An Enquiry-Based Chemical Engineering Design Project for First-Year Students

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Abstract

This work describes the student-centred approach followed in the Design Project in the first-year Chemical Engineering course at The University of Manchester. This new approach has allowed students to reinforce and apply subject knowledge, whilst developing key skills such as teamwork and communication. The introduction of peer-assessment also provided students with the opportunity to make informed decisions and judgements and to learn from their peers. Design tasks aimed at developing critical thinking and problem solving skills within an industrial setting were employed. The project has been successful at improving students' engagement and sense of responsibility within a more active learning environment.

Background

Designing a chemical plant, a product or process can be a highly creative activity. Although restricted by the physical world and what can be achieved, the only initial restrictions in the design of a chemical plant are imposed by the raw materials and the end products considering that the path followed to go from one to the other is quite open (Figure 1).

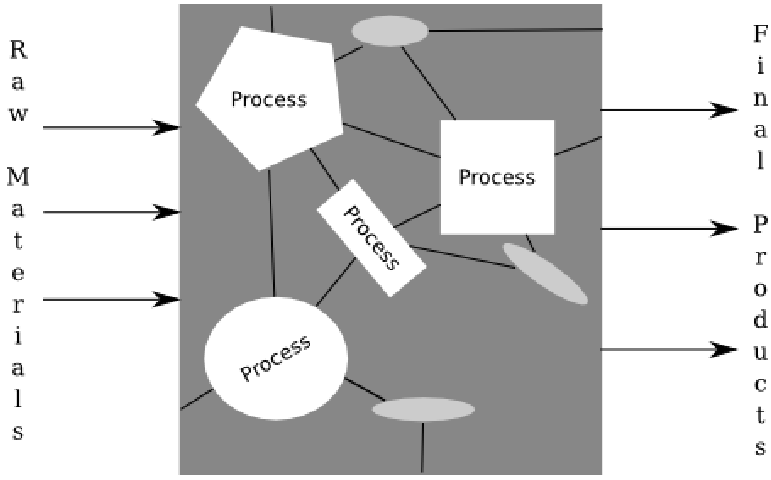

Figure 1 Designing a chemical plant consists mainly in choosing the path to get from raw materials to final products and requires decision making, creating solutions and integrating different concepts.

From this perspective, a Design Project lends itself naturally to teaching methods such as Enquiry-Based Learning where students once given an open-ended problem have to look for a way to solve it and during the process learn different concepts and ideas. In more general terms, Problem-Based Learning or Enquiry-Based Learning can also provide a framework in which students have opportunities to develop essential skills as they are required to obtain, communicate and integrate information (Duch *et al*. 2001).

There have been some adjustments on the types of problems that are being used for Design Projects, especially in the final year of the curriculum. Shaeiwitz and Turton (2006) pointed out that as the industry moves from a commodity-chemical-based to a product-based industry the nature of the problems chosen for the final year design in future years ought to change. This, together with requirements for new graduates to have transferable skills, has made it necessary to modify how the Design Project is taught. The role of the Design Project as a way for students to develop transferable skills is also supported by Kentish and Shallcross (2006) in their comparison of final-year design project curricula in different Chemical Engineering departments across Singapore, Australia and the UK.

The Design Project is a key module in the Chemical Engineering course at The University of Manchester. It is part of the curriculum in each year. In the first year, the module is taught in two parts. The first part occurs during the first week of the first semester and aims to introduce new students to the dynamics of the Chemical Engineering course.

The second part takes place during the last two weeks of the second semester and it is organised as an intensive module in which students are fully immersed in the project, as no other teaching is timetabled. This case-study concerns the Design Project carried out in the second semester of the first year.

Rationale

The main purpose of the Design Project in the first year is to integrate concepts and knowledge learned from different modules throughout the year, thereby providing a framework for the design of chemical plants and processes. It also helps to make students aware of the different roles that chemical engineers can play in industry.

Traditionally, the approach to the Design Project has been based on a problem with quite fixed boundaries. Although the project has not been planned around group work, most of the time students were found working together. The design project required students to perform a number of tasks related to the different stages of the process of designing a chemical plant. Students were asked to present individual reports for each task at the end of each working day. Given the fact that some students worked together during the task, it was difficult to tell who had contributed to the work and by how much; inevitably, the situation lent itself to collusion. On many occasions, some students had resorted to plagiarism as a way forward. Students mentioned in their feedback that the short time to perform each task had led to too much pressure, resulting in plagiarism. These events and facts prompted the staff to take a different approach to the project.

The new approach to the Design Project intended to make use of methods such as Enquiry-Based Learning to provide students with a learning experience that reinforces their knowledge in an integrated way and also provided opportunities to develop transferable skills. Thus, the new approach consisted of a more open-ended problem in which students could explore different routes, make decisions and find different solutions depending upon those decisions. The project also tried to simulate an engineering working environment by using role-playing. Finally, more emphasis was given to the importance of work presentations both in oral and in written form.

The new student-centred approach of this Design Project provided students with an environment in which they were able to:

- apply subject knowledge and relate it to an industrial situation
- identify issues and research relevant information
- develop and apply effective and efficient problem-solving strategies
- evaluate situations, draw conclusions and make decisions
- work in teams
- communicate well (both verbally and in writing)
- meet deadlines

Details of the approach taken are described below.

Approach

The Design Project proposed in this project comprised several tasks and stages as shown in Figure 2.

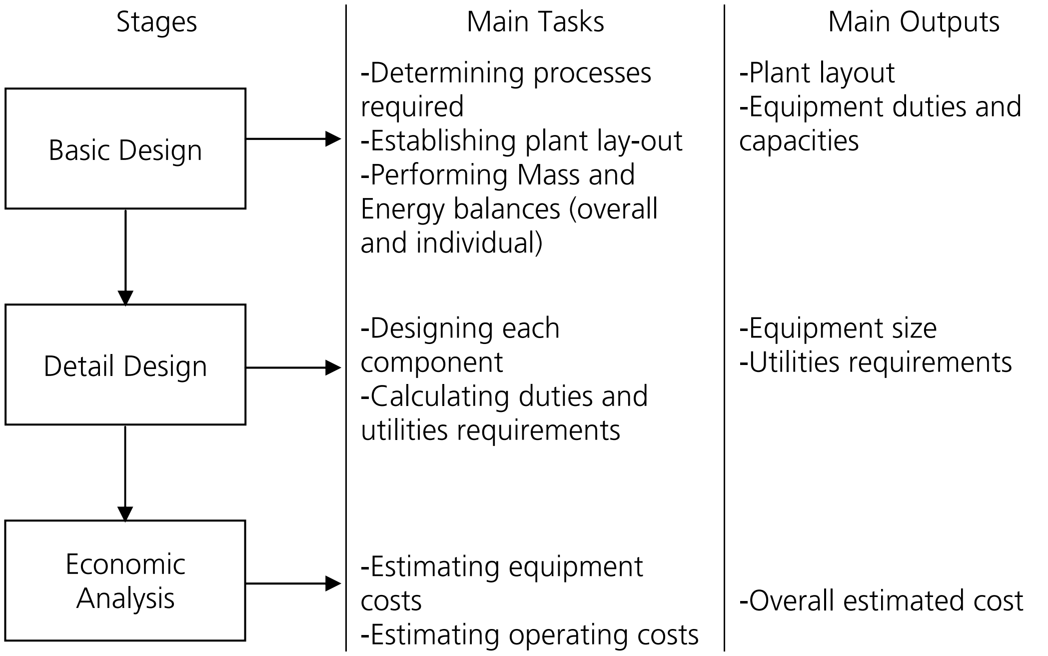

Figure 2 An overall description of the main stages, tasks and expected outputs of the Design Project in the first year chemical engineering course, cohort 2006.

The initial stage involved a conceptual design that consisted of structuring the plant layout, with all the processes required, and determining overall mass and energy balances, accounting for both the feed of raw materials and the resulting products. At this stage, it was important to determine what units or equipment was required, including utilities. These all form the basis for the more detailed design that followed. In the next stage, students were asked to design in more detail separate units or equipment. Each unit or piece of equipment had a set of variables and also constraints determined by the initial conceptual design. These variables resulted in the production of a wide range of different designs. At this stage, it was also necessary to determine the utilities requirements. Finally, an economic analysis was conducted to account for the equipment and plant operating costs, which were linked to the original choice of design variables.

The 2006 cohort consisted of 140 students. The work was carried out in small groups (10-12 students) in which students took different roles. The use of role-playing has been successfully used by Shaeiwitz and Turton (2006) in their final-year Design Project and has been introduced in some of the tasks associated with this project.

The academic staff played a supporting role and acted as consultants to the groups. Also, postgraduate facilitators were present during group work and gave assistance with technical and organisational issues.

The Design Project was carried out over two weeks at the end of the second semester. Each day there was a briefing session in which tasks were presented and some guidance was given regarding the most important aspects of the problem. These briefing sessions were also used to clarify difficulties or common misconceptions observed from previous tasks. Group work commenced after the briefing sessions. Students were given specific deadlines and were expected to manage their time and resources accordingly. At the end of each task students were asked to submit their work.

Details of the approach taken in two of the main tasks comprising the project are as follows:

Reactor Design Task

One of the major components of the project was the task of designing the reactor, which in this case was the core of the production process. The task was expected to be completed in one day and students were asked to present a specific set of results, which were dependent upon their particular choice of conditions and parameters. Potentially, this meant that each student would have a different design. Although the students were working in teams, a separate design was expected from each student. The individual work was assessed through a peer-assessment scheme for which guidelines were also provided. The peer-assessment aimed to give individuals the opportunity to not only make an informed decision on the quality of a piece of work but also to be able to discuss technical issues of choices and methods with a peer. Details of the assessment criteria are given below in the section concerning assessment.

Distillation Design and Economic Analysis

The design of the distillation process and the economic analysis were performed and assessed as group work. For these tasks, groups were divided into smaller teams (each group formed typically three to four teams). Each team was given different design parameters and asked to discuss its findings with the other teams. The working groups were expected to compare and contrast the results of the team findings and make recommendations. The groups were then asked to report on these results. The use of different design parameters for each team was intended to develop and improve communication between students and teams within the group, and at the same time make students aware of the different roles that an engineer could play within an industrial environment. Additionally, it was found that by having different sets of parameters specified for each team issues with collusion and plagiarism were less problematic. Kentish and Shallcross (2006) also found that when a few different topics were used for final-year Design Projects with the same cohort collusion and plagiarism were less evident.

Assessment

Different assessment strategies were used throughout the project. In previous years, assessment was based only on individual work and was carried out by the instructors. On this occasion, peer-assessment was included as one of the major tasks of the project. As Biggs (2003) pointed out, peer-assessment allows students to gain the ability of making judgements according to established criteria, which is a skill often overlooked in most teaching and learning activities. Furthermore, students were assessed on their individual contributions and the work presented as a group, aligning assessment with the purpose of the group work.

The Reactor design task used a peer-assessment scheme where one student evaluated the work of a peer using a marking scheme that accounted for the use of correct methods and answers (33%), the presentation of the results (33%) and finally, further explanations and reflections on the rationale of their choices (33%). The marks had to be agreed between both parties to ensure accountability in the marking process.

The assessment of the Distillation Design and Economic Analysis tasks was mainly based on the collective work of the group presented as a whole. This assessment was carried out by the instructors and took into account the work submitted by each team and the work of the group as a whole during the presentation of the individual team results.

Conclusions

The Design Project for the first-year students required them to make use of subject knowledge learnt over the whole academic year. The new approach taken for the teaching of the Design Project has provided students with a learning experience that brought together not only the subject knowledge previously acquired but also opportunities to explore new areas of knowledge and develop their critical thinking and problem solving skills. Tasks based on teamwork have improved students' engagement with and reflection on their own work. They also have encouraged students to act responsibly as the work of the group required input from all members. Students have also developed their ability to communicate effectively with their peers and have improved their time-management skills when compared with previous years. Overall, this has been a successful experience for both students and staff in a more active-learning context.

References

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