Joint Projects and Assessments of Chemical Engineering Units: An Approach to Enhance Student Learning

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Abstract: *The ability to apply knowledge of basic science and engineering fundamentals associated with each and every subject learnt in their undergraduate program is an essential attribute of the chemical engineering graduate. Even though principles of chemical engineering are distributed across the units from first to fourth year, a chemical engineer should be able to relate all these principles to solve chemical engineering problems. However, relating these principles and drawing parallels between these subjects is not an easy task unless during their undergraduate study, a chemical engineering student was given training in doing projects involving principles across a variety of units. In view of the above necessity, chemical engineering at Curtin University has implemented combined projects and joint assessments between two units which not only provides an avenue for students to experience relating concepts they learnt from different units, but also reduces the work load for both teaching staff and students. In this paper, two experiences of having combined projects and joint assessments between units in chemical engineering program are presented and discussed.*
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Keywords: *joint assessment, joint project, chemical engineering units*

Introduction

The chemical engineering undergraduate programme is normally designed as a four year Bachelor of Engineering degree (Sen et al, 2010). Consequently, chemical engineering material is learnt through units distributed over a four year study period and comprises physical sciences, mathematics, general engineering units, core chemical engineering units, and advanced chemical engineering projects and design studies. The chemical engineering curriculum is structured in such a way that students learn the pre-requisite units before they learn the advanced units.

An ability to apply knowledge of basic science and engineering fundamentals associated with each unit learnt in their undergraduate program is an essential attribute of chemical engineering graduates (ABET, 1997; IChemE, 2001; IEAust, 1996). Even though the principles of chemical engineering are distributed across the units from first to fourth year, a chemical engineer should be able to relate all these principles to solve chemical engineering problems. However, relating these principles and drawing parallels between these subjects is not an easy task unless during their undergraduate study, the chemical engineer student was given training in doing projects that involved using knowledge and skills that spanned units. In view of this necessity, Chemical Engineering at Curtin University has implemented combined projects and joint assessments between two units. This not only provides an avenue for students to relate concepts they learnt in different units but it also reduces the work load for both teaching staff and students. Further, it acts against the perception that students sometimes have that their course consists of isolated units with little connection to each other.

In this paper, two experiences of having combined projects and joint assessments between units in the chemical engineering program are presented. The units are ChE 322 Process Plant Engineering, ChE 321 Mass Transfer Operations, ChE 228 Process Heat Transfer and ChE 224 Process Systems Analysis. The rationale behind the joint projects, problem set-up and project assessments in the selected units will be discussed.

Implementation of Joint Project and Assessment in ChE 321 and ChE 322

Unit information and rationale behind the joint project

Both units are third year, first semester units where students learn the theories and apply them in the design of a particular process and its associated process equipment. The syllabuses of the units are summarised in Table 1.

Table 1: ChE 321 and ChE 322 syllabuses.

ChE 322 Process Plant Engineering	ChE 321Mass Transfer Operations
- Introduction to Plant Design, PFDs, P&IDs, and Preliminary Economic Analysis - Material Selection - Piping and Pumping System Analysis and Design - Pressure Vessel Design - Utilities	- Introduction to Separation Processes - Molecular Diffusion and Interphase Mass Transfer - Distillation Column Analysis and Design - Absorption Column Analysis and Design - Extraction Column Analysis and Design - Humidification and Cooling Tower Analysis and Design

It can be seen from Table 1 that most of the components in ChE 321 Mass Transfer Operations involve the analysis and design of mass transfer process equipment. Meanwhile in ChE 322 Process Plant Engineering, students gain knowledge of how to analyse and design process vessels (including selection of materials of construction), piping, pumping and utilities. All these topics are relevant to the analysis and design of mass transfer equipment. Therefore, to assist students relating principles they learn in these two units, to train them in having a holistic approach to chemical engineering design and at the same time reducing the work loads for students and teaching staff, a joint project for ChE 321 and ChE 322 was proposed, rather than having two independent projects.

Project set-up and description

To accommodate both these units, the scope of the project was defined as seen in Table 2. Also shown in the table are relevant topics from two second year units, ChE 227 Process Principles and ChE 228 Process Heat Transfer, but these units were not part of the joint project. The project was done in groups of four to five students with a timeline of 8 weeks.

Table 2: Description and scope of the joint ChE 321 – ChE 322 project.

Project description	ChE 227 Process Principles (2nd year)	ChE 321Mass Transfer Operations	ChE 322 Process Plant Engineering	ChE 228 Process Heat Transfer (2nd year)
A distillation system is proposed to take a feed stream of 3 L/min at 20°C containing 3-6 M of nitric acid laced with radioactive components and separate into two feed streams. In order to comply with government disposal regulations, the distillate system must have an acid concentration of no more than 10 ppm nitrate concentration. To become beneficial to other parts of the plant, the bottoms product stream must have an acid concentration between 12 and 15 M. Due to the azeotropic natures of the acid-water mixture, 15.6 M is the practical upper bound on the bottoms concentration. The proposed unit must fit into an empty room 30 ft long by 30 ft wide, with a height 13.5 ft. A door 7 ft tall by 3 ft wide is the only access into the room. Your project team is to submit a tender to build the final stage distillation system to meet the above specified requirements. You are also required to do economic analysis for the proposed work. The system design and equipment selection needs to be chosen such that all of the design constraints and objectives could be met while keeping the total cost of equipment and operation at a minimum.	- Mass balance - Energy balance	- Operating conditions - Equilibrium data/curve - Choice of the type of the column - Operating reflux ratio - Number of equilibrium and actual stages - Flooding and weeping points - Height and diameter of the column - Reboiler and condenser duties	- P&ID - Material selection - Column and piping pressure drop calculation - Piping and pumping design - Mechanical design of process vessel - Utilities - Economic analysis	- Reboiler and condenser analysis and design

Assessment

This joint project contributed to 25% of the marks for both ChE 321 Mass Transfer Operations and ChE 322 Process Plant Engineering. The project was assessed through a written report (15%) and an oral presentation (10%). The report included the proposed mechanical design of the distillation column and a profitability analysis, and it had to be submitted before the presentation. The presentation was assessed by two academic staff and other student groups using a peer-assessment form.

Reflections on the usefulness of a combined ChE 321-322 Project in effective course design

Project based learning is a teaching and learning model that emphasizes student-centered instructions by assigning projects. Assessment and their effectiveness in preparing the students for handling real engineering issues at workplace were evaluated. This had been measured by eVALUate survey reports as student's learning experience at the end of course. eVALUate is Curtin's online system for the gathering and reporting of feedback on teaching and learning both quantitatively and qualitatively. Research also indicates that students are the most qualified sources to report on the extent to which the learning experience was productive, informative, satisfying, or worthwhile. While opinions on these matters are not direct measures of instructor or course design effectiveness, they are legitimate indicators of student satisfaction and there is substantial research linking student satisfaction to effective teaching. Higher student satisfaction is the results of good learning and effective course delivery. Therefore students opinions reflects that the implementation of combined project on ChE 321 and ChE 322,in terms of critical thinking, problem solving skills, leadership and team work, has given them very positive learning experiences (with student satisfaction above 92%).

Implementation of Joint Project and Assessment of ChE 228 and ChE 224

Unit information and rationale behind the joint project

Both units are second year, second semester units where the mathematical methods to find solutions to ChE 228 Process Heat Transfer problems are being learnt in ChE 224 Process Systems Analysis. The syllabuses of the units are summarised in Table 3.

Table 3: ChE 228 and ChE 224 syllabuses.

ChE 228	ChE 224
- 1 – D steady state conduction - 2 – D steady state conduction - 1 – D unsteady state conduction - 2 – D unsteady state conduction - Heat exchanger - Internal forced convection - External forced convection - Natural Convection - Radiation	- One dimensional optimisation - Multidimensional optimisation - Constrained optimisation - Numerical solution to integration - Numerical solution to simultaneous linear equations - Numerical solution to ordinary differential equation - Numerical solution to partial differential equations

All topics in ChE 228 Process Heat Transfer involve mathematical modelling, including some differential equations, and mathematical analysis to find the solutions, using either analytical or numerical methods. On the other hand, students learn numerical solutions to differential equations and other mathematical constructions in ChE 224 Process Systems Analysis. Therefore, to assist students relating principles they learn in these two units and at the same time reducing the work loads for students and teaching staff, a joint project between ChE 228 and ChE 224 was proposed rather than having an independent project in each unit.

Project set-up and description

The scope of the project was designed to cover topics learnt in both ChE 228 and ChE 224 as seen in Table 4. The students were placed in groups of four students. The project had a timeframe of 8 weeks.

Assessment

This joint project contributed 20% of the marks for both ChE 228 and ChE 224. The project was assessed by report only. In the report, each group had to include minutes of their meeting, which were helpful in cases where disputes arose among group members. The final mark for each student was determined by taking the group mark for the report and multiplying it by a peer-assessment factor, which is an average percentage of contribution as assessed by other members of the same group.

Reflections on the joint project

The joint project was generally received positively by the students, mostly we think because of the perception of reduced workload, but partly also because of the clear link that was demonstrated between two of the units they studied. There were negative comments from a small number of students who took only one of the units that semester, either because they had studied one of the units already, or they were due to study the other unit later. These students had two areas of concern: (1) that they could not contribute to both aspects of the project and thus their group mates would mark down their efforts via the peer assessment factor, or (2) they felt that they contributed a full project workload in both units when they were enrolled in only one. These concerns only became apparent part way through the project. We were able to compensate for the first concern by modifying the peer assessment factor calculation, if necessary. For future projects, the handling of students who take only one unit should be addressed before the project is released.

On balance, most staff also felt that the joint project was a good idea, for much the same reasons as the students. However a joint project leads to some difficulties also. First, it limits the type of projects that can be set, because the same project must meet the learning outcomes of two separate units. For example, a project on heat exchanger design would certainly be appropriate for ChE 228 Process Heat Transfer, but might not be suitable for ChE 224 Process Systems Analysis because such a project might not need any of the numerical methods taught in the latter unit. A joint project also has to avoid unwanted duplicate assessments of the same skills, which further restricts the project topic. Second, there can be a problem with timing of the material delivery – that is, when the material needed for the project is taught at different times in each unit. For example, the joint project had to have enough non-numerical, heat transfer content for the students to work on while they were yet to learn the Matlab skills needed to complete the numerical component. (Please note that Table 4 does not contain the full project brief with its detailed tasks and marking scheme.) A further minor matter was that students were sometimes unsure which staff member to approach for getting help with problems.

Table 4: Description and scope of the joint ChE 228 – ChE 224 project.

Project proposal	ChE 228 Process Heat Transfer	ChE 224 Process Systems Analysis
You are a graduate engineer working for Curtin Polymer Corporation in the Technical Development Group (TDG). Your manager has asked you and your teammates to assist the Lab Manager in investigating a potential anomaly related to product testing in the lab.Lara, the Lab Manager, says: "Ok team, as you probably know, one of the quality parameters we report to customers is the polymer softening point. It's measured with the thermo-mechanical compression test apparatus (TCTA), which I've sketched here. The TCTA applies a fixed weight to a thin disc of the polymer sample and measures small changes in sample thickness. The temperature of the base plate is precisely controlled and it's ramped up during the test. The softening point is the temperature where there's a sudden change in the thickness versus temperature curve. Alright? Now, we might have a problem since I suspect that the actual sample temperature might not be the same as the temperature of the base plate, which is what we've been assuming. This means that we might be giving our customers misleading softening point results. What I'd like to know is how different the polymer temperature gets from the base plate temperature as the TCTA goes through its measurement cycle." You reluctantly go to see Herman, who is an experienced (but rather grumpy) process engineer in the TDG. He listens to your explanation while maliciously stroking a white long-haired cat (surprisingly present on-site despite OH&S legislation) and then says: "Ah, newbies... Look, try a quick calc to start off: assume steady state, constant properties, 1-D conduction, no thermal contact resistance, no heat transfer from the sides and assume that the base plate is at its highest temperature. There's natural convection from the top plate, so try a h of about 10 W/m^2°C, I guess. What's the temperature of the polymer at the interface with the top plate? Is it much different from the base plate temperature? To check on the dynamic behaviour, you need to set up a transient nodal analysis. Use the same assumptions as above, apart from steady state of course. Try this nodal scheme [see next page]. Be careful that you get the various Δy's right and make sure you code it up so you can handle a variable number of nodes (but I'd use $N_s = 5$ and $N_t = 10$ to start with) and don't let me see you hard-coding numbers into your nodal equations – I mean if your nodal equation's got $k/(\rho c p \Delta y)$ in it then you should code it as "k / (rho * cp * deltay)" not "0.15 / (700 * 1800 *0.0001)" or whatever, and use Matlab not Excel, and you'll probably need to use ode15s in Matlab rather than ode45, and show the results in °C not Kelvin."	- Energy balance - 1 – D unsteady state conduction - Finite difference nodal temperature equations	- Numerical solutions to differential equations using Euler method, Runge-Kutta and adaptive or multi step methods - Matlab simulation

On a related topic, our feeling is that still more needs to be done to show how the units in the course are linked together. Traditionally, in chemical engineering degrees, the entire course is brought together in the final year Design Project, but this is rather late in the degree to show how all the units depend on each other. Joint projects between pairs of units in years 1 to 3 are one method, but we are interested in exploring others and would welcome any suggestions that readers may have.

Conclusion

Two joint projects with shared assessments in chemical engineering units have been explored and demonstrated. Through the joint projects, students were given a chance to show their ability to apply fundamental theories learnt in different units to solve engineering problems. Due to the nature of projects, which covered topics across several units within the chemical engineering programme, the students were also trained to relate principles they learnt in different units. As a result of such multi-units projects, an enhancement in the level of knowledge of the students can be expected. Students were also given an avenue to learn teamwork and communication skills through group work, written report and oral presentations. Moreover, through this joint project and assessment, the workloads of the students and teaching staff were less compared with having an independent project in each unit. Finally, we feel that joint projects help students recognise that the course represents an integrated body of knowledge and techniques, rather than an isolated collection of units, but we welcome suggestions about other ways to demonstrate how different units in a course are interrelated and interdependent.

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Copyright statement

Biography:

Dr Agus Saptoro is a lecturer at the Department of Chemical Engineering Curtin University Sarawak Campus. His current research is in the multivariate data analysis, process modelling, optimisation and control, transport phenomenological modelling of extraction process and engineering education