# Technology Engineering and Management: An Integrated Approach to Process Design

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## INTRODUCTION

The Technology Engineering and Management (TEAM) program is a cooperative venture between academia and industry that is managed by the Department of Chemical Engineering at Queen's University, Kingston, Ontario. This program is open to senior undergraduate students in the Faculty of Engineering, the School of Business, and other interested departments. Recently, the scope of participation was expanded with the inclusion of students from the Environmental Studies department. Where appropriate, graduate students are added to the project group to provide a level of expertise not necessarily available from a team consisting solely of undergraduates.

TEAM is equally beneficial to the students involved and to the industrial sponsor. A unique opportunity is presented for students to work together in multidisciplinary teams, which focus on real projects for industrial clients. TEAM is an academically rigorous exercise, which involves non-traditional instructional methods such as problem-based learning, multidisciplinary teams, and self-directed project work, creating a learning environment paralleling that of a professional engineering or business office. On the client side, the project groups provide innovative solutions to engineering design and business analysis projects. Creativity can flourish since the students have not been exposed to and are not restricted by existing business rules and assumptions.

## PROGRAM APPROACH

In the fall term, students participate in the foundation component of the TEAM course, where they are introduced to the concepts of basic project management and team building, in addition to industrial topics such as Health and Safety. Before the Christmas break, these skills are put into practice as the students are expected to select the project of their choice and to form teams, thereby aligning themselves with one of the potential industrial clients. Teams of 4 to 6 members (5 is ideal) are selected by the course coordinators on the basis of the students' choices, their background, and the nature of the project, with a multidisciplinary makeup whenever possible.

At this point, the course coordinators also assign an advisor to each team. The majority of project advisors are career engineers from local industries such as DuPont and Fluor Daniel, or faculty members within the university. These people commit many hours to their teams. TEAM provides an excellent opportunity to develop relationships between the industrial clients and advisors that often leads to further research and business cooperation.

Teams make the initial contact with their client near the end of the fall term to organize and confirm project-related details. Negotiations between the students and the client result in a project timeline and deliverables along with a formal contractual agreement including intellectual property rights and waivers of liability. Concerns about intellectual property and disclosure of confidential data are negotiated between the client and the student team. In the past, these issues have been resolved without difficulty.

In the second term, the teams of engineering, environmental science and business students work on the projects developed in the fall term. Throughout the duration of the project, the industrial client representatives are in frequent contact with the teams to ensure that project milestones are being met. At the end of the winter term, each team delivers to its client a comprehensive written report and oral presentation.

Upon completion of the projects, the response of the students is generally enthusiastic! This is clearly a different learning environment for students, as they are expected to be much more responsible for many aspects of their education and learning. Although some students have difficulty adapting to this environment, by the end of the program the vast majority of students successfully make the shift from a teacher-centered learning environment to a student-centered learning environment. This, of course, is essential for successful professional careers. The team's success also depends on their leadership skills, enthusiasm and commitment.

TEAM CLIENTS

Industrial clients are charged a modest fee of $3,000 for the project. The fee serves two purposes. First, it covers some course expenses and provides minimal infrastructure support. Secondly, the fee ensures the attention of the client!

The clients recognize that TEAM only accepts projects that involve real needs on their part. As a result, the level of challenge is quite high, and the cooperation of the client personnel is always excellent.

The TEAM program began in 1994 with a pilot project from DuPont. Since the inception, projects have been successfully completed for an eclectic list of clients. Participants in the program range from large multi-nationals such as Imperial Oil, DuPont, Stone and Webster and Celanese, to small and medium size enterprises, such as Hyprotech Ltd. and Beaver Dental. Client satisfaction can be gauged by the high rate of repeat client participation. (Nine of the twenty one clients have come back for a second year or more.)

In 1995 and 1996, TEAM ran six projects each year. In 1997, the number increased to thirteen. TEAM had nine projects in 1998, and there are eleven projects for 1999. The number of students enrolled in any year limits the number of projects TEAM accepts.

Queen's University plans to continue the development of TEAM, in particular to expand the role of the program in other engineering departments as well as in departments such as Environmental Studies. An interesting partnership currently under discussion may lead to technology students from a local Community College joining TEAM. The University is also investigating the possibility of providing a team of students as part of the Experience Option, an internship program, where the team would work with this client for a term of up to 16 months.

## TEAM RESULTS

The responses of industrial clients indicate tremendous satisfaction with the quality of the work delivered by the students. Stone & Webster and Consumers Gas, for example, have participated every year since 1995 and 1996, respectively. More than one client has provided the program with a substantial bonus payment. In some instances, these projects contribute to significant capital project investment decisions in Ontario.

There is no question that all parties benefit from their involvement in TEAM: students, the University and the industrial clients. It is obvious that students benefit, since they have an opportunity to apply and develop their knowledge on challenging, multidisciplinary industrial problems. The University benefits from increased exposure to current industrial needs and trends. Unquestionably, the industrial client benefits from the infectious enthusiasm that the students bring to the project. In addition to receiving an innovative solution to their process design and/or business analysis project, in many cases companies are exposed to new computing and information technologies. Also, the industrial client has the opportunity to access, through the student teams, the extensive resources of the university, which are not otherwise readily available. Finally, companies have an opportunity to constructively participate in the programs of education and research at the University and get to meet first hand students who could be potential employees.

The project-based, self-directed learning paradigm is not without problems. Most students have been exposed for their entire education to a Platonic lecture/exam approach and find the TEAM program challenging. The necessity to accept ownership for their learning can be quite intimidating. It has been quite encouraging to observe that most students accept the challenge, and by the time that they have to face their client for the final presentation, they have been able to assemble a most presentable and technically sound product. Another encouraging aspect is the leadership qualities that appear in some individuals whose academic record is often less than outstanding.

Course assessments which have been established for the traditional approach are simply not suitable for a project-based course such as TEAM. The typical result of these assessment procedures can often appear quite negative. These negative assessments could have a devastating effect on the career of a young tenure track professor.

TEAM is a very demanding program, not only for the students but also for the course organizers. Among other issues, it requires the introduction of mathematical and scientific concepts in the context of application, and the broad use of information technology. While the approach is not a panacea, it has clearly demonstrated that in the role of essentially a mini-internship for our senior students, it has been a great success.

THE DESIGN ASPECT OF THE TEAM PROGRAM

It is necessary to examine the nature of design. Lockyer[1] (1993) gives a good general summary.

> *Design is a most essential component of our society - it is the art or profession of creating a plan for something yet to be. The "something" can be a work of art, a manufactured product, a societal system, a business system, or the structure of an organization. It generally integrates theory and practice, and requires knowledge, skill and imagination in order to be successful.*

TEAM projects are quite diverse in nature involving some sophisticated process engineering design challenges, business systems, and market research. The people associated with this program have, in the most part, many years of industrial experience. This background provides a more holistic understanding of the design process that is necessary to prepare our students for leadership roles in the industrial/business community. There is an occasional misconception on the part of some of our students that a scientific or academic career path will not involve management and business issues.

This paper, however, illustrates two cases, which are design projects in the narrow sense of what has traditionally been understood to be Chemical Engineering design. The first case is a design exercise recently conducted for Imperial Oil, Products and Chemicals Division. The second project is one that a team of students will complete in April 1999 for Hyprotech.

Case A

Imperial Oil presented their student team with a proposal to produce a product destined for a niche market. The students were provided with Imperial Oil's scope design for production of this product, whose market had developed as a result of changing environmental regulations.

It must be appreciated that most hydrocarbon specialties are produced by separation of a narrow distillation cut from the various hydrocarbon streams available from crude oil processing. In some limited instances, the product is a discrete molecule, such as n-hexane, which has been used in oil-seed extraction. Of course there are instances where an additional processing step is required in order to produce a specification product.

The product in question required two such processing steps, a cracking step and a hydrogenation step. Following these steps were the usual fractionations required to produce a product of required quality that would meet the sales specification. The original proposal presented to the students involved separate reactors and several fractionation steps in order to produce the desired material.

It was suggested to the design team that process compression, a term for closer integration of processes and separations, might be appropriate. Catalytic distillation is one aspect of process compression that is being used successfully in a growing number of applications, the best known being the manufacture of MTBE (Methyl Tertiary Butyl Ether) from isobutylene and methanol. The students were successful in developing a model of a proposed process that in fact combined the cracking and hydrogenation steps in a single unit. This unit also achieved the bulk of the fractionation requirements. The solution was quite an achievement, because it took advantage of the most sophisticated modeling capabilities of the Flowsheet Simulation software.

The other important aspect of this project was the development of a capital cost for the design proposal, and an economic assessment of the project. This was an interesting exercise for the students since the raw material for this process had several other potential uses. These various scenarios had a profound effect on the economics of this project since they influenced the transfer value of the feedstock into the process itself.

Throughout this project, the student team had support at the University as well as support and guidance from the people at Imperial Oil. Upon completion of the project the team made their presentation before a senior management group at the offices of the client.

The significance of this project was that although Imperial Oil was appreciative of the pedagogical aspects of the project, they also expected a fair return on their investment of time and money. This was definitely not a make-work project for the students, rather it represented a real need for Imperial Oil. The student team has been subsequently advised by Imperial Oil that it was a beneficial outcome from their perspective.

Case B

Although this project is somewhat similar to the Imperial Oil project, it represents some unique challenges as well. This project is underway at the time of writing.

Hyprotech has a suite of integrated software products, which can be used by process engineers throughout the plant lifecycle. In the initial design phase, the engineer utilizes HYSYS.Concept to establish many of the thermochemical and thermodynamic strategies necessary for a successful flowsheet simulation. This conceptual design package provides a tool for the design and screening of the most economical separation systems. The results obtained from HYSYS.Concept can then be transferred to HYSYS.Process, which is a state of the art Flowsheet Simulator with steady state and dynamic capabilities. In the steady state simulation environment, snapshots of the process can be quickly and efficiently examined. Once a satisfactory model of the process has been obtained, dynamic simulation is used to investigate alternate control strategies and to monitor the effects on key process variables due to changes in the system.

The students are expected to develop a design case using both HYSYS.Concept and HYSYS.Process. The challenge that we have chosen is the conversion of a “catalytic” distillation MTBE process for the manufacture of ETBE (Ethyl Tertiary Butyl Ether). On the surface this would appear to be a relatively trivial exercise, the substitution of ethanol for methanol as a feedstock. This is not the case however, since the replacement of the methanol with ethanol presents many design challenges. There are many studies available in the literature for MTBE simulations, but there is little data available for ETBE. Two recent publications by Sneesby et al.[2,3] will be used as a basis for this study by the student team.

Catalytic distillation combines reaction and distillation in a single vessel. This often leads to interactions between various design variables that can result in unusual responses to changes in operating conditions. The other major change is some striking differences in phase behaviour between the MTBE and ETBE systems, which require different designs, and operating conditions. Simple extrapolation of concepts from MTBE synthesis to ETBE synthesis can in fact be quite misleading.

## SUMMARY & CONCLUSIONS

The TEAM concept, in which students have the opportunity to conduct a consulting project for an industrial client, has been quite successful. In addition to allowing the students to participate in a real world design experience, it introduces them to many aspects of an actual business environment. Having to meet deadlines and to deal with such issues as confidentiality and intellectual property are unique challenges for most undergraduates. Since there is an expectation of professional quality reports and presentations, the opportunity to enhance their abilities in this regard are one of the most vital learning experiences that TEAM offers. The instructors are constantly impressed with the quality of these reports and presentations. Students generally see this as a challenge and spend considerable time on the design of their presentation material.

Although few of our graduates will find employment as career design individuals, the technical and "soft" skills that are enhanced by the TEAM experience will give our students an excellent start as emerging professionals.

## ACKNOWLEDGEMENTS

We could not even consider such a venture as TEAM without a major commitment of support from our industrial colleagues. Organizations such as DuPont Canada and Fluor Daniel support us by providing advisors for the student teams. Of major importance is the establishment of a client base that provides the students with their projects. These clients expect value for the money and time that they invest in the program, and they must be prepared to work with the students as mentors. We have been very fortunate in establishing such a client base, which is quite eclectic and constantly expanding. The past support of organizations such as Materials and Manufacturing Ontario has been instrumental in ensuring the success of this program.

TEAM details can be found at our web site: http://www.chemeng.queensu.ca/TEAM

## BIOGRAPHIES

### Barrie Jackson

Mr. Jackson joined the Department of Chemical Engineering as Queen's University in 1988 after retiring from more than 30 years of international experience with the Shell group. Since that time he has been responsible for the capstone chemical engineering design course, and more recently, the Technology Engineering and Management (TEAM) program. Mr. Jackson was awarded the 1998 Canadian Council of Professional Engineers Medal of Distinction in Engineering Education. This national award recognizes the unique and innovative contribution of the TEAM program to Engineering Education in Canada.

John Pongo

John Pongo holds the dual role of University Programs Liaison for North America and Tactical Development Engineer at Hyprotech. He has been with the company since obtaining a B.A.Sc. degree in Chemical Engineering from the University of Waterloo in 1995.

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