A project-based learning Design course: experience, developments and assessment.

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Abstract

In the academic year 2005-06 the second year Engineering Design course offered by the School of Mechanical and Systems Engineering at Newcastle University was overhauled to be based entirely on project-based learning. In groups of five, students undertook a two-term design project. They were given a design brief which was developed in conjunction with a local engineering company which manufactured caravans. The design brief was changed slightly in the 2006-07 academic year. Assessment in both years was by group presentations and reports at the end of each term, and by the submission of an individual logbook. In the academic year 2007-08 the author, who had previously taught on the Design course, became module leader. Maintaining the benefits of project-based learning, group sizes were increased and innovative topics related to 'green engineering' were introduced. Assessment load was reduced and re-distributed so that rather than two end-of-term 'peaks', assessment took place more often. Priority was given to formal written feedback, provided within one week after submission. Under a title of 'greening our homes' the 2007-08 topic considered domestic scale energy generation and energy conservation measures. It was found that the students engaged with the 'green' topic far more than with the previous caravan projects. Students also commented positively on the creativity allowed them and the sense of ownership of their learning which this engendered, as well as the regular assessment and feedback. The author wished to innovate the course further, in particular by setting aside time for students to manufacture and assemble their designs. The 2008-09 design topic was entitled 'from kilobytes to kilowatts'. Here, ten groups of students, of no less than seven per group, were given a redundant computer and printer. From these they had to design and manufacture a wind turbine, which was tested in a wind tunnel at the end of the first term. In the second term, having learnt from this experience, each group was given a budget and allowed to take their designs of wind turbine forward, as they saw fit. Student feedback has been very positive for the 2008-09 course.

Background

The School of Mechanical and Systems Engineering at Newcastle University currently offers a three-year BEng degree in Mechanical Engineering together with a suite of four-year MEng degrees in Mechanical Engineering based disciplines [1]. All degrees are accredited by the Institution of Mechanical Engineers or the Institution of Engineering and Technology. As with many such degrees, engineering design is seen as a core subject. At the School of Mechanical and Systems Engineering, engineering design is taught at first and second year. First year Design is a 20 credit module which includes the study of structures, full training in AutoDesk® Inventor® solid modelling software, introduction to BS8888 and a bridge design, build and test exercise, as well as an introduction to machine shop equipment.

In the School of Mechanical and Systems Engineering, a second year cohort typically consists of 70 students. For second year Design, prior to 2005, students worked alone to design a winch mechanism, an exercise which included specifying gear ratios, sizes and materials; shaft dimensions, material and design, choice of appropriate bearings, etc. In 2005, a new module leader was appointed, with the old module leader no longer involved in the course. The new module leader made significant changes to the module. At that point in time there were four members of staff involved in the teaching of second year Design, one of whom was TJ, the author of this paper. The second year Design module was worth 15 credits and teaching took place over two terms. Four hours per week of contact time were allocated, broken down into a one-hour lecture and a three-hour slot where the students worked in their groups. Under the new module leader, students worked in pre-assigned groups of 5, on open-ended projects which allowed more creativity in the design process. Through an ongoing Knowledge Transfer Partnership (KTP) a design project was set up with a local company which manufactured Caravans (Explorer Group, Consett, UK). Linkage to an engineering company was intended to give industrial relevance to the project, while group based learning allowed 'soft' skills such as team working to be developed. Projects in academic years 2005-06 and 2006-07 concerned the design of folding bed mechanisms. Each were 'paper' exercises in that the final output included a full set of engineering drawings and a written group report.

Assessment was by a group presentation and a group report at the end of each term. Groups were told to decide on the allocation of marks for group members. In addition, in part as a method of assessing and rewarding individual contributions, each student had to keep a 'logbook' which served as a contemporaneous record of their contribution to the design project. Logbooks were assessed at three points: early in term 1 to check that fundamentals were being adhered to; at the end of term 1 alongside the group 'interim' reports; and at the end of term 2 again alongside the group 'final' reports. In summary, assessment was completely through course work and consisted of the following components: logbook; interim group report; final group report; interim presentation and final presentation.

Module developments since 2007

In 2007, following the departure of the previous module leader to a different university, TJ was appointed module leader. This also meant that the second year Design module was reduced to three members of teaching staff. Based on previous experience of teaching the module, discussions with colleagues, feedback from students and his pedagogical ideas, changes were made to the module which were hoped and intended to improve it.

Some aspects of the Design course were maintained. Group projects based on open-ended learning were continued to ensure that creativity was prioritised and that students had a sense of ownership of their project and thus of their learning. In addition, those aspects of the marking methodology based on peer-informed assessment were maintained. Assessment continued to include individual logbooks, and interim and final group reports.

However it was felt that improvements could be made. Firstly, student feedback supported comments by staff that a caravan based project was somewhat lacking in inspiration. In addition it was felt that a more socially relevant engineering project would enthuse the students more.

The 2007-08 project was entitled 'greening our homes'. The design project was to come up with three conceptual designs of domestic scale energy saving devices or energy generation devices. These three concepts were described in a 3,000 word interim report

after which one concept was taken forward and designed in full during the second term. This description formed the basis of the 3,000 word final report.

The 2008-09 design topic had a title of 'from kilobytes to kilowatts'. Here, ten groups of students, of no less than seven per group, were given a redundant computer and printer. From these they had to design and manufacture a wind turbine, which was tested in a wind tunnel at the end of the first term. No additional material or components were permitted. In the second term, having learnt from this experience, each group was given a budget of £100 and allowed to take their design of wind turbine forward, as they saw fit. In both terms, laboratory space was set aside for manufacture and assembly of the wind turbines using basic hand tools.

There were concerns over the assessment methodology and burden from previous years, especially when staff numbers had been reduced from four to three in 2007. Having two 'peaks' of assessment at the end of each term was felt to reduce student effort at the early and mid-term points. Therefore the presentations were removed, as these were felt to take up a significant amount of student and staff time when the bulk of the assessment marks was obtained from the project reports. Marks which had been allocated to the presentations were passed to a new form of assessment, named the 'Weekly Update'.

Over the course of the two terms each group had to submit seven Weekly Updates. Each Weekly Update consisted of two sides of A4. The first side aimed to summarise the previous week's project work by asking open-ended questions such as: what information sources had been investigated and what data had been gained from them; how had the design progressed that week; what challenges had been overcome; and what were the aims for next week. The intention of these questions was to allow students to see the progress they had made and appreciate their successes in the design process.

The mark allocation of these Weekly Updates was intended to encourage both individual and group effort. As there were seven Weekly Updates, so each member of a group was made responsible for one Weekly Update. This individual was allocated a mark out of 5% of the total mark assigned to them. Another 3% was assigned to the group. Weekly Updates were marked and returned together with feedback to students the week after they had been handed in. Feedback was given to each group in turn, so that each group had dedicated feedback with all the potential benefits of this. The Weekly Update was limited to two sides of A4 so that marking time was minimised and the document facilitated regular and rapid feedback.

Another change was introduced in 2007-08 to reduce what was felt to be the excessive marking of logbooks. As may be appreciated, a huge amount of staff time was needed to mark the logbooks of 70 students, each on three occasions. In 2007-08 logbook assessment was reduced to a single marking at the end of the project. During the project, checking of logbooks was made the responsibility of each member of each project team when it was their turn to complete the Weekly Update. In addition a table of criteria against which the logbooks were marked was provided as a Word document on Blackboard™. Students were encouraged to copy this table, paste it in their logbooks and offer page numbers as evidence of how the different criteria were met.

Full attendance at all Design classes was strongly encouraged through the taking of registers and it was felt that peer-group pressure also supported high attendance rates. In the first week of the module a group essay related to sustainable development was set. This exercise gave students an introduction to the forthcoming design project. A straightforward change introduced in 2007-08 was to use Blackboard™. This served as a depository for all course documentation, background reading and allowed quick

communication with the student cohort. Group size was increased slightly, from 6 in 2006-07 to 7 in 2007-08 and 2008-09.

In summary, the assessment (and % marks) for 2007-08 onwards consisted of a group essay related to sustainable development (5%), an Interim Report (33%), seven 'weekly' updates (21% + 5%), and a Final Report and Logbook assessment (36%).

The School of Mechanical and Systems Engineering gathers feedback from students on all of its modules. This allows a comparison of student opinion on all modules. From 2007-08 the current Design module leader (TJ) introduced an additional and more comprehensive feedback form for the module. The anonymised form consisted of 10 questions which were answered on a 5-point scale. In addition there were four open-ended questions where more qualitative data could be obtained. Informal feedback was gathered during the course and the ongoing interaction with the different groups provided copious opportunities for feedback.

Results

In the years in which the Design course has run in the form of group projects there have been very few students who have failed the module. Those students who have failed have not engaged and contributed to the group and thus been penalised by the group. It has always been the case that such students have failed many other modules within the second year and have left the School or, on just one occasion, re-sat the entire year.

For the years 2005-06 and 2006-07 informal student feedback showed that students enjoyed and felt they benefitted from many of the aspects of the group work. However, there was less enthusiasm about the caravan related projects, despite its linkage to local engineering industry and the 'prize' of a summer work placement with Explorer Group where the 'winning' design could be taken forward to be manufactured and included in a caravan. For these reasons the 2007-08 Design module was changed as outlined above.

For 2007-08 formal student feedback showed high satisfaction with the course. The topic of 'green' engineering, the open-endedness of the project and the creativity allowed, were all positively appreciated by the students. From the closed questions the lecturers' interest and enthusiasm in the subject was particularly highly rated by the students. From the open ended questions students positively acknowledged the creativity allowed them in the projects. Interestingly the value of the Weekly Updates was also appreciated by the students who noted how this document helped them in the design process.

For 2008-09 student feedback has been even more positive. The enthusiasm shown by the students in the 'workshop' sessions has resulted in praise from technicians and other staff who have seen the students at work. Such hands-on work has also helped, in the opinion of the majority of students, them to better understand basic engineering concepts. One commented, "there is no way I would have learnt so much from lecture material alone. Having to get the wind turbine to work was a tremendous challenge but a unique learning experience".

In terms of academic quality, it is felt that the students' designs were of a high quality. From the 2007-08 cohort, one student actually took a year out to further his group's design and the design, of a thermostatic valve for domestic radiators, is now being manufactured. Images of two wind turbines designed and manufactured by 2008-09 students are given in figures 1 and 2. Figure 1 shows a horizontal axis wind turbine produced from components and materials from a redundant printer and computer. It produced 1.4W when tested in the wind turbine. Figure 2 shows a dual-rotor, horizontal axis wind turbine, based on out-sourced components which produced 8W when tested.

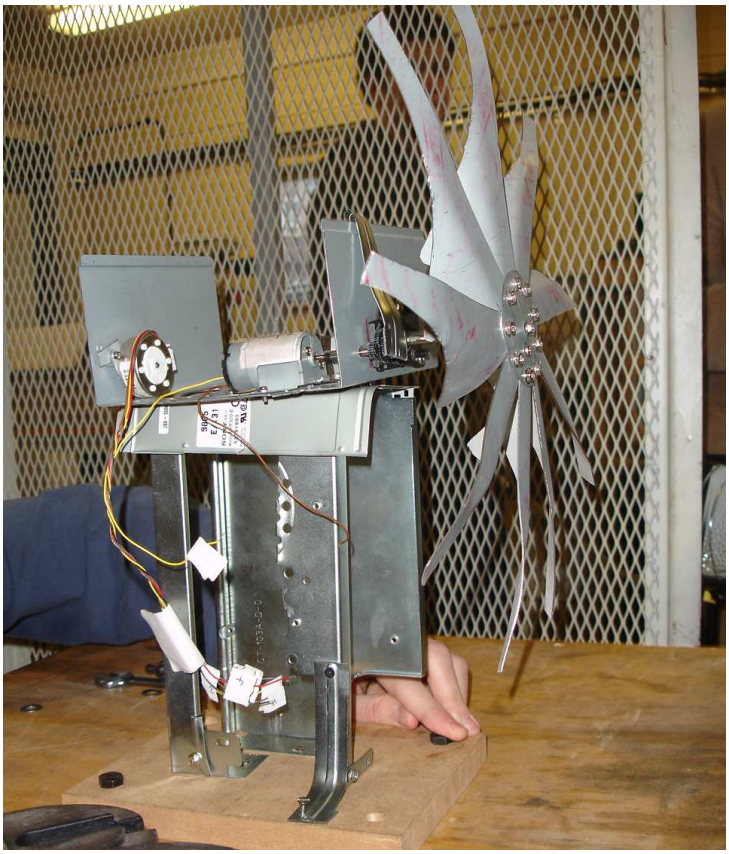

Figure 1: a wind turbine based on components and material from a redundant computer and printer

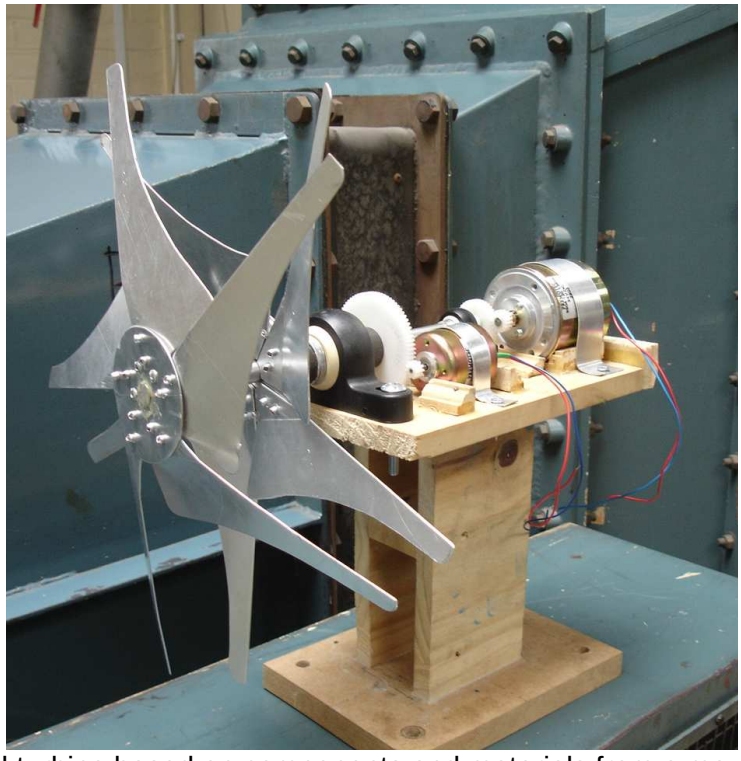

Figure 2: a wind turbine based on components and materials from a maximum of a £100 budget

Discussion

For the academic years 2005-06 and 2006-07 the students all passed but there was limited enthusiasm for a caravan based design projects. For 2007-08 and 2008-09 this was countered by a 'green' engineering theme which it was hoped would interest the students, while creativity in the design process was maintained by offering open-ended projects. Formal written feedback from the students showed that both creativity and relevance were achieved.

For 2007-08 laboratory space was requested for term 2 to allow models of the students' design to be made. Unfortunately this did not happen due to space and timetable restrictions. However it did occur in 2008-09, over both terms, and the students responded positively.

If a student contributed to the group then it was unlikely they would fail the Design module. The few failures were due to a low allocation of marks from the group, through the peer-moderated marking scheme. All failures that occurred were associated with students who performed very badly across all their modules, not just Design. The peer-moderated marking scheme was felt to be fair and to work well, supporting literature which suggests that it can give a fair assessment of student input into team projects [2].

There is a great deal of literature which supports the use of project based learning [3]. Such project based learning is said to be a constructivist pedagogy practice and to offer a student centred approach [3]. Moreover the real or quasi-real aspects of the projects are said to offer relevance to students [3]. Similarly there is a wealth of material to support the use of challenge based or enquiry based learning [4,5] in which students are given greater responsibility for their own learning. Feedback from students taking the Design course indicate that they enjoyed this challenge of designing, building and testing their wind turbines, and they felt they learnt more from this process than they would have from 'conventional' lectures. Additionally the benefits of hands-on work to engineering students have been recognised [6].

In the Design course, lecturers see themselves primarily as facilitators [6] although some lectures are given in which technical information is offered. For engineering students, the value of being an experienced and skilled team player as well as being a good engineer has been recognised [7]. It is felt that the experience gained during the Design course will help students in this respect. Moreover the shared learning aspects of group working should be appreciated too [5,8].

It is felt that the Design module has been improved year on year, with parallel increases in student satisfaction and student learning. Part of the ethos of the module can be supported by comments taken from the 2005 'Educating Engineers in Design' publication from the Royal Academy of Engineering: *And what do we need to teach? We don't. We need to give the opportunity to gain experience and awareness in multi-disciplined team environments and let the confidence of youth loose on a prepared world. What can we give students in a university department? Experience of working in multidisciplinary teams working on realistic projects.* [9]

Conclusion

The developments in a second year engineering design course have been outlined. Building on the benefits of group work and open-ended projects which permit student creativity to be exploited, the projects have been themed on 'green' engineering and include hands-on work to manufacture and then test the students' designs. Student and staff feedback has been overwhelmingly positive.

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