Implementing the CDIO Framework in a General Engineering Department: A Case Study

N. Chalashkanov

Department of Engineering, University of Leicester, Leicester, LE1 7RH, UK

ABSTRACT

The Engineering Department at the University of Leicester offers a wide range of accredited undergraduate courses including: aerospace, mechanical, general, electrical and electronics, software and electronics, and communications and electronics engineering. Design teaching is a core activity in our curriculum for all our degrees and appears at all levels (BEng, MEng and MSc) and all years of study. This report focuses on the second year design teaching, where engineering design is taught as a Design and Build group project. In the second year design module, the students are required to work in teams and the exercise provides the students with a platform to think across the disciplines and to apply their discipline specific knowledge to system design. Following the CDIO approach, we have integrated developing technical fundamentals with transferable skills and career development. In order to promote active learning and to improve the student experience we have introduced a student-staff mechanical workshop in the design teaching, where the students build their prototypes during the manufacturing stage of the project. Another recent innovation in our design teaching was to introduce career awareness, in partnership with the Career Development Service at the University, as a part of the learning and teaching activities in the module.

KEYWORDS

Design teaching, CDIO, Integrated approach, Design and Build project

INTRODUCTION

The Engineering Department at the University of Leicester offers a wide range of accredited undergraduate courses including: aerospace, mechanical, general, electrical and electronics, software and electronics, and communications and electronics engineering. Design is one of the core activities that professional engineers undertake (Dym et al., 2005) and teaching engineering design is a central theme in our curriculum at Leicester (Dong et al., 2009). The requirement for design to be at the core of the engineering education is also emphasized in the UK-SPEC (2013) of Engineering Council Standard.

Our curriculum has recently undergone a major review, which affected all our degrees. This report focuses on the second year design teaching and the changes that have taken place as a result of the implementation of the new curriculum. Thorough description of the old curriculum can be found in Dong (2009). As a result of the new curriculum, the duration of the design module in the second year has been increased from one semester (the second semester of the second year) to two semesters. The credits for the module have also been increased from 10 credits (under the old curriculum) to 20 credits (under the new curriculum), respectively. In the first semester the students have 2 hours of practical work and 1h lecture per week and in the second semester the students have 6 hours of practical work and no lectures.
IMPLEMENTING CDIO CONCEPTS – SECOND YEAR DESIGN

Design Task

Project based learning has been implemented in the design teaching in the second year of study at Leicester since the mid-1990s (Dong et al., 2009). The projects originally started as “partial design” (Pugh, 1991) and then evolved to integrated system design (“total design”) in the early 2000s. The CDIO concepts (www.cdio.org) have been adopted in our design teaching since the late 2000s (Dong et al., 2009). The project titles since the implementation of the CDIO concepts are given Table 1.

The students are grouped in design teams and the teams need to design, manufacture a prototype and compete for the performance of their prototypes with each other and against the specifications given.

Table 1. Design tasks in the Department of Engineering at Leicester implementing the CDIO concepts

<table>
<thead>
<tr>
<th>Year</th>
<th>Design task</th>
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<tbody>
<tr>
<td>2009</td>
<td>Water turbine</td>
</tr>
<tr>
<td>2010</td>
<td>Path following vehicle</td>
</tr>
<tr>
<td>2011</td>
<td>Hovering robot</td>
</tr>
<tr>
<td>2012</td>
<td>Unmanned aerial vehicle (UAV)</td>
</tr>
<tr>
<td>2013</td>
<td>Sky crane</td>
</tr>
<tr>
<td>2014</td>
<td>Wind turbine</td>
</tr>
</tbody>
</table>

Our latest project was to design and build a model wind turbine out of a 0.5 m x 1.0 m x 0.7 mm thick aluminum sheet. The aim was to operate the model turbine at a wind speed of 15m/s to generate an electrical power output for the purpose of running a device such as a mobile phone, as a minimum.

The project specifications were the following:

1. Maximum overall size: 0.4 m x 0.4 m x 0.4 m
2. Fitting to a standard base plate, dimensions given
3. Featuring an eye bolt at the top of the structure
4. Maximum output voltage: 24V DC
5. Featuring a two-terminals chock block electrical output
7. Free-stream wind speed: 15 m/s ≤ u ≤ 18 m/s.
8. Test environment: Charles Wilson wind tunnel closed-walls test section, 4.8m (long) x 1.15m (wide) x 0.84 m (high).
9. Two PP3 9V batteries can be used to power the electronic components of the system. However, batteries are not allowed anywhere in the power output system
10. Only permanent magnet DC motors should be used as generators.
11. The groups must design and manufacture their own turbine rotors and any supporting structure from the 0.5 m x 1.0 m x 0.7 mm thick aluminium sheet. No other structural material is allowed, other than nuts and bolts as fasteners.
12. The system must have a storm protection blocking brake that is active at u∞ ≥ 17m/s.
13. The system must safely withstand an 18 m/s wind.
14. Monitoring:
   • Rotor Speed (rpm)
- Wind Speed (m/s)
- Output Voltage (V)
- Output Power (W)
- Estimate of the overall electromechanical efficiency, based on the available wind power
- Operational status (standby, generating, blocked (due to storm conditions), no wind)

**Design teams**

It is noteworthy that the composition of the design team has not changed over the years (see Dong et al., 2009), although the number of students involved in the second year design module has increased significantly (from approximately 70 students in 2007-2008 academic year to more than 200 students in the 2013-2014 academic year) and new degree courses have been introduced in our teaching, e.g. aerospace engineering. The composition of the design teams is given in Table 2.

<table>
<thead>
<tr>
<th>Team manager (1-2)</th>
<th>4th year MEng students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer (1)</td>
<td>Visiting Design Professors</td>
</tr>
<tr>
<td>Team supervisor (1)</td>
<td>Academic staff member</td>
</tr>
<tr>
<td>Technical support (2)</td>
<td>Mechanical technician</td>
</tr>
<tr>
<td>Team members (6-10)</td>
<td>Mechanical sub-team</td>
</tr>
</tbody>
</table>

The team manager(s) are one or two 4th year students who perform the human resource and the project management. By doing these, the 4th year students get hands-on experience with the application of management principles in a real-life situation.

There are currently six Visiting Design Professors (VDPs) in our department. The VDPs are approved and supported by the UK Royal Academy of Engineering. The VDPs are distinguished senior engineers working in industry. Their role is to act as customers for the design prototypes. The VDPs interview the students on three occasions during the project progress and provide assessment and feedback to the students. The VDPs also present lectures on various aspects of the design process from an industrial perspective.

The team supervisor is a member of the academic staff who provides technical advice to the team throughout the project development. The team supervisor also assesses the concept selection report and the final design report written by the team.

The electrical and mechanical technicians provide technical advice to the design teams and also manufacture some of the components of the system (if required).

The team members are composed of up to ten 2nd year students who carry the design task. The percentage of electrical, mechanical and software students within the team varies from year to year depending on the number of students in the cohort of each specialization. However, at least one student of each of the main specializations must be present in each team.
Key activities

Following the CDIO initiative our design projects cover all four stages of the design process: (1) conceptual design; (2) detail design; (3) implementation; and (4) operation. A flow-chart of the key design activities is given in Figure 1.

The project started in early October with the announcement of the design task and the corresponding design specification. The first task for the 2nd year students was to apply for a “job” position within the team. In order to do this they had to write their CV and cover letter. The career awareness was introduced in the design module in partnership with the Career Development Service at the University of Leicester. The aim was to prepare the undergraduate students for the job application process after their graduation. As a part of the preparation process, two lectures were presented to the 2nd year students by an expert from the Career Development Service. The first lecture was on the CV and cover letter writing process and the second one was on the job interview process. In the meantime the 4th year students participated in a couple of workshops, which aimed to facilitate their understanding of the job application process from a human resource management point of view. The selection process finishes with assigning roles within the team to all team members by the
4th year students (team managers). We believe that this simulated job application process provides our students with important transferable skills in accordance with the CDIO concepts.

The key activities involved in the conceptual design stage, the embodiment of the concepts and the detail design stage are thoroughly described elsewhere (Dong et al., 2009).

In order to promote active learning and to accommodate for the increased number of students (teams) and hence the increased number of prototypes to be built, a staff-student workshop has been introduced in our design teaching in the academic year 2013-2014. The 2nd year students were required to manufacture most of the components for their prototypes by themselves in the workshop under the supervision and the guidance of the departmental technicians. The majority of the students provided a positive feedback about the staff-student workshop in the latest student feedback survey and acknowledged that they have acquired new practical skills.

The wind turbine prototypes had been tested in the two wind tunnels available in the Department of Engineering at the University of Leicester. The testing was done under a strict schedule since there were 24 design teams and hence 24 prototypes to be tested. All groups managed to produce a complete prototype of a wind turbine and to test it in accordance with the announced schedule.

The Design Competition was held on the 26th March 2014 and involved a structural test of the turbines. The results from the final aerodynamic tests in the wind tunnel have been considered as performance indicators towards the final competition. The Design Competition was assessed by the VDPs as a panel of judges.

CONCLUDING REMARKS

We have implemented an integrated approach to design teaching in a General Engineering department adopting the CDIO concepts. The design and build project of an integrated system provides our students with a basis to think across discipline-specific fundamentals. The team work nature of the project provides the students with an opportunity to develop their personal and interpersonal skills. The learning and teaching activities involved in the module require that the students develop their team work, leadership, presentation and report writing skills. We have introduced career awareness and a staff-student workshop in our design teaching in an attempt to cover the entire range of professional skills the future engineers require. The selection of a new project task each year is an ongoing issue.

ACKNOWLEDGEMENT

The author thanks the Academic Practice Unit at the University of Leicester for the travel grant provided to attend the CDIO 2014 Conference.

REFERENCES

www.cdio.org


BIOGRAPHICAL INFORMATION

Dr. Nikola Chalashkanov is Teaching Fellow in the Department of Engineering, University of Leicester, UK. He is the 2nd year Design module coordinator and the CDIO leader for the University of Leicester.

Corresponding author

Dr. Nikola Chalashkanov
Department of Engineering
University of Leicester
University Road
Leicester, UK, LE1 7RH
tel. + 44 (0) 116 223 1870
nc137@le.ac.uk

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