Developing tools for teaching Chemical Engineering unit operation design

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Abstract: The teaching of chemical engineering unit operation design in a project week environment is essential for a synoptic course and enhanced student learning. This mini-project, funded by the Engineering Subject Group of the Higher Education Academy aims to improve student awareness of resources available for Chemical Engineering design.

There is a wealth of online and paper-based resources for Chemical Engineering Design, however students are often unaware of their existence and are reluctant to search for them. A significant amount of time when supervising design projects is therefore spent directing students to resources where they can find information. The rationale behind this work is that by providing a more thorough grounding on the resources available in their 2nd year, students will be better prepared for their IChemE accredited design project and for life as a Chemical Engineer.

The 2nd year design week, which involves a task based design focussing on prescribed unit operations in a defined process, is ideal for directing the students to design resources relating to both underlying theory and practical design of unit operations and is used as an example of how different resources can be introduced and used in a design exercise. This paper discusses the online learning module that has been created to raise student awareness of the online resources available. Questionnaires were used to show the impact that the learning module had on the 3rd year design project.

Introduction

The teaching of chemical engineering unit operation design in a project week environment is essential for a synoptic course and enhanced student learning. This work is part of a project funded by the Engineering Subject Centre of the Higher Education Academy and aims to collate design resources relating to both underlying theory and practical design of unit operations and present the material in an accessible way for students.

Background and Motivation

Experience of supervising a steam methane reforming 3rd year design project group in academic year 2009/10 highlighted the strengths and weaknesses of the way unit operation design is currently taught to first and second year students. Many 3rd year students struggle to design non-standard items as they do not know where to look to find the information required. Teaching 2nd year tutorial classes in Chemical Reactor Engineering has also highlighted how much better the students respond to realistic situations (as opposed to, for example A → B).

One of the key aims of this project was therefore to develop an online learning module for students to raise awareness of the online resources available for design of unit operations.

The 2nd year Chemical Engineering Design Course is used as a platform to assess this work. This part of the module includes 8 two hour taught sessions (combination of lectures and tutorials), followed by
a design week. Design week is a Project Based Learning (PjBL) environment in which groups of students design basic unit operations. It is a task based design, focused on prescribed unit operations in a defined process, so is ideal for directing the students to the wealth of new online design resources relating to both underlying theory and practical design of unit operations. This prepares the students for more open-ended use of the resource in their problem based 3rd year design project. The synoptic nature of the project week makes it a vital part of the curriculum to ensure student understanding.

PjBL has been defined in many different ways; however perhaps the most useful is “Project-based learning begins with an assignment to carry out one or more tasks that lead to the production of a final product - a design, a model, a device or a computer simulation. The culmination of the project is normally a written and/or oral report summarizing the procedure used to produce the product and presenting the outcome” (Prince and Felder, 2006). Within the UK, PjBL has been facilitated by government investment in university-based Centres for Excellence in Teaching and Learning (CETLs) and in particular through the PBLE (problem based learning in engineering) project (Engineering Subject Centre, 2003). The project produced a useful guide, including several case studies and advice for designing PjBL courses (Crawford and Tennant, 2003).

The effectiveness of PjBL in engineering is difficult to assess, however Mills and Treagust (2003) state that “Students who participate in project-based learning are generally motivated by it and demonstrate better teamwork and communication skills. They have a better understanding of the application of their knowledge in practice and the complexities of other issues involved in professional practice. However they may have less rigorous understanding of engineering fundamentals”. This statement demonstrates why many institutions adopt a blended learning approach, combining traditional lectures with PjBL (or problem based learning, PBL) work (Rossiter et al., 2010, Graham and Crawley, 2010, Mills and Treagust, 2003, Crawford and Tennant, 2003). This is perhaps due to the technical nature of engineering - lectures are used to deliver technical content including science and engineering fundamentals, whereas the PjBL is used to apply that knowledge in a design context. This course takes just that approach, combining lectures, tutorials and PjBL work.

Methodology

Surveys

It was important to find out what previous year groups thought of their project week and design project and the resources available to them. The 2011 3rd year cohort were surveyed to find out what they thought of their 2nd year design week, focusing particularly on how well it prepared them for their 3rd year design project. A paper based questionnaire (one side only) was used, which was handed out during a lecture and collected in a box as the students left the lecture theatre at the end. By having only one side of mainly tick boxes, a high response rate was ensured.

Prior to design week (February 2011), the 2nd year cohort were surveyed to find out their current knowledge and use of design resources and search engines. The same resource list as that in the 3rd year questionnaire was used to allow a comparison. Again a one-sided paper based questionnaire was used.

The 2nd years were surveyed again after design week (Summer 2011) to find out what they thought of the design week and also what resources they had now used. Again, a one side paper questionnaire and the same resource list were used.

The 2011 2nd year cohort were then surveyed again in March 2012 (they are now 3rd years) to find the impact that 2nd year design week had on their 3rd year design projects. A similar questionnaire to the first 3rd year questionnaire was used.

Collation of Resources

A list of resources available for use in chemical engineering design was collated through discussion with colleagues, the university library and online searches. Discussion with these parties ensured a representative list of resources that students were likely to have used. This material was then developed to provide online content easily accessible by the students. Once the new student material was complete it was reviewed and tested by postgraduate students who were previously undergraduates in the department. This gave direct feedback on its potential impact and allowed development of the material for maximum benefit and ease of use. Only very few changes were made after the review process.
The list of online resources was made into a learning module, hosted on the University WebCT platform MOLE. A screen shot of the learning module is given in Figure 1. As well as online resources the learning module also includes links to useful text books (both online and paper available from the University library e.g. Coulson & Richardson’s Chemical Engineering Volume 6 by Sinnott (2005) and Perry’s Chemical Engineers’ Handbook by Green (2007))

![Figure 1: Screenshot of the Learning Module](image)

2nd Year Design Week

The learning module was trialed during the second year design week. Students were emailed the week before design week to tell them to look at the learning module and find out their group allocation. At the start of design week students were then given the design brief.

“Design Brief: A mixture of benzene and toluene is to be pumped from a tank to a distillation column via a heat exchanger and separated to give a required purity.”

The design may be divided into five main tasks which each group must complete:

1. Feed heat exchanger design
2. Ideal column calculation (including Pro II design)
3. Design of column internals
4. Feed-flow system design
5. Heat exchanger cost estimate

Each group is assigned a feed flowrate and composition, a storage temperature, a heat exchange fluid and an R/Rmin value. They must concentrate the feed such that the top product is 99.9 mol% benzene and the bottom product is 99.9 mol% toluene.
In the past students have used Sinnott (2005) almost exclusively as the items to be designed are all standard. In 2011 they were encouraged to use other resources available as well.

Design week started at 9am Monday. 5 bonus marks were awarded for completion of the project by Thursday afternoon. Friday was available for groups that needed extra time.

Results and Discussion

Previous year group: 2011 3rd Years

There were 40 responses to the 3rd year questionnaire (total cohort size 70 – 57% response rate). The y axes on the following figures are scaled such that the top of the axes represent the 100% of the answers received.

Students were asked “Do you feel that second year project week prepared you for your 3rd year design project?”. This question received a very mixed response, as seen in Figure 2, with 64% answering yes to some degree and 36% answering no. If students answered “no” they were asked what they thought was missing that would have helped. Two students responded saying that the items designed in 2nd year are standard and follow books, whereas the items designed in 3rd year are not. It is hoped that the online learning module created will help next year’s 3rd years in design of non-standard items by pointing them in the direction of useful design tools.

Students were also asked was “Did you use any of the resources that you learnt about in second year project week whilst doing your 3rd year design project?”. 86% of students replied “yes”, as see in Figure 3, however 14% of students answered “no”. This is a surprising answer as most 3rd years will at least use Sinnott (2005) at some point during their design project. The results perhaps highlight the variation in design projects the MEng cohort take, with each project being designed by the supervisor and related to their research in some way.

The final question in the survey asked students to tick any of the list of resources they used in their 3rd year design project. By far the most popular resources were Sinnott (2005) and The Engineering Tool Box (2012) with many students using both the online and text book version of Sinnott, as seen in Figure 4. All of the resources in the list were used by at least 10 students, highlighting the need for students to be aware of their existence.
Overall the third years appear to use a side variety of resources, although the survey results suggest that many of them were “self-taught” during the 3rd year design project. It is hoped that by introducing the resources via an online learning module in 2nd year, the students will find their design projects easier to manage.

2nd Year cohort 2011

Prior to the design week, students were asked to select from a list any of the resources they had used for Chemical Engineering design. There were 66 responses to the second year questionnaire (total cohort size 94 – 70% response rate). Later in the year the 2nd years were then surveyed again to gauge their use of the resources discussed. 72 responses were received (total cohort size 90 – 80% response rate). A comparison between the resources used before and after design week is given in Figure 5. A percentage scale is used on the y axis to allow direct comparison between the two sets of data. It is immediately noticeable that before design week a much lower proportion of students had used the design resources compared to the 3rd year surveyed.

Four of the resources listed had been used by less than 10 people and all but steam tables, online unit converters and Sinnott (text book) had been used by less than half. In the second year cohort a much larger proportion of students used the text book version of Sinnott and Perry’s rather than the online version in comparison with the third years. This may be because they were not aware of the online versions at this point. After design week it is obvious that the students are aware of many more resources compared to before. In particular the online version of C&R vol 6 (Sinnott) shows a large increase. In all but two cases awareness increased significantly after design week. The use of paper steam tables remained the same (only half the class have steam as a heat exchange fluid), however the use of online steam tables increased dramatically. The use of online unit converters decreased, the reason for this is unknown but may be because students do not feel they need them anymore.

After the design week a small number of 2nd year students were questioned to find out their perspectives on the week. All said that it extremely useful and they had enjoyed the week. In particular they highlighted their use of online resources.
Follow up survey: March 2012

There were 60 responses to the follow up survey (cohort size 90 – 67% response rate). This survey was given to the same group of students that the two 2nd year surveys were given too, but by then they had also completed their 3rd year design project. Figure 6 shows the student response to “do you feel that second year project week prepared you for your 3rd year design project?”. 87% of students answered yes definitely or yes partially. This is a dramatic increase on the previous year where only 64% of students answered yes definitely (see Figure 2). The project brief and material were the same between the two years, the only difference was that the material is now all online and the learning resources were discussed explicitly. Figure 7 shows the student response to “Did you use any of the resources that you learnt about in second year project week whilst doing your 3rd year design project?”. 98% of students answered positively. Again, this is a large increase on the previous year where 86% of students said yes (see Figure 3). This comparison is made across two different cohorts of students, however the average grades across the board for the two cohorts are the same, meaning it is unlikely that the differences seen here are a result of a more talented or hardworking cohort. There is therefore strong evidence that introducing a variety of design resources to the 2nd years very much helped them during their 3rd year design project.
project?” whilst doing your 3rd year design project?”

Figure 8 shows a comparison between the resources used by the 3rd years in their design projects in 2011 and 2012. The majority of resources were used by a similar percentage of students across the two years, however the online version of C&R vol 6 (Sinnott) and the IChemE website (Knovel) showed large increases in use.

![Figure 8: Comparison between the resources used in 3rd year design projects in 2011 and 2012](image)

The results above suggest that students in 2012 were less “self-taught” than those in 2011 – they used the design resources that they learnt about in 2nd year design week, along with other resources they found themselves.

**Conclusions**

The previous third year was relatively knowledgeable about some of the online resources available, although other useful resources were not used by more than half the cohort. This cohort received no training on online resources and is in the main self-taught. The more motivated students have therefore sought out online resources whereas the others have not. There were mixed feelings on the usefulness of the 2nd year design week, reinforcing the need for change.

Before design week the second year students had low knowledge of the resources available. After design week, student awareness of resources increased dramatically. Informal feedback on the learning module created suggests that the students find it useful.

The follow up survey on the second year cohort after they completed their third year design project showed that 87% of students felt that second year design week prepared them for their design projects. 98% of students said they had used resources they learnt about during their second year design week. Use of the online version of Sinnott and of the IChemE Knovel library in the design project increased dramatically between the previous third years (2011 cohort) and the new third years (2012 cohort). The results suggest that students in 3rd year in 2012 were less “self-taught” than those in 2011 – they used the design resources that they learnt about in 2nd year design week, along with other resources they found themselves.
References


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