AUGMENTING THE CHEMICAL ENGINEERING CAPSTONE DESIGN PROJECT EXPERIENCE THROUGH INDUSTRY INVOLVEMENT

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Introduction

Many universities and colleges across the world recognise the capstone design project as an effective vehicle to round out the undergraduate education in chemical engineering (Kentish & Shallcross, 2006). The objective of the design project is to provide students with a valuable opportunity to do the following: apply their technical knowledge, build on professional skills (e.g. communication, decision-making, and teamwork), and enhance their analytical, critical and creative thinking abilities. In the Department of Chemical and Biomolecular Engineering (ChBE) at the National University of Singapore (NUS), all chemical engineering undergraduates are required to take and complete the capstone design project as part of the core curriculum module. This module has a strong technical and professional component, with students having to review and evaluate process alternatives, simulate and optimise the chosen process using Aspen HYSYS[1] and/or Matlab packages, size process units/equipment, conduct safety, health and environmental studies, and perform economic analysis. Details of the design project structure and implementation methodology at ChBE, NUS can be found in our previous article (Bansal et al., 2012).

The scope and format of the design project is based on the expected learning outcomes and objectives (outlined in the earlier paragraph) which are in line with the Department's vision to produce dynamic, innovative and ethical engineers with a strong engineering foundation. The module emphasises the development of soft, hard and ethical skills of undergraduates with the intended result of producing graduates who are ready to pursue challenging engineering careers. To meet these aspirations, the teaching and learning practices in ChBE are constantly being evaluated and refined; these include enhanced industry involvement in the capstone design project. This paper discusses various aspects of industry involvement in the design project over the past two academic years (AY2013/14 and AY2014/15) and their implications–from industry personnel being invited to be guest speakers and external advisors for the project, to students going on plant visits.

Industry Involvement in the Chemical Engineering Design Project

Industry personnel as guest speakers

Industry talks have long been recognised as an effective pedagogical tool (Wolfe & College, 2006). Inviting experienced engineers as guest speakers provide elements of an authentic learning environment (Donovan, Bransford, & Pellegrino, 1999; Herrington & Herrington, 2006), and help to enrich the students' overall learning experience in several ways. The guest speakers provide relevant up-to-date industry-specific information. They also share real-world experiences and give students valuable insights into their respective fields of practice. Every year, practising engineers from Singapore's numerous chemical process industries are invited to present technical talks on a range of topics related to the design project[4]. Six or more industry talks were arranged during each of the two academic years mentioned; details of these talks can be found in Figures 1 and 2. These talks, each lasting between one and one-and-a-half hours and prepared in consultation with ChBE's faculty advisors, serve to bridge the gap between classroom education and industrial experience, as well as provide students valued exposure to industry perspectives and engineering practices. According to Herrington and Herrington (2006), such talks give students access to expert knowledge and performance that would provide "a model of how a real practitioner behaves in a real situation" (p. 5). For the benefit of students unable to attend, the talks were webcast and made available on the Integrated Virtual Learning Environment (IVLE).

Industry personnel as external advisors

Members of the industry could impact students' learning experience by serving as external advisors for the capstone design project. As external advisors, they can support the "collaborative construction of knowledge" (Herrington & Herrington, 2006) by contributing significantly to the formulation of the engineering problem statement for the design project, sourcing for realistic data, advising students, and more. One of the primary requirements towards achieving the intended learning outcomes for the design project is the formulation of an open-ended engineering problem that is realistic and accurately reflects the constraints found in the industry. Though faculty advisors are responsible for preparing the problem statement, feedback from the members of the industry can be very helpful in ensuring that the proposed design project problem is industry-relevant and adequate in preparing students for their professional careers. Furthermore, the industry representative can contribute by interacting with students, participating in meetings, as well as sharing insights and practical experiences. Working along these lines, the Department of ChBE appointed Dr. Gavin Towler (Chief Technology Officer and Vice President of R&D, UOP[2]) as external advisor for the design project in AY2013/14 and AY2014/15. Over the past two academic years, Dr. Towler has contributed in a variety of ways: reviewing the design project's problem statement, delivering talks, participating in the team leaders' meeting, and offering consultation to students. The design project and students involved have benefitted immensely from his expert suggestions and involvement.

Partnering industry to organise industrial visits

Another form of industry involvement in the capstone design project is through the plant visits for students. Visits to the industries, particularly to plants with manufacturing activities closely related to the design project problem, can help students broaden their learning experiences by helping them gain a better understanding of the overall process as well as by facilitating awareness of new technologies, good industrial practices, and safety issues. The visit to a related industry in the midst of working on the design project is particularly beneficial for students, even though many of them have to complete a 24-

week industrial attachment before doing the design project. For example, during Semester II of AY2013/14, students were assigned to work on the phenol manufacturing process using cumene[3] as the feedstock. To help students acquaint themselves with the production process and obtain a closer view of the large-scale unit operations/equipment, we worked with our industry partners to organise a visit to Mitsui Phenols Singapore Pte Ltd. Students valued the visit to the plant as they gained a deeper insight into the process and had the opportunity to talk with the engineers, make queries, and clear doubts. In continuation of such efforts, an industry visit to Asia-Pacific Breweries Singapore was organised during Semester II of AY2014/15. More than 100 final year undergraduates participated in both visits[5].

Student Response and Feedback

On conclusion of the design project, an online survey was conducted via the IVLE to evaluate students' perceptions and learning from having enhanced industry involvement in the design project. The anonymous survey collected both quantitative and qualitative feedback from students. A total of 105 and 200 students participated in the survey conducted in AY2013/14 and AY2014/15 respectively. The quantitative responses are summarised in Figures 1 and 2.

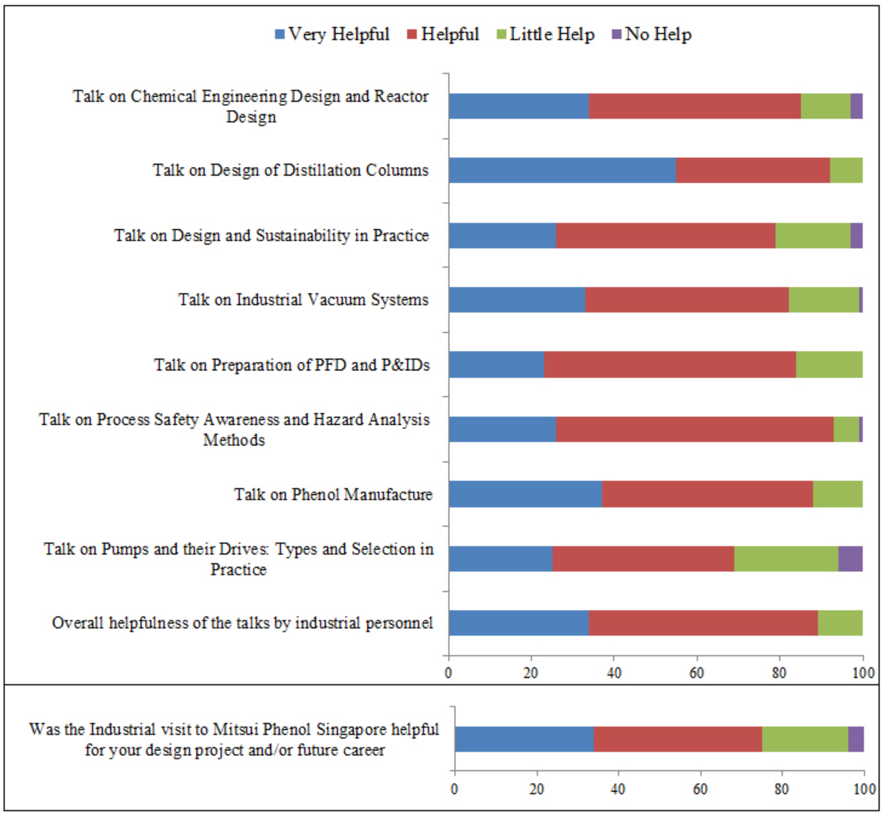

Figure 1. Students' quantitative responses to the survey questions (AY2013/14).

Quantitative feedback

The student feedback results were highly encouraging, with a majority of the students in both academic years (>70%) finding the industrial talks and visit 'helpful' or 'very helpful'. The positive feedback clearly indicates that students embraced the industry talks as well as the visits, and considered them to be valuable and practical learning resources with long-lasting learning benefits. As part of the survey, students were asked if there were other topics they felt should be included in future industry talks. Among the various topics suggested, the following appeared most frequently: economic analysis, design of absorption columns, and heat integration.

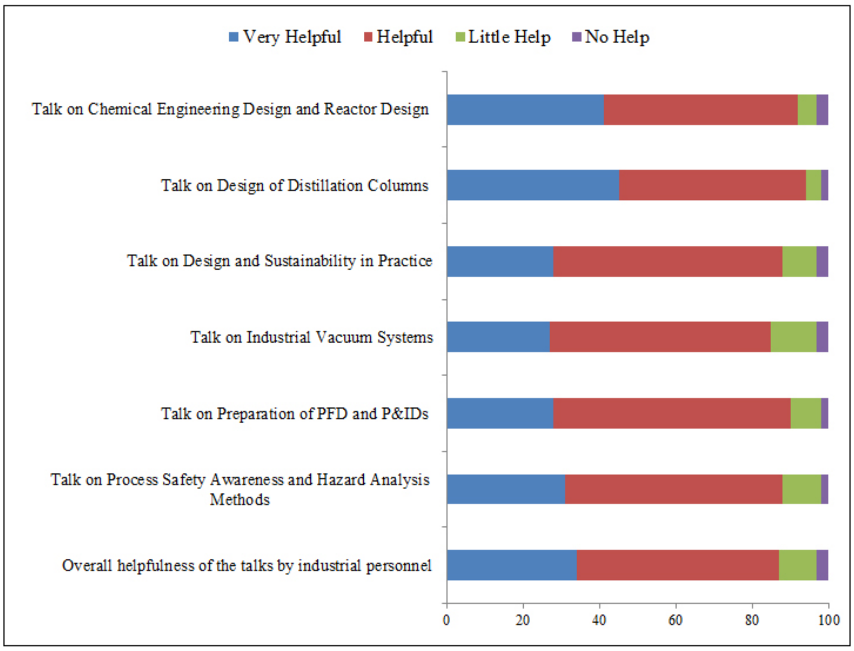

Figure 2. Students' quantitative responses to the survey questions (AY2014/15).

Qualitative feedback

The qualitative feedback also indicated a very positive student response to industry involvement in the design project. Some of the students' comments on how such industry involvement had enriched their learning experience are shown below:

- "The industry talks and visit were very useful. They set the foundation and initiate the thinking process for students. They give us a yardstick to which we can compare our calculations to and ascertain if our calculations are meaningful on an industrial scale…"
- "The talks were pretty useful, especially the talk by Dr. Towler. They gave a good insight into the industrial practices."
- "Talks were useful as they provided knowledge beyond those available in books and we could apply them in our design project."
- "They are very useful, particularly the plant visit because it gave an opportunity [for us] to talk to the engineers who are involved in running the plant. We can thus become aware of what's practically correct and what's not."

Conclusion

Farr et al. (2001) stated that "relevant, industry partnered design is an important part of the undergraduate education experience for tomorrow's engineers" (p. 193). Our approach is a step in this direction. In view of students' positive feedback and apparently enhanced performance, evident from the improved quality of the written reports submitted and students' responses to questions during the oral presentations, we will continue to incorporate and strengthen industry involvement in the capstone design project. Given the industry's expectations when it comes to the skills that entry-level engineers should possess, it is important to understand and identify the most effective means for preparing undergraduates to meet these expectations. The active involvement of industry personnel in the chemical engineering design project as formulators of the design project problem, guest speakers, external advisors, and hosts for industrial visits can make a significant impact on students' overall learning and preparation for their professional careers. We are grateful to the practicing engineers in the chemical process industries for their support and cooperation in the past, and look forward to the continued support in the future.

Endnotes

1. HYSYS is a powerful software tool which is commonly used for the simulation of chemical process plants including petroleum refineries and petrochemicals. It includes tools for estimation of physical properties and vapour-liquid phase equilibria, heat and material balances, and simulation of many types of chemical engineering equipment.

2. UOP, formerly known as Universal Oil Products, is a Honeywell company which develops and delivers technology to the petroleum refining, gas processing, petrochemical production, and major manufacturing industries.

3. Cumene is the common name for isopropylbenzene, an organic compound that is based on an aromatic hydrocarbon with an aliphatic substitution. It is used in the production of phenol, acetone and other derivatives.

4. We are grateful to Dr Gavin Towler (of Universal Oil Products), Ms. Lau Sue-Ann (of Sulzer Chem-Tech), Mr. Joseph William Eades (of Isaphan Group), Mr C.C.S. Reddy (of Singapore Refining Company), Mr. Satendra Singh (of Foster Wheeler), Mr. Raman Balajee (of Air Products), and Mr. L. Srinivasan (of Shell) for giving the industry talks

5. We are grateful to Mr. David Sugiman and Mr. Brendan Ng (of Mitsui Phenols Singapore Pte Ltd) and Mr. Derek Ho, Ms. Irina Cristina, Ms June Koh and Mr. Chan Chan Heng (of Asia Pacific Breweries Singapore) for hosting students from ChBE.

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About the Author

***Dr Satyen Gautam** is the corresponding author for this article and part of the academic team coordinating the Design Project for Chemical Engineering students. He believes that education is a progressive journey of becoming better and that students learn best when they are in harmony with their learning environment. Also, learning becomes most efficient if it can appeal to students at both a personal and an intellectual level.*