What Makes the Process Engineering Design Project Different

M.M. FARID
Chemical and Materials Engineering, The University of Auckland, Private Bag 92019, Auckland, New Zealand. m.farid@auckland.ac.nz

S.D. OAKLEY
Chemical and Materials Engineering, The University of Auckland, Private Bag 92019, Auckland, New Zealand. sd.oakley@auckland.ac.nz

B. THOMPSON
Beca Simon Ltd., Consulting Engineers, PO Box 5647, Auckland, New Zealand. bthompson@beca.co.nz

J.J.J. CHEN
Chemical and Materials Engineering, The University of Auckland, Private Bag 92019, Auckland, New Zealand. j.chen@auckland.ac.nz

KEYWORDS: *process engineering design, project, accreditation, team and individual work, assessment*

ABSTRACT: *The Process Engineering Design Project is a requirement of an accredited chemical engineering degree programme. At the University of Auckland, it is part of the final year of a four-year programme and carries the weight of three-fourteenths of the year's work. Students in teams of 4 or 5 carry out the design of an assigned process plant covering process selection, site location, plant layout, piping and instrumentation diagram development, detailed process and mechanical design of some nominated pieces of equipment, hazard and operability analysis, environmental impact assessment, cost estimation and economic analysis. The team submits a joint design report at the end of the year for staff evaluation.*

At the University of Auckland, the design topic is chosen such that the design is research-based, often involving recently developed technologies. Because of this, the students are highly motivated. Students integrate all the knowledge they have gained from courses they have studied to date. The final grade awarded to individual students is based on on-course assessments, oral interviews, the joint design report, and taking into account confidential submissions provided by fellow team members.

1 INTRODUCTION

Design is a very important feature in the Auckland Bachelor of Engineering programme. While elements of design are incorporated in almost all the courses, those courses that are specifically designated as Design are aimed at the analysis techniques and using the knowledge learned in other courses. These courses enable students to acquire further knowledge on their own and develop self-learning skills. The students should gain an understanding of professional, ethical and social responsibilities. They also develop the ability to communicate effectively. As the process of engineering design involves a heuristic approach, teamwork and project management, the students must be given the opportunity to learn through personal experience. The students will integrate all these knowledge and techniques into synthesising a process or product, producing pragmatic solutions to real life problems with clearly defined objectives.

The process engineering design project is part of the requirements of an accredited chemical engineering degree programme. The Institution of Chemical Engineers, London, (IChemE) accreditation requires that the following five learning outcomes are achieved by the graduates:

1. Mathematics, underlying science (chemistry, physics, biology) and associated engineering discipline
2. Core chemical engineering
3. Design
4. Social, environmental and economic content
5. Engineering Practice

In this paper, only Topic 3, Design, is specifically addressed. Furthermore, it will consider only the Design Project undertaken in the final year of the four-year degree programme. However, it is obvious that Design is intrinsically linked to the other four topics.

The IChemE defines Design as "The creation of a process, product or plant to meet a defined need", and the learning outcome achieved is given as "Graduates must display competence in chemical engineering design, which requires bringing together technical and other skills, the ability to define a problem and identify constraints, the employment of creativity and innovation. They must understand the concept of 'fitness for purpose' and the importance of delivery".

At the University of Auckland Chemical and Materials Engineering Department, while the following course titles include the word "design", elements of design are contained in almost all the courses covered in the programme.

Year 1:

Engineering Design 1A ($^1/_{14}$ of the year's work)

An introduction to engineering design and the design process. Overview of the practice of engineering design. 3-D visualisation and representation, graphical communication and graphical problem-solving. Exercises in conceptual design and computer-aided drawing.

Engineering Design 1B ($^1/_{14}$ of the year's work)

The design process and introduction to production development. Projects in preliminary design; conceptual design and 3-D solid modelling techniques.

Year 2:

Process Design 1 ($^1/_{14}$ of the year's work)

Safety issues in chemical plant design. Selection and specification of nominated items of equipment, e.g. reactors or pressure vessels. Mechanics of solids and approximate analysis of stress and strain. Design of thin-walled pressure vessels. Applications to the design of pressure vessels, reactors, piping and heat transfer equipment.

Year 3:

Process Design 2 ($^1/_7$ of the year's work)

The nature and function of design-process conception, alternatives, constraints and their simulation. Raw materials, safety and environmental considerations. Flow sheet representation of information. Separation systems, heat exchanger networks, and specification of equipment. Process economics and project documentation.

Year 4:

Design Project ($^3/_{14}$ of the year's work)

Specification, planning and executing a specific process design project. The detailed considerations in the project to include environmental impact, safety and occupational health issues, materials selection, process energy demand and efficiency, costing and economics, process start-up and operation.

In the Design courses in the first three years of the degree programme, the students learn the basics and the different aspects of engineering design. The students are exposed to a range of lecturers comprising academics with industrial experience and practising design engineers.

The Design courses in Year 1 are common to all engineering students. It introduces students to Design through graphical skill exercises and assignments, design and build projects, and conceptual design assignments. The students undertake design-and-build projects in teams of three. Examples of these projects include:

- a truss where students are given hot dog sticks, bolts, nuts and glue to design and build a truss which is tested to destruction.

- a device to move an object or send a projectile as far as possible.

Students will need to produce a poster and make an oral presentation. A written report and supporting calculations are also submitted. During the process of analysis, design and construction, the students learn through their discussions and develop teamwork skills.

The Design courses in Year 2 and Year 3 of the Chemical and Materials Engineering programme provide students with the basic knowledge in Process Engineering Design. In Year 3, the course will enable students to carry out a preliminary process appraisal involving a process conception, a selection among alternatives, flow-sheet preparation, some equipment selection, costing, economic analysis and design project reporting. Plant safety and flow-sheet optimisation will also be covered. Standard design packages such as HYSYS and HYSYM are introduced. The students work on a team-based mini-project during the second semester of Year 3.

This paper is concerned with the Design Project in Year 4, the final year of the degree programme, which is intended to provide an integrated approach to chemical engineering and encourage the students to apply chemical engineering principles to problems of current and future importance, taking into consideration sustainable development, safety, ethical, environmental and other local issues. Often, information available may be uncertain or even conflicting. Students are encouraged to evaluate what limited information is available and arrive at choices or decisions. The Design Project also serves to develop students' skills in professional communication and team work. In the first semester of their final year, the students are taught further tools for process synthesis and evaluation. The students are required to submit two independent assignments. In the second semester, the students work in teams on an assigned design project topic.

2 DESIGN PROJECT

The Design Project is carried out as a team exercise where the class members are assigned by the academic staff into teams of four or five students. In the team selection, account is taken of factors such as academic ability, staff's knowledge about the students, ethnicity, etc. The work involved covers process design, economic evaluation and detailed design of selected items of equipment. The students will participate in team management, discussion and design work to the satisfaction of their fellow team members and to the staff.

The students are encouraged to develop a critical perspective on problems and apply their initiatives in terms of synthesis and analysis, and develop a logical approach to problem solving with creativity, sound judgement and clarity of thoughts. The students will then be able to apply the scientific, technical and other knowledge taught elsewhere in the course, as well as any knowledge gained through research and self-learning.

Students make use of software packages available on the School of Engineering network, these include HYSYS, HYSYM, energy and water minimisation packages such as Pinch Technology. These packages are introduced in Year 3.

3 TOPIC FOR THE DESIGN PROJECT

Each year, the topic for the Design Project is deliberately chosen such that it is not viewed as a paper exercise employing old-fashion or mature technologies. The topics are often recently developed technologies and hence there is not much data available. The team members need to carry out in-depth literature search on possible processing routes that may replace existing or obsolete technology in order to select the most suitable process. The students also need to do a considerable amount of research on the technologies and obtained the necessary design data. Furthermore, the topics are chosen such that they involve real processes and are real life problems linked to local New Zealand industries and are of national relevance. The students can relate to them, finding them challenging and very rewarding, and are hence very highly motivated.

The following are the topics for the past few years.

1998: Casein manufacture
1999: Manufacture of cheese, whey proteins and butter
2000: Wet air oxidation

2001: Production of biodiesel from tallow
2002: Sulphuric acid manufacture
2003: Biofuel production from plastics

4 INVOLVEMENT WITH INDUSTRY

As the selected projects are related to the local industry, the students are required to visit a number of relevant industrial plants. These visits have a very positive impact on their design process, as they are able to compare what they design with what is actually practised. It also provides additional insights when evaluating the safety, environmental, social and various other aspects of their design.

In addition to having a conventional academic staff member teaching the course, we also have a "Designer-in-Residence" who is a chemical engineer in private practice playing a major role in the teaching. We regularly invite speakers from the industry to give specialised lectures on different topics related to the project thus providing students with industry-based knowledge. Furthermore, we are able to have a practising engineer from a major engineering consulting firm to participate in the design project discussions and evaluations throughout the course. This participation includes advice to the students on presentation of their work, practical details for equipment design and layout, sources of design information and both general and process-specific "know-how". The industrial input helps provide the students with a practical perspective on the plant design process.

5 TYPICAL SCOPE OF THE DESIGN PROJECT

As an example, a typical scope of the Design Project is listed as follows:

(i) Process Design
- a. Materials balance – with the flow and compositions of all the streams calculated and tabulated
- b. Process flow diagram (PFD) for the complete plant with all major items of equipment. The operating temperatures and pressures for each unit should also be indicated.
- c. Materials of construction, and provide chemical, corrosion and economic information to justify the selection
- d. Energy balances for the major operations with preliminary estimates of the energy requirements for the total plant
- e. Equipment schedule including duty specifications for all major items of equipment
- f. Dimensional sketch of the plant layout, with attention to access and water treatment needs. Carry out a preliminary audit of the process to identify major environmental impacts
- g. Indicate safety measures required bearing in mind the nature of the materials being handled
- h. Estimate the installed capital costs of the plant. Estimate the pay-back period based on the value of the product(s) in the current economic climate, and estimate the plant operating costs. Assumptions are made about the time taken to build the plant, and the scrap value after a specified operational life.

(ii) Chemical engineering design

Design of a number of specified items of equipment. This includes both process and mechanical design and sketches suitable for submission to a drawing office. Students are encouraged to work individually or in pairs within the team.

(iii) Process Control

Complete Piping and Instrumentation Diagrams (P&ID). Apply Hazard and Operability Studies (HAZOPS) techniques on this P&ID to ensure safety during start-up and shutdown, and during operation.

6 TEAM WORK AND ASSESSMENT

While the students work in teams, each member of the team has to work individually in the design of some specified items of equipment. This is in addition to the two individual major design assignments which account for 20% of the final grade.

Working in teams is a very important element in professional engineering. Chemical engineers usually work as members of a design or management team and their productivity and effectiveness is strongly dependent on team work. One of the major aims of our Design Project learning experience is to sensitise students to the importance of this factor. 30% of the grade that the students receive will be based on a written submission and formal interviews. The written submission from each student is treated with complete confidentiality. There are three parts to the submission:

(a) An individual accomplishment report: This report provides a review of their own personal contribution, and a self-assessment of their strengths and weaknesses.

(b) A peer-review report. This report provides an assessment of the specific contribution of the other members of the team including an evaluation of the strengths and weaknesses of the individuals.

(c) Assessment of the value of the team effort: The student reports on their views on the value of the Design Project in their own personal development. They should also describe their own understanding of the nature and purpose of chemical engineering design.

The academic staff, when evaluating the formal written submissions, will take the following into consideration:

(a) How well it is written

(b) How mature and convincing the student's judgements appear.

(c) How accurate are the statements and conclusions based on the examiners' knowledge of what has been done by the team and the individuals in it and on the submissions of the other members of the team

Two formal interviews are conducted with each student. A preliminary oral interview will take place in late August when individual student will be asked to show their contributions. They are expected to provide a full description of their processes including a process flow diagram, piping and instrumentation diagram, complete mass and energy balances and a preliminary costing. After the Design Report is submitted about mid-October, a final oral examination takes place in early November. The interviewing panel consists of all those with direct teaching responsibility for the course, and any academic staff member who is available. Individual students are interviewed and questioned on the content of the Design Project Report submitted by the team and on their individual contributions. The grade awarded in this category will also take into consideration the observations and judgements made by the academic staff during the course and from informal discussions with the team members.

All students are expected to keep a logbook showing their individual contribution. This log book is submitted with the design report and is taken into account when assessing the student' individual effort.

The grade awarded to each student has the following components:

1. Preliminary piping and instrumentation diagram of a specified process, 10%
2. Design of a specified piece of equipment, 10%
3. Design Project Report (Team work), 50%
4. Oral examination, individual accomplishment report and peer-review report, 30%

7 CONCLUDING REMARKS

The topics chosen for the Design Project are real-life problems of direct relevance, particularly to the New Zealand environment. The topics are of a nature such that the students are required to carry out significant research in the process selection, as well as in obtaining the data for design calculations.

During the course of the Design Project, students are supervised and guided by staff members, as well as by practising design engineers. Furthermore, visits to related industrial plants are incorporated in the course so that the students gain practical insights into plant design and plant operation.

The grade awarded to each student has the following components: observation and judgement by the staff throughout the course; independent work submitted by individual students; the Design Report submitted by the team; oral examinations on the team work and individual contributions; and confidential formal written submissions by each student which contained assessments of the accomplishments by themselves, as well as by fellow team members, and an assessment of the value of the team effort.

The final year Design Project at The University of Auckland Chemical and Materials Engineering Degree Programme provides senior students the opportunity to work in teams in a manner that emulates real life professional engineering practice. The last accreditation of the Degree by the Institution of

Chemical Engineers (London) was in August 2000 and the accreditation panel reported that the Design Project more than adequately meets IChemE requirements for the MEng degree in the UK.

ACKNOWLEDGEMENTS

We are grateful to Beca Simons Ltd. for providing the services of an experienced design engineer at no cost to the Department.

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