate a small number of cases in-depth from a real context. The evidence used is from multiple sources: interviews, module documentation and student module feedback forms.

### 1.3 Context of this research and methodology

Design projects have been an integral part of the engineering curriculum in Loughborough University since the 1980s and evolved to reflect the needs of the industry since the Grant Report. To provide students with experience of realistic projects, the projects build upon established industrial links [5]. These links provide an understanding of the types of skills and knowledge required by the industry and have been instrumental in the development of design project modules.

Eleven in-depth interviews were carried out with different module leaders in 2006/2007 from six engineering related departments. For this paper four contrasting modules, from four different departments, were selected for further exploration based around the themes identified in this paper. The modules and departments that are investigated are shown in the table below.

*Table 1 Summary of the modules and departments*

<b>Module name</b>	<b>Department</b>
Structural Design Project (2 <sup>nd</sup> year)	Aeronautical and Automotive Engineering (AAE)
Application of Product Design (2 <sup>nd</sup> year)	Wolfson School of Mechanical and Manufacturing Engineering (MME),
Programming for Real World (2 <sup>nd</sup> year)	Electronic and Electrical Engineering (EEE)
Building Design Project (3 <sup>rd</sup> year)	Civil and Building Engineering (CBE)

The methodology that is employed is a case study research method. This approach is used because it provides an opportunity to investigate a small number of cases in depth in a real-life context and evidence used are from multiple sources: interviews and module documentation. Key themes were extracted and examined from the perspective of the educators involved in these modules.

The interview transcripts were first transcribed word by word. The verbatim were then categorised into themes. For each module key sub-themes within the main themes were identified. In addition formal module specifications were used to triangulate the data from the interview data and add evidence under each theme.

## 2 ANALYSIS AND RESULTS

### 2.1 Key features of design projects

All design projects are in teams of 3, 4 or 5 where team members are selected either through self-selection, random, or based on team skills. The context is always set within a real world application where problem solving is a key element. Where a real life problem cannot be replicated it is adapted e.g. in the Building Design Project (CBE) a building site is adjusted with respect to building or functionality to reflect the course objectives. Industrial partners sometimes provide the problem scenario but do not always define the actual problem.

The design projects are used to integrate knowledge of theory and practice that students have learnt previously. A key feature is that they promote independent learning in students by encouraging students to find their own answers, and manage their own time. Students are thrown in at the deep end and are expected to find their way to the end solution and if understanding of a new technology is required for their project they are expected to learn this independently. The students develop different skills than they would within a traditional taught course and hence students have the opportunity to demonstrate a wide range of skills.

The type of design project varies, from just developing a brief of the design, while others goes through the entire cycle of design including product development, testing and evaluation. Where students are involved from two separate programmes, the module is timetabled separately or sometimes different topics or materials are used. For example on one combined module aeronautical students use aluminium in designing their structure whilst automotive students use steel which has implications through the whole design, manufacture, test and evaluation process.

Within the design projects there are some alternative approaches: for example second year students design the product and first year students test from the client's perspective; in another module students do a small mini project to get into the right mind-set followed by the main design project.

## 2.2 Constructive alignment

The range of learning outcomes, teaching approaches and assessment methods from both the interviews and the module specifications were analysed to determine whether the activities were constructively aligned in the design project case studies [2] and to identify interesting commonalities and differences. A summary showing the common features of the four design projects is presented below in Table 2.

*Table 2 Constructive alignment across the four module (brackets show no' of occurrences)*

<b>Learning Outcome</b>	<b>Learning and Teaching Approach</b>	<b>Assessment Method</b>
Develop subject specific knowledge (3)	Lectures and Tutorials (3)	Multiple choice assessment (1) Assessed tutorials (1)
Understand the design process (3)	Student Centred Learning (2)	Design Evaluation (2)
Understand design within the specific discipline (4)	Tutorials to support designing a discipline specific item (3) Coursework clinics (1)	Design Report (3) Submit product for assessment (2) Testing of the finished product (1)
Communicate effectively (3)	Deliver an oral presentation (4) Produce a poster (1)	Assessment of presentation (4) Assessment of poster (1)
Work as part of a team (3)	Work in a group to design the project (4)	Peer Assessment to moderate marks (2)

There are many similarities in the learning outcomes across the four modules even though they were developed independently and delivered through four different departments. In teaching approaches, for example subject specific knowledge is developed through lectures and tutorials, the design process is learnt through personal experience of working independently in teams and communication through oral presentations. These approaches map well to the learning outcomes.

There are some interesting differences such as the use of coursework clinics instead of tutorials, where the clinics are particularly focused upon preparing students for the assessment. There is a good mapping of outcomes to assessment methods even though there is a diversity in the assessment methods employed. Two of the projects result in a design whereas the other two result in the production of a product and as a result the product itself is also assessed. The testing of one of these products also enables the students to evaluate the product performance themselves.

All four projects involve group work within a team, however only three of the projects define this as a learning outcome and only two of them defined an approach to assessing the team-working. Three modules specify the development of subject specific knowledge which is delivered through supporting lectures and tutorials, however only two of these are assessed in a conventional way through coursework tutorials and multiple choice assessment. Three modules also specify an outcome will be an understanding of the design process, but only two of them incorporate a design evaluation which enables both the staff and the students to assess this outcome. Within all four modules the students deliver oral presentations and all of these are assessed, however only three of them specify presentation and communication skills as an intended learning outcome.

### 2.3 Higher order learning and assessment

Each assessment was classified according to the predominant higher order skills which were being employed, although this classification is not discrete and there is also some overlap with skills at both lower and higher levels[7]. A summary is represented within Table 2.

It is clear from the table that design projects can employ a wide range of assessment methods and a high proportion are associated with higher order skills. This shows that there is no need to assess both ‘knowledge’ and the ‘application’ of knowledge as evidenced by the four departments who only assessed either knowledge (AAE, EEE) or the application of knowledge (MBE, CBE).

It is interesting that three entirely different approaches to assessment; can be used to engage students in analysis (breaking data down into parts to understand the structure and draw inferences and conclusions) which are all equally valid.

*Table 3 Mapping of assessment methods to Bloom’s Taxonomy cognitive levels of learning*

	<b>Knowledge</b>	<b>Comprehension</b>	<b>Application</b>	<b>Analysis</b>	<b>Synthesis</b>	<b>Evaluation</b>
AAE	Assessed Tutorials	Oral Presentations		Test completed product	Individual and Group Design Reports	Test results in terms of cost efficiency
EEE	Multiple Choice Tests	Oral Presentations		Submission of designed software	Originality and innovation within design	
MME		Oral Presentations and Conceptual Ideas report	Interim Report	Report on concept of design	Individual and Group Design Reports	Self and peers contribution
CBE		Oral Presentations	Client Briefing Site Analysis Report		Individual and Group Design Reports	Self and peers contribution

Three out of four of the modules required a group design report which necessitated that the student ‘synthesise’, i.e. design, formulate and integrate a solution to an open ended problem. The remaining project did not require a design report and instead synthesis was assessed through requiring the students to make deductions and report on the originality and innovation within their design.

The design projects all involved an element of team working and to differentiate between the marks for individuals within teams two methods were employed. The first approach applied peer assessment where students marked themselves and their team members against fixed criteria which resulted in individual moderation of the marks resulting from a single group report. The second approach involved students submitting individual pieces of work which were marked separately.

## 3 DISCUSSION AND CONCLUSION

### 3.1 Strengths of these design projects

The main strength of the design projects studied in this research is that experiential learning is embedded in the way the tasks (design problems) are set. As a results students’ level of engagement and motivation is high.

Previous research[4] found that students had difficulties working in groups specifically with leadership, responsibilities, planning and evaluation but in these projects groups overcame these difficulties by taking initiative, additional effort or discussing working issues within groups. There

was no evidence from the staff interviews or student feedback forms that team working was a major issue for any of the design projects.

There is a general consensus from the academics interviewed that students value what they experience in design project modules. These projects enable students to be artistic in an engineering sense. Design projects stimulate a genuine interest in the subject as it gives the flavour of what they will do in their future career. Students find the experience rewarding because they undertake a mixture of tasks: designing, testing or evaluating the design. Students appreciate that design projects integrate knowledge they have learnt previously. Finally students genuinely enjoy design projects because it mimics reality. These results agree with the literature that design projects reduce student's attrition through increased student motivation, engagement and self-confidence [8]. In addition students feedback (CBE) indicated that a large proportion of students appreciate that they have better understanding of the design process and found the module enjoyable because they could relate their learning to real world application.

### **3.2 Limitations of these design projects**

One of the main challenges of design projects are with assessment which includes marking group work that reflects contributions of the individual effort, setting marking criteria to assess the process rather than the final product (e.g. drawing), resolving marking variations resulting from different academic members marking the same coursework and when industrial partners are involved in judging a piece of work there is often conflict with balancing judging transferable skills against technical skills. These findings support the evidence from the literature [3] on challenges with design and delivery of design project such as coordination with a staff member and time intensive supervision.

With respect to assessing product versus process, this is inevitable because process appears to be less subject specific and is more challenging and time consuming to assess. Although in two cases the process was assessed to some extent through the students' own evaluation of the design.

The modules are structured so that students engage in lectures in the early stages of their project and as the project progresses they work independently in groups to solve a design problem. Although the structure of the modules have strong elements of independent learning the students there are expected to follow a fixed timetable and solve preset problems that are not entirely open ended and as a result students cannot always fully explore creative aspects of design.

Literature shows that design project can be made by the lecturer, students or by a client or industry [1]. Industrial involvement provides context to design project modules and there are many benefits however issues can arise when industrial partners are involved in assessing the students' works and in ensuring that the projects set are at the right conceptual level to match the module objectives. Therefore maximising the benefits of the industrial partners needs to be investigated further. In addition in this investigation there were no group projects specified by the students. The way in which projects are selected to balance students needs, enthuse and motivate needs further investigation [6].

Finally, there is no formal and independent reflective practice with any the design projects for students, although in some instances it is integrated within the deliverables. For example in students presentations they are questioned about their testing methods and how they would do it differently next time. Students also have feedback sessions with the lecturer where they are asked to reflect on their performance. This limitation is also evident with lecturers where they do not engage in formal reflective practice although informally they undertake a review meeting with students which is chaired by a third-party staff member. All aspects of the module are discussed: lectures, booklist, coursework, exam organisation etc.

### **3.3 Implications for learning and teaching**

The process of constructive alignment highlighted that academics were better at articulating the learning outcomes, assessment methods and teaching approaches through interview than they were at documenting them in the module specifications. This has implications for module review, with the

outcome that the modules may be under-sold and also that mapping to programme outcomes and UK-SPEC could be enhanced.

A diverse range of assessments were applied yet each module addressed most of the cognitive levels within Bloom's taxonomy, which indicates that it is not necessary to be prescriptive in how to teach engineering design and instead to focus on enhancing existing practice identified through this type of analysis.

These results showed that a process needs to be implemented to engage academics in reflective practice, e.g. supported by a peer mentor. This reflective practice can involve engaging with the process of constructive alignment, reviewing the process as the module progresses and looking holistically at the end of the module, where constructive alignment could be used as a useful framework. During this reflective practices limitations of assessment, nature of design project and issues with industrial involvement can also addressed.

### 3.4 Future research

There are mainly two main limitations of this research. First is that this study only includes four design projects out of over fifty design projects within the University. As a result this limits any comparative analysis between different disciplines or even within the same discipline. This initial investigation identified the process of reviewing the diverse projects from across the engineering faculty for future comparative analysis

The second limitation is that it does not incorporate students' perceptions and views of design projects. Investigating students perspectives will provide an alternative views to enhance learning and teaching of design projects.

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# AN INSTITUTIONAL ANALYSIS OF DESIGN PROJECTS

**Author ONE<sup>1</sup>, Author TWO<sup>2</sup> and Author THREE**

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**(NOTE: DO NOT ADD AUTHORS OR AFFILIATION FOR 13<sup>th</sup> FEBRUARY SUBMISSION)**

*Keywords: design project, project based learning, problem-based learning, engineering design education*

## **SUMMARY OF PAPER**

There is an established trend in engineering education to incorporate a design component for preparing students for real life practices.

A recent report entitled *Educating Engineering for the 21<sup>st</sup> Century*[9] stresses that engineering courses need to adapt to the changing needs of businesses and to place a greater emphasis on real-life problems by working in collaboration with industrial partners.

A review of design projects was carried out to understand the breadth and depth of design projects. This includes analysis of learning and teaching activities, learning outcome and assessment with reference to constructive alignment.