World Transactions on Engineering and Technology Education
Vol.6, No.2, 2007

Integrated delivery in chemical engineering education

Mohd S. Takriff, Siti R.S. Abdullah, Nor H. Tan Kofli & Darman Nordin

Universiti Kebangsaan Malaysia
Bangi, Malaysia

ABSTRACT: Surveys conducted on graduating classes over the past few academic years at the Department of Chemical and Process Engineering at the Universiti Kebangsaan Malaysia (UKM), Bangi, Malaysia, found that there was a lack of integration in the delivery of chemical engineering curriculum and that students were overburdened with too many projects in a given semester. An innovative delivery approach via an integrated project was formulated and implemented in order to address the concerns raised by students. In this article, the authors discuss the formulation and implementation of the integrated project. The implementation of the integrated project successfully relates and reinforces various chemical engineering subjects to the overall chemical engineering curriculum and provides excellent opportunities for the development of soft skills such as teamwork, independent learning and communication.

INTRODUCTION

As part of the Continual Quality Improvement (CQI) process in the Engineering Faculty, Universiti Kebangsaan Malaysia (UKM), each academic programme is required to seek feedback from students and devise an action plan to improve the quality of the programme. One of the techniques employed by the Department of Chemical and Process Engineering is to conduct an exit survey of graduating students towards the end of their final semester. The objective of this exit survey is to obtain feedback regarding the learning process that the students have gone through for four years in the Department. The survey was conducted for the first time in the 2004/2005 academic year.

The results of the surveys conducted over the past three years have indicated common concerns raised by the graduating students. The more significant concerns include the following:

- A lack of integration in the delivery of the chemical engineering curriculum: each course has focused only on its own scope and no effort was made to relate subjects with other courses in the same or previous semesters;
- Students were overloaded with a number of projects in a given semester. Every semester, almost all courses that students enrol in have significant project components, thus students did not have enough time to prepare good reports for all the projects.

The only exception where students were required to integrate the knowledge that they had learned was the plant design course in the final semester of the four-year chemical and biochemical engineering programmes. Reflecting on students' feedback and the existing delivery approach, the Department's members agreed that students raised valid concerns and an innovative delivery technique was required to improve the curriculum delivery. Thus, in this article, the authors highlight the integrated delivery approach that was formulated and implemented in the Department beginning in the 2006/2007 academic year.

INTEGRATED DELIVERY

Integrated delivery was achieved via an open-ended integrated project for all chemical engineering courses in a given semester. The integrated project's components, implementation and assessment techniques are elaborated on below.

Objectives of the Integrated Project

The integrated project was formulated to address the concerns raised by students and the development of soft skills, such as communication, teamwork and independent learning. The specific objectives of the integrated project are as follows:

- Integration aspects of different courses in the chemical engineering curriculum;
- Application of basic knowledge and theories obtained from lectures in a project;
- Project work that satisfies and, at the same time, does not overburden-students;
- Application of professional chemical engineering software, such as *HYSYS*® or *SUPERPRO*®, in students' early years;
- Development of soft skills in communication, teamwork and life-long learning to obtain current and updated information on the project, as well as recognising the environmental issues.

Components of the Integrated Project

The integrated project was implemented for the first time to second year students in the first semester of the 2006/2007 academic year and who were enrolled in three of the Department's courses, namely *Chemical Process Principles*, *Chemical Engineering Thermodynamics* and *Physical Chemistry*.

An integrated project covering a wide range of topics from material and energy balances, thermodynamics and physical chemistry was formulated to ensure that these students were provided with an opportunity to apply the chemical engineering knowledge that they had already learned and, at the same time, not overburden them with too many projects. The details of the project's scope and elements for the semester 1 second year courses are presented in Table 1.

Table 1: Components of the second year integrated project in semester 1 of the 2006/2007 academic year.

Components	Details
Courses enrolled in semester	KR2313: *Chemical Process Principles*; KR2333: *Chemical Engineering Thermodynamics*; KR2353: *Physical Chemistry for Engineers*
General components	Supply and demand scenario for products, use of products, and environmental issues on waste generation and discharge limits
Chemical Process Principles	Energy and mass balance for a single component, plus energy and mass balance for multiple components
Chemical Engineering Thermodynamics	Property estimation and vapour-liquid equilibrium calculations such as dew points, bubble points and flash estimations
Physical Chemistry for Engineers	Chemical and physical properties of the components involved, plus basic chemical kinetics
Chemical engineering professional software	Simulation of the entire process and a comparison of results with those obtained from *HYSYS*® and *Superpro*® software

The second semester focused on second year students enrolled in three chemical engineering courses: *Organic Chemistry*, *Transport Phenomena 1* and *Chemical Engineering Reaction 1*. The elements of the courses in the first semester, such as property estimation (*Chemical Engineering Thermodynamics*), and energy and mass balances (*Chemical Process Principles*), were included in the project's scope. The details of the project's scope and elements for the second year courses in semester 2 are presented in Table 2.

The soft skills targeted included teamwork, communication and independent learning. For teamwork, students were divided into teams of four and the instructors decided on a team's members as suggested by Oakley et al [1]. Each group elected a team leader who was responsible for leading the team discussion and project implementation. The integrated project also required both written and oral communication. Students were required to present their findings orally and written communication was in the form of a technical report and the minutes of group meetings.

To encourage independent or active learning, in the last four weeks, students completed the integrated project with minimum supervision from the lecturers. Students planned for their group meetings and searched for the required materials in the library or on the Internet using their own initiative. The Department's lecturers were always available for consultation. In addition, the integrated project required students to use professional simulation software. This helped introduce the application of professional simulation software at an early stage, as suggested elsewhere [2][3]. Students were provided with an overview in lectures on the use of professional simulation software plus the necessary reference materials.

Table 2: Components of the second year integrated project in semester 2 of the 2006/2007 academic year.

Components	Details
Courses enrolled in semester	KR2413: *Organic Chemistry*; KR2433: *Transport Phenomena I*; KR2453: *Chemical Engineering Reaction I*
General components	Raw materials and use of products, supply and demand scenarios for products, determination of physical properties for chemicals, heat and mass balance, and process flow diagrams
Organic Chemistry	Stoichiometric equations for processes, specifying any by-product of the process and identifying separation methods of this by-product, and indicating a way to stabilise this monomers
Transport Phenomena I (momentum transfer)	Application of the Bernoulli principle to fluid flow systems, incompressible and compressible fluids, and fluid-moving machinery (pump and compressor)
Chemical Engineering Reaction I	Choice of reaction path, reactor selection, reaction kinetics and mole balance
Chemical engineering professional software	Simulation of the entire process, a case study on pump and compressor performance, generation of a pump performance curve, and a case study on reactor performance

Implementation

Students were informed about the implementation of the integrated project in the first week of the semester. The learning activities throughout the 14-week semester covered both traditional lectures by the course instructors for 10 weeks and independent study by students on the integrated project in the final four weeks. The traditional lectures for each course provided the necessary course syllabus coverage. However, the depths of topics that were covered by the project were kept to the basics. Students were expected to cover the necessary depth in the integrated project.

The project question sheet was handed to students in the third week and a constant reference was made to the integrated project in the first 10 weeks. A Web-based learning portal that all students had access to was utilised for storing the necessary documents. Students were required to submit their group report and present an oral report on the project in the last week of the semester in the presence of all the lecturers for the chemical engineering courses that the students had enrolled in for that particular semester. Students were provided feedback on their performance in completing the integrated project by the respective lecturers. The typical activities for chemical engineering courses in a given semester are listed in Table 3.

Assessment

Assessment on the integrated projects covered technical evaluation on the report submitted, oral presentations and peer assessment. The technical evaluation was carried out by the lecturers for the respective course or subject matter. Students were required to present an oral report on the project in the final week of the semester. On the day of the oral presentation, the lecturers would pick one member of the team randomly to present the report. The purpose of doing so was to ensure that every member would prepare for the oral presentation and to also allow the lecturers to test whether they had worked together

Table 3: Coursework activities.

Activity	Week													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Traditional lecture														
Introduction to integrated project														
Handing out project statement														
Professional chemical engineering software														
Industrial visit														
Completion of PFD														
Project work														
Report submission & oral presentation														

or otherwise by evaluating the response of the other members when answering questions from the lecturers. During the oral presentation, students were graded based on the presentation quality, ability to answer questions and professionalism. The final form of assessment was peer assessment on the performance of each team members. Since students had spent the last four weeks in a 14-week semester working together, the projects carried a 25% weight of the final grade for each course.

DISCUSSION

A survey was conducted at the end of the semester in order to gauge the effectiveness of the delivery technique and further improve its implementation. Feedback from students covered the aspects of integration, implementation and soft skills. Figure 1 shows students' views on the implementation in the 2006/2007 academic year. Based on students' feedback, the initial implementation of the project in the first semester of the 2006/2007 year required improvement. With the improvement that was incorporated, the majority of students agreed that the integrated project was implemented smoothly in the second semester of the 2006/2007 academic year. This figure shows that for both semesters, most students agreed that despite lacking formal lectures in the last four weeks of the semester, the lecturers were readily available for consultation and students were provided with the adequate guidance to carry out the project. The survey results indicate that the majority of students agreed that handing over the project statement to students at the beginning benefited them. However, only slightly more than half of students agreed that four weeks was adequate for completing the project. An improvement on the project scope was incorporated in the second semester of the 2006/2007 academic year, but students' opinions remained the same. The results imply that either the open-ended integrated project failed to address the issue related to students being overburdened with the project or the scope of the project was not communicated clearly to students. A dialogue session was conducted with student representatives to determine the reasons for such a situation. Based on that dialogue, it was found that most students misunderstood the scope of the open-ended project and better communication on the scope of the project was required.

The integrated project was formulated to provide opportunities for students to practise the technical knowledge that they had learned and to bring together the various aspects of chemical engineering courses to the overall engineering objectives. Figure 2 shows students' feedback on these elements of the integrated project. More than 85% of students in the first semester and 90% in the second semester agreed that the project successfully integrated the different aspects of chemical engineering courses. Regarding opportunities to apply their chemical engineering knowledge, 86% of students in the first semester and 93% in the second semester agreed that the integrated project allowed them to practise their technical knowledge and reinforced the various chemical engineering subjects to the overall chemical curriculum.

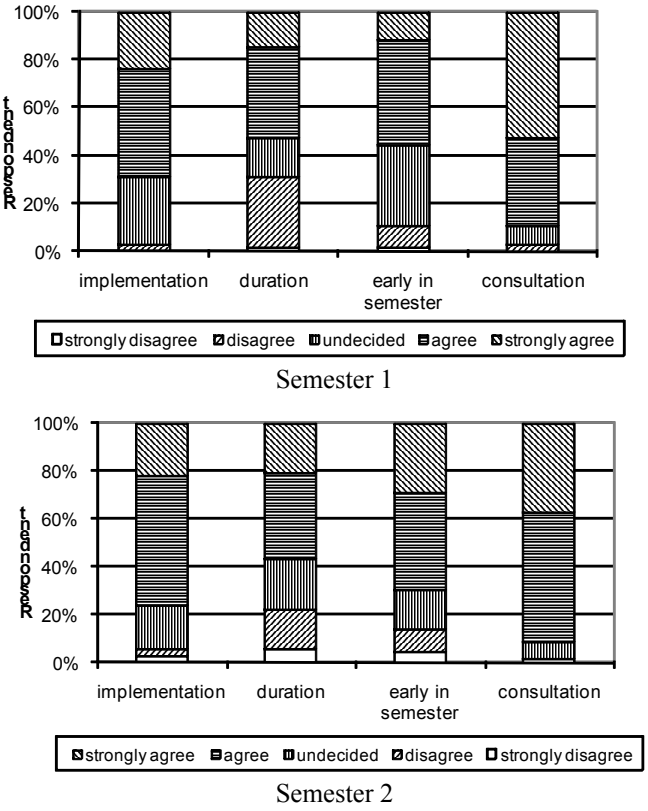
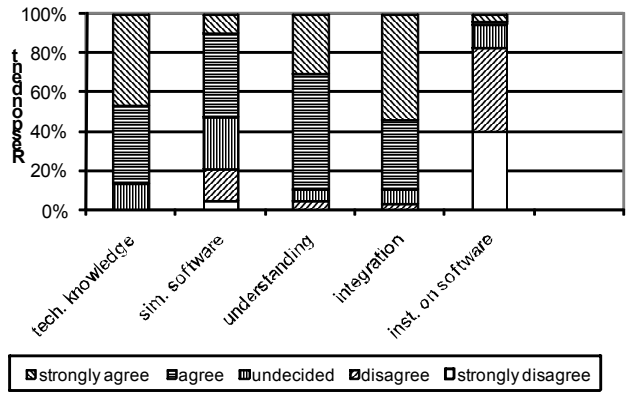


Figure 1: Implementation of the integrated project.

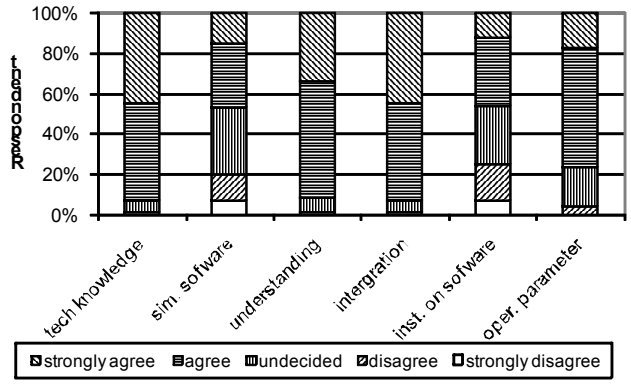
Figure 2 also shows that the introduction and application of professional simulation software helped to show the relevance of the different subjects to the overall engineering objectives. The application of professional software helped students to gain a better understanding of the lecture topics and to appreciate the influence of operating parameters on chemical engineering unit operations. However, most of the students felt that they were not provided with adequate exposure and instruction on the use of the professional software.

The outcomes of the two engineering degree programmes offered in the Department targeted graduates having the soft skills required of practicing engineers. The implementation of the open-ended integrated project provided excellent opportunities for the development of soft skills, such as teamwork, independent learning and communication. Figure 3 shows students' opinions on the targeted soft skills. More than 90% of students agreed that the integrated project required them to carry out independent learning or active learning. More

than 90% of students in the first semester and over 96% in the second semester of the 2006/2007 academic year agreed that the integrated project provided an excellent means to develop their teamworking skills. Figure 3 also shows that most students agreed that the integrated project allowed them to practise their communication skills, both oral and written.

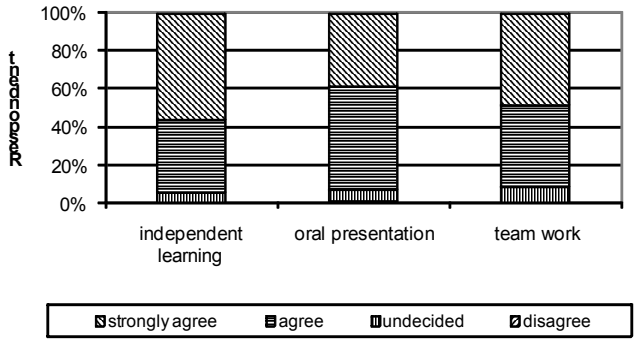


Semester 1

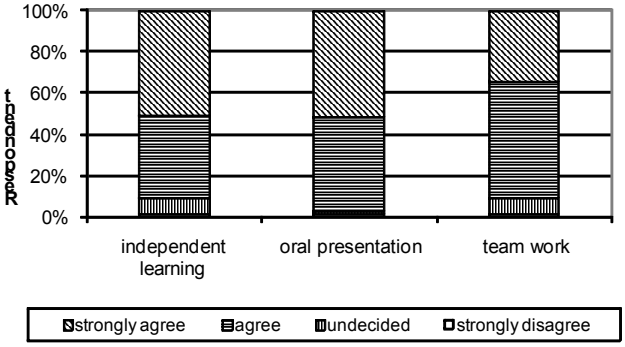


Semester 2

Figure 2: The application of chemical engineering knowledge and the integration of different courses.



Semester 1



Semester 2

Figure 3: The development of students' soft skills.

The UKM engaged two leading chemical engineering scholars from the University of Manchester, UK, and Monash University, Australia, to provide an assessment of its biochemical and chemical engineering degree programmes, respectively. Both had a high regard for the integrated project. Webb stated in his assessment report:

> *The introduction, recently, of an Integrated Project to bring together aspects of several course units is a particularly innovative feature of the degree program. It was introduced in response to graduate and industry feedback and is an excellent example of how useful such feedback is. Student feedback since its introduction has been very positive and students appreciate the opportunity to reinforce what they have learned in several modules, while at the same time recognizing that it also helps with preparation for formal assessment. The marks awarded for the project serve as the coursework element for the relevant course modules* [4].

Rhodes considered this as a novel feature in the programme and stated the following in his report:

> *… some courses in a given semester are linked through integrated projects. Towards the end of the semester students work in teams to tackle projects where the skills developed in individual courses are applied to a single project. For example: in semester 3, a single process becomes the focus of an integrated project where skills developed in Chemical Process Principles, Chemical Engineering Thermodynamics and Physical Chemistry for Engineers are applied. The 2nd year student interviewed by the assessor reported that students found this approach to be very useful in showing the relevance of the different subjects to the overall engineering objectives* [5].

CONCLUSION

The implementation of an integrated project is an innovative delivery technique that successfully relates and reinforces the various chemical engineering subjects to the overall chemical curriculum. The integrated project was formulated in response to graduate and industry feedback, and is an excellent example of how useful such feedback is. It has provided excellent opportunities for the development of soft skills like teamwork, independent learning, communication, etc, among students.

REFERENCES

1. Oakley, B., Felder, R.M., Brent, R. and Elhajj, I., Turning student groups into effective teams. *J. of Student Centered Learning*, 2, **1**, 9-34 (2004).
2. Mohmmad, A.W. and Takriff, M.S., Using professional simulation software for better integration in the chemical engineering undergraduate curriculum. *World Trans. on Engng. and Technology Educ.*, 2, **2**, 321-324 (2003).
3. Mohamad, A.W., Takriff, M.S. and Basri, M.F., Integrating professional software in an undergraduate distillation course. *Proc. 4th UICEE Conf. on Engng. Educ.*, Bangkok, Thailand, 284-286 (2001).
4. Webb, C., External Assessor Report, Biochemical Engineering Program. Bangi: Dept of Chemical & Process Engineering, Universiti Kebangsaan Malaysia (2007).
5. Rhodes, M., External Assessor Report, Chemical Engineering Program. Bangi: Dept of Chemical & Process Engineering, Universiti Kebangsaan Malaysia (2006).